There Will Be Blood: The Impact of Drug Traffic on Violence

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Abstract

This paper examines the relationship between illicit drug markets and violence in producing countries by focusing on the case of Colombia and the impact of coca production along trafficking routes. By using data on coca crops and crime incidents, and constructing a predicted network of coca-trafficking routes, we aim to identify the causal impact of local exposure to drug markets on homicide rates. Our identification strategy leverages the quasi-experimental setting provided by the unanticipated announcement by the Colombian government in 2014 of a crop-substitution program (PNIS) which led to a sizeable increase in coca production. The results highlight a significant and positive association between the amount of coca trafficked through a municipality and the homicide rate. These findings underscore the importance of understanding the spillover effects of drug production and criminal networks, emphasizing the need for comprehensive policy interventions.

JEL codes: H50, P35, O13
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1 Introduction

Understanding the dynamics of violence in the context of the illegal drug trade is crucial, particularly amidst the ongoing global debate on the effectiveness of public policies to curb crime. Despite various international and local governmental efforts, drug production and violence associated with trafficking, and consumption of illicit drugs persist. Colombia, serving as a major hub for cocaine production and trafficking in recent decades, witnessed a record-breaking surge in coca cultivation in 2018, with 171,000 hectares of coca crops estimated. Alongside, the country struggles with high levels of violence resulting from conflicts involving illegal armed groups such as guerrillas, paramilitaries, and drug cartels. In 2020, the United Nations documented 66 massacres, claiming the lives of 255 individuals, and reported 120 targeted killings of human rights defenders (OHCHR, 2020).

Although a substantial number of works have explored the impact of crime policies and drug production on violence in the drug-growing regions (Angrist and Kugler, 2008; Dube and Vargas, 2013; Brückner and Ciccone, 2010), the spillover effect along the trafficking network is still under-investigated. Importantly, neglecting municipalities along the drug trafficking routes could lead to an underestimation of the true impact of drug production. This paper aims to address this gap by examining both illegal networks and the efficacy of public policies on criminal violence. Specifically, our study focuses on assessing the effect of local exposure to illicit drug trafficking on violence in municipalities situated along the drug trafficking routes.

We consider the period from 2011 to 2021 and combine information on geolocalized coca crops at 1 km^2 grid granularity with municipal crime data. We estimate the impact of cocaine being trafficked through municipalities on violence using predicted optimal trafficking routes. We construct a network of "optimal" routes for cocaine transportation, connecting coca-growing areas to the nearest major export point, and identifying the municipalities located near these trafficking routes. Since the exact quantity of illicit drugs passing through these routes cannot be precisely measured, we rely on a predicted measure of a municipality's exposure to drug trafficking. This measure is obtained by aggregating the 1 km^2 grid-cell level coca cultivation data based on growing areas. We then leverage the variability in the production of coca in the growing areas to induce variation in the exposure to drug trafficking for municipalities along the routes.

To address potential endogeneity arising from unobserved time-varying local factors that could simultaneously influence coca production in growing areas and the homicide rate along the trafficking routes, we exploit the quasi-experimental setting provided by the unanticipated announcement by the Colombian government in May 2014 of a crop substitution program (PNIS) offering material incentives to replace growing coca with legal crops. As documented by (Prem et al., 2023), the announcement resulted in a sizeable increase in coca production in areas with higher suitability for coca cultivation. Our identification strategy relies upon this policy shock to construct an instrumental variable for the amount of coca produced in cultivation areas and then trafficked along the routes.

The results in this study consistently indicate a positive and significant effect of coca trafficking on violence, which is measured by the homicide rate per 100,000 inhabitants. Point estimates range from 1.12, in OLS estimate on the whole group of municipalities, to 3, in 2SLS estimate on the sample of municipalities in the proximity of trafficking routes. More in detail, the latter indicates that a 1% increase in the amount of coca trafficked through a municipality is associated with a 0.03 increase in the homicide rate. Considering that the average yearly change in predicted trafficked coca corresponds to 42.1%, this impact amounts to about 1.1 additional homicides per 100,000 inhabitants every year. This corresponds to about 3.5% of the sample mean in the homicide rate over the whole period. The results are robust to the inclusion of a large battery of control variables at the baseline. Moreover, we test whether narco-traffickers, to avoid detection by police authorities, randomly choose the routes to move coca from growing areas to destination points. We do so by performing a sequence of 100,000 iterations of placebo estimates where our predicted measure of trafficked coca is randomly reshuffled across municipalities. The placebo estimates never replicate our baseline findings based on the network of shortest routes.

While extensive literature has explored the impact of drug production and government crackdowns on violence, the focus has primarily been on studying growing areas and assessing the well-being of farmers, neglecting to consider the spillover effects in regions where illicit drugs are trafficked. Building upon the framework established by Becker (1968) in his seminal work on crime, scholars have developed a solid theoretical foundation for understanding the behavior of individuals involved in criminal networks. In line with this framework, scholars agree that drug trafficking organizations (DTOs) employ violence to gain a larger market share or deter the entry of new gangs (Fiorentini and Peltzman, 1997; Donohue and Levitt, 1998; Kugler et al., 2005; Ballester et al., 2006, 2010; Castillo and Kronick, 2020). Additionally, drug dealers compete through violent means to control trafficking routes in regional oligopolies (Echandía, 2013; Mejia and Restrepo, 2016).

Empirical studies provide valuable insights into the link between drug production, illegal markets, and violence. For instance, Angrist and Kugler (2008) found that the expansion of coca paste production resulted in modest economic gains but a significant increase in violence in rural regions. The authors highlighted that natural and agricultural resources with substantial black market value, such as coca, opium, and diamonds, are particularly prone to exploitation during civil conflicts. This pattern extends beyond cocaine, as evidenced by Chimeli and Soares (2017) who estimated the use of violence in Brazil following the declaration of illegal status for the mahogany trade. Similarly, Rigterink (2020) discovered that variations in the price of labor-intensive, lootable natural resources like diamonds can lead to heightened violence in resource-abundant areas. Berman et al. (2017) demonstrated a positive association between mining activities and local-level conflict in Africa, with the historical rise in mineral prices accounting for a significant portion of the average violence levels across African countries.

Nonetheless, due to data limitations on trafficking, limited empirical evidence has been provided on the violent dynamics of criminal networks within the context of trafficking routes. To construct our trafficking network, we draw upon the research conducted by Dell (2015), which examines the relationship between government crackdowns on drug trafficking and violence within the context of the Mexican drug war. The study employs a regression discontinuity approach to estimate the effects of victories by the Partido Acción Nacional (PAN) on violence. This approach takes advantage of the fact that the party affiliation of a municipality's mayor changes abruptly at the threshold between a PAN victory and loss, with PAN mayors exhibiting a higher propensity to intensify efforts against the drug trade. The empirical findings indicate that more frequent crackdowns weaken incumbent criminals, thereby fueling violence among traffickers. More recently, Millán-Quijano (2020) employs an alternative identification strategy, assuming exogenous fluctuations in international cocaine prices and price takers DTOs. His study reveals a positive association between internal cocaine trafficking and armed violence, particularly in areas with higher poverty and inequality. However, unlike prior literature, our study investigates the dynamics of criminal networks by leveraging local crime policies implemented in growing areas, cross-sectional geographic factors, and actual coca cultivation volumes. This approach allows us to induce credible exogenous variation in drug trafficking exposure for municipalities along the trafficking routes.

This paper is structured as follows. In Section 2, we offer a comprehensive overview of the drug trafficking and violence context in Colombia, as well as an examination of the public policies implemented by the Colombian government to combat crime.
Section 3 outlines the various data sources utilized in this study and introduces the variables employed to analyze drug trade organization choices, drug networks, violence, and economic development. Specifically, in Subsection 3.1, we describe the construction process of the optimized routes network.

In Section 4, we describe the empirical strategy, with a particular focus on addressing the econometric challenges associated with assessing the impact of drug trafficking on violence. In Subsection 4.1, we discuss potential endogeneity arising from unobserved time-varying local factors that could simultaneously influence coca production in growing areas and the homicide rate along the trafficking routes. In Subsection 4.2, we discuss our main empirical finding.
Finally, in Section 5, we conclude the paper by discussing the key findings and their potential implications.

2 Context

South America has been a major hub for cocaine production and trafficking in recent decades. Coca crops, the primary input in cocaine production, began to increase rapidly in the Andean region in the 1990s, with Colombia emerging as the leading producer and exporter of cocaine. Despite a sharp decrease between 2000 and 2013 (Figure 1), the United Nations Office on Drugs and Crime (UNODC, 2018) reported a sudden growth in coca cultivation from 2014 onward, leading to an all-time production record in 2018, with an estimated 171,000 hectares of coca planted, accounting for more than 85% of the total coca cultivation in the South American region. The remaining coca cultivation was concentrated in Peru and Bolivia and remained stable over the years[1].

Beginning in the late 1990s, the Colombian government, with the support of the United States of America, has implemented a variety of policies aimed at reducing coca cultivation and drug trafficking. Aerial eradication of coca crops through fumigation with glyphosate, an herbicide, had been one of the pillars of the war on drugs carried by the Colombian National Police with the support of the US Drug Enforcement Administration (DEA). These operations were extensively carried out throughout the first decade of the century and potentially contributed to the sizeable drop in coca cultivation over the same period. However, a decision in 2015 by the Colombian Constitutional Court imposed a ban on fumigation because of concerns about its environmental impact.

Colombian national and local governments also implemented a series of policies aimed at favoring the transition from coca to alternative and legal crops. The most relevant was the Comprehensive National Program for the Substitution of Crops for Illicit Use (PNIS). This program involved the provision of economic incentives to coca farmers to transition from growing coca to cultivating alternative legal crops. Notably, this policy garnered considerable attention due to its unanticipated announcement in May 2014, and its potential implications on farmers' and drug trade organizations'

[1]It is essential to note that neither case experienced the same surge in Coca cultivation as Colombia. This shows no dramatic increase in international demand for cocaine.

behavior. According to the findings in Prem et al. (2023), the announcement, specifying incentives for impoverished regions with a history of coca cultivation, resulted in farmers increasing their coca cultivation to obtain greater financial benefits from the government. The actual implementation of the program did not occur until 2017, when cash transfers from the Colombian government were initiated, providing financial support to farmers who participated in the substitution program.

Despite these efforts to combat drug trafficking, Colombia still remains plagued by high levels of violence connected with conflict involving illegal armed groups such as guerrillas, paramilitaries, and drug cartels. These criminal organizations primarily generate profit by producing and transporting cocaine to the U.S. and European illicit markets. To gain a larger market share and dominate trafficking routes, they compete fiercely and use violence to intimidate and eliminate rival organizations seeking to enter the market (Mejia and Restrepo, 2016). The ongoing conflict has resulted in thousands of deaths and disappearances, including those of human rights defenders and social leaders. In 2020 alone, the United Nations recorded the deaths of 255 people in 66 massacres and the killing of 120 human rights defenders (OHCHR, 2020). According to the Office of the United Nations High Commissioner for Refugees (UNHCR), Colombia has one of the highest rates of forced displacement in the world, with more than 1.8 million people forced to flee their homes due to the internal armed conflict fueled by the drug trade (Engel and Ibáñez, 2007).

3 Data

The analysis relies on very granular information on coca cultivation, which is obtained from satellite imagery and estimated annually by the Integrated Monitoring System of Illicit Crops (SIMCI). The program is operated by the UN Office on Drugs and Crime (UNODC). We use the data from SIMCI covering the period from 2011 to 2020, which provides the number of hectares of coca cultivated per 1 km^2 grid-cell.[2]

[2] It should be noted that the estimation of coca hectares is conducted on an annual basis, specifically on December 31 of each year. For the purposes of this analysis, we treat the observation on coca produced in year $t-1$ as the contemporaneous situation in year t.

Panel A of Table 1 shows that around 10 percent (slightly less than 115,000 out of approximately 1.150 million) of all grid cells in Colombia had coca cultivation at some point in the period under consideration. The geographical distribution of coca crops is displayed in Figure 2. Among the grids where coca cultivation occurred at least once between 2010 and 2021, the average cultivated area was approximately 0.96 per 100 hectares.

We employ a municipality measure of coca suitability developed by Mejia and Restrepo (2016). This is based on information gathered from various rounds of a nationally representative household survey of coca farmers conducted by SIMCI/UNODC between 2005 and 2010. The survey sample consists of 1,678 farmers from 64 municipalities throughout the country, randomly selected using satellite estimates to identify where coca crops were located. The survey provides self-reported data on coca crop yields, integrated with exogenous geographic and climatic variables at the municipal level to estimate an index of each municipality's suitability for coca growing. Altitude, soil erosion and aptitude indexes, minerals, geography, and average rainfall levels are among these features. The suitability index is normalized to zero and ranges from -1.57 to 3.01 (see Table 1). For the purpose of our analysis, we follow the procedure in Prem et al. (2023) and derive a 1 km^2 grid-cell level measure of coca suitability.[3]

To evaluate the effect of the increase in illegal drug cultivation in the municipalities along the predicted drug trafficking routes, we use publicly available data on crime statistics from 2012 to 2021 provided by the Colombian Ministry of Defence. These include information on crimes such as homicide, lesions, theft, terrorism, and domestic violence. The nature, date, and municipality of each crime are provided. To assess the impact of drug traffic on violence we will exclusively focus on the number of homicides per municipality.[4] As indicated in Panel B of Table 1, municipalities sit-

[3]We first consider 19 bioclimate variables at the 1 km^2 grid-cell level from wordclim.org and take their average between 1984 and 2013. We then train a random forest algorithm with the municipality-level measure of suitability as outcome and the 19 bioclimate variables as predictors. We performed 100,000 simulations and for each predictor, we consider the average of the estimates across all iterations. Finally, we use these results to assign to each grid cell a predicted measure of coca suitability based on the corresponding values of the 19 bioclimate variables.

[4]Estimates with other types of crime as outcome yield no significant impact of drug traffic. There results are available on request.

uated along drug trafficking routes exhibit a higher average level of violence. Across all municipalities in Colombia, the homicide rate is 25.5 per 100,000 inhabitants. However, when focusing on the subset of municipalities located along drug trafficking routes, the average homicide rate slightly increases to 31.08 per 100,000 inhabitants.

Lastly, we gather several municipality-level variables that we add as controls to test the robustness of our results. This group includes economic indicators in the baseline period such as 2010's population, poverty index and average night-time lights intensity (Zhao et al., 2022), 2005's share of employment in agriculture, and distance from department capital. Moreover, we employ Data on Violent Presence of Armed Actors (ViPAA, Osorio et al., 2019), which reports violent activities by municipality, year, and type of armed actor involved (criminal organizations; paramilitary; insurgents; government). We use this information to define the number of criminal gangs involved in violent activities between 2000 and 2010, before the period under observation.

3.1 A network of optimal routes for cocaine traffic

To examine the effects of trafficked cocaine along the drug routes, we build a network of optimal routes for cocaine traffic by connecting coca-growing areas to the nearest country's main export point and we identify the municipalities located in the vicinity of trafficking routes. We then leverage the variability in the production of coca in the growing areas to induce variation in the exposure to drug trafficking for municipalities along the routes.

More in detail, we first resort to UNODC data on coca cultivation at 1 km^2 cell-level and pick all those cells where at least once between 2010 and 2020 a positive amount of coca was grown (1.3 million cells). Because of computational limitations, we group the coca-growing cells into $J = 1000$ clusters, with the largest one having a 15 km^2 area. Secondly, we consider a group of sixteen Colombian main export points and the entire network of roads and rivers from the most updated version of OpenStreetMap (2023). The latter is used to draw 1000 optimal routes that represent the shortest connections, either by road or by river, between each coca-growing cluster j and one of the sixteen export points. The lengths of the routes range from 8.7 km to

1,406 km. The average length of the routes is 449 km (see the descriptive statistics in Panel C of Table 1). Since coca bushes are principally located in rural areas lacking infrastructure, drug routes mainly start from small rivers or secondary roads.

Next, we identify all the municipalities located within 1 km buffer from every trafficking route. We determine for each origin cluster j the set $\tilde{\boldsymbol{j}}$ including all the municipalities lying on the corresponding trafficking route. Finally, we predict the amount of cocaine trafficked through municipality m as follows:

$$\widehat{Cocaine}_{mdt} = log(1 + \sum_{j=1}^{J=1000} Coca_{jt} \times \mathbb{1}\{m \in \tilde{\boldsymbol{j}}\}) \tag{1}$$

where $Coca_{jt}$ is the number of hectares of coca grown in year t and cluster j, and it is computed by collapsing UNODC 1 km^2 cell-level data by cluster. $\mathbb{1}\{m \in \tilde{\boldsymbol{j}}\}$ is an indicator variable equal to 1 if the municipality m lies on the trafficking route originating from cluster j, and basically imputes the hectares of coca produced in a particular cluster j only to municipalities belonging to the set $\tilde{\boldsymbol{j}}$. The underlying assumption is that the cocaine produced and then trafficked until the closest export point is strongly correlated to the number of cultivated hectares of coca.[5] Thus, we argue that the amount of coca grown in origin clusters represents a fair proxy of the volume of cocaine subsequently trafficked along the drug routes.

4 The effect of cocaine trafficking on violence

Next, with the aim of studying the impact of local exposure to illicit drug traffic on violence, we employ the following two-way fixed effects model:

[5] The coca leaf is not the final trafficked illicit product, as it must be transformed into coca paste and ultimately cocaine base. This conversion process involves the use of several ingredients such as water, sodium carbonate, kerosene, sulfuric or hydrochloric acid, potassium permanganate, and ammonia, and typically takes place in a structure located near the harvesting site, or at a point further along the trafficking route where a water source is accessible (U.S. Department of Justice - Drug Enforcement Administration Report).

$$Y_{mdt} = \alpha + \beta \widehat{Cocaine}_{mdt} + \mu_m + \phi_{dt} + \varepsilon_{mdt} \quad (2)$$

where the outcome variable, Y_{mdt}, is the homicides rate per 100 thousand inhabitants, and the main explanatory variable, $\widehat{Cocaine}_{mdt}$, is the log-amount of our predicted cocaine trafficked during year t through municipality m, located in department d. As extensively described in section 3.1, it is computed by collapsing UNODC 1 km^2 cell-level data by cluster of origin, and then assigned to each municipality m lying on the shortest route to the closest export point. Municipality fixed effects, denoted as μ_m, account for time-invariant cross-sectional differences, including historical and geographical factors that may affect the level of violence and criminal organizations' activity. Department-by-year fixed effects, denoted as ϕ_{dt}, control for common shocks to all municipalities within the same department, while ε_{mdt} represents an idiosyncratic local component. Standard errors are clustered at the municipality level.

We estimate model (2) on two distinct samples: the full sample of municipalities, and a sub-sample consisting only of municipalities that were crossed by drug trafficking routes between 2010 and 2020. The reason for this choice is that the full sample includes municipalities located away from main roads and rivers, which may introduce bias into our estimates of β. These remote areas might have different levels of economic development and are far from the main transportation routes, potentially impacting our results. Moreover, the sample of municipalities along the routes allows to almost exclusively exploit the variation at the intensive margin in the predicted revenues from drug traffic.

4.1 Identification strategy

The OLS estimation of model (2) may yield a biased estimate of the average causal effect of exposure to drug trafficking if unobserved time-varying local factors influence both the production of coca in growing areas and the homicide rate along the routes.

This may particularly apply to municipalities located in proximity to coca-growing areas. For instance, a political shock, such as the election of an administrator who is lenient toward criminal gangs, could increase incentives for producing a significant volume of coca while simultaneously reducing the utility derived from exerting violence, resulting in a lower homicide rate.

To address these concerns, we leverage the quasi-experimental setting provided by the unanticipated announcement, by the Colombian government in May 2014, of a crop substitution program that involved financial aid for those farmers who would have replaced coca cultivation with alternative and legal crops (PNIS). The announcement contributed to a sizeable and persistent increase in coca production, especially in areas with higher suitability for coca production (Prem et al., 2023). We exploit the PNIS announcement to induce plausibly exogenous temporal and spatial variation in coca production and in the exposure to drug trafficking for municipalities along the routes.

We first resort to 1 km^2 grid-cell and follow Prem et al. (2023) by specifying the following econometric model:

$$Coca_{cmdt} = \lambda + \delta S_c \times Post\text{-}ann._t + \theta_c + \chi_{mt} + \upsilon_{cmdt}, \tag{3}$$

where the outcome variable, $Coca_{cmdt}$, is the number of hectares of coca grown in a grid-cell c, located in municipality m, at time t. $Post\text{-}ann._t$ is an indicator for post-PNIS announcement years, i.e., from 2014 onward. S_c is the coca suitability index at the grid-cell level, described in section 3, which quantifies the cross-sectional exposure to the announcement. The rationale is that areas with higher suitability for coca cultivation were more responsive to the economic incentive generated by the announcement. The model includes cell and municipality-by-year fixed effects which are denoted by the parameters θ_c and χ_{mt}, respectively. This specification therefore captures time-invariant characteristics at the most granular level (grid-cell) and time-varying shocks, including changes in political, economic, and climatic factors, at a very detailed level (municipality). Moreover, we estimate Conley's standard errors (Conley, 1999) to account for spatial dependence, up to 100 km, and serial correlation until $t-2$.

Table 2 shows the estimated impact of the crop-substitution program announcement on coca production. The model estimated in column 1 features department-by-year fixed effects, while column 2 displays the result from the specification with municipality-by-year fixed effects as in equation (3). In line with the findings in Prem et al. (2023), Table 2 reports positive and significant point estimates. The result from the more demanding specification in column 2 indicates that one standard deviation increase in the coca suitability index in post-announcement years is associated with a 0.036 increase in the hectares of coca per cell which amounts to roughly more than 100% of the sample mean before 2014.

We examine potential pre-existing trends in coca production across grid-cells with different suitability by employing a dynamic version of the model (3), using 2013 as the baseline year — one year prior to PNIS announcement. In Figure 6, it is evident that, in comparison to the baseline, there are no significant differences in coca production in the years leading up to the announcement. However, a positive and significant impact is observed from 2014 onward.

We use the point estimates from the estimation of model (3) to construct the instrumental variable for the municipality-level measure of predicted exposure to cocaine traffic along the routes that we defined in equation (1).

We first impute the estimated coefficient $\hat{\delta}$ from model (3) to each coca-growing cell and in post-announcement years according to its level of coca suitability S_c, as follows:

$$\widehat{Coca}_{ct}^{Ann.} = \hat{\delta} \times S_c \times Post\text{-}ann._t \tag{4}$$

We then add up these cell-level predicted values for each of the 1000 coca-growing clusters to obtain:

$$\widehat{Coca}_{jt}^{Ann.} = \sum_{c \in \tilde{j}} \widehat{Coca}_{ct}^{Ann.} \tag{5}$$

Finally, analogously to equation (1), we define the instrumental variable for the cocaine trafficked through municipality m as follows:

$$\widehat{Cocaine_{mdt}}^{Ann.} = log(1 + \sum_{j=1}^{J=1000} \widehat{Coca}_{jt}^{Ann.} \times \mathbb{1}\{m \in \tilde{\boldsymbol{j}}\}) \tag{6}$$

Table 3 collects the first stage estimates. The estimation sample in column 1 includes all Colombian municipalities, while in column 2 we only focus on municipalities located in the proximity of trafficking routes. Both estimates exhibit a significant and positive correlation between the predicted measure of cocaine trafficked through a municipality and the instrumental variable. As for the complete sample, a 1% increase in the instrument is associated with a 0.43% increase in the predicted amount of cocaine trafficked through a municipality (Column 1). When considering municipalities on the trafficking routes only (Column 2), the point estimate equals 0.71%. The F-statistic for weak instrument test ranges between 419.5 (Column 2) and 465.5 (Column 3), well above 10 which is the conventional rule-of-thumb threshold for a robust first stage (Stock and Yogo, 2002).

4.2 Drug traffic and violence: empirical findings

Table 4 presents the estimated effects of exposure to coca trafficking on the homicide index according to the specification of model (2). Columns 1 and 2 show the OLS estimates, while Columns 3 and 4 the 2SLS estimates with the PNIS announcement IV. We display the outcome from the estimation on the entire sample in odd columns, whereas even columns consider the sample of municipalities on the trafficking routes.

The results point to a positive impact of coca trafficking on homicides across all the specifications. The statistical significance is stable, at 1% significance level, across all specifications except the one in column 3 (2SLS, all municipalities) which is less precisely estimated. The results on the sample of municipalities on the routes reveal a slightly higher, although not significantly different, estimated impact, suggesting that the effect might be mainly driven by the variation at the intensive margin. Point estimates range from 1.12 in column 1 (OLS, all municipalities) to 3 in column 4 (2SLS, municipalities on the routes). More in detail, the latter indicates that a 1% increase in the amount of coca trafficked through a municipality is associated with a 0.03 increase in the homicide rate. Considering that the average yearly change in predicted trafficked coca corresponds to 42.1%, this impact amounts to about 1.1 additional homicides per 100,000 inhabitants every year. This corresponds to about 3.5% of the sample mean in the homicide rate ($1.1/31.2 = 3.5\%$).

It is worth noting that point estimates from OLS are substantially lower than the 2SLS counterparts. As we discuss in the identification section 4.1, the downward bias is likely due to time-varying factors, such as the election of local administrators who are lenient toward criminal organizations, which might simultaneously affect in different directions the incentive to produce coca in growing areas and the utility from exerting violence.

4.3 Robustness tests

4.3.1 Controls at the baseline

As a first robustness test of our baseline results, we estimate an augmented model featuring several baseline municipality characteristics interacted with year dummies. The augmented specification allows to control for differential changes in violence due to the control variables at the baseline. The group of baseline characteristics first includes a series of economic indicators - population (log), poverty index, and average night-time lights intensity (log) (Zhao et al., 2022) in 2010; share of employment in agriculture in 2005; distance from department capital (log) - with the aim of capturing differential trajectories due to diverging economic development. The set of controls also comprises the homicide rate in 2011, immediately prior to the period under investigation, to account for differential trends related to the level of violence at the baseline.

Because the past presence of violent actors, such as criminal gangs or paramilitaries, might as well influence the subsequent dynamics of violence and drug traffic along the routes, the set of controls is also complemented by an indicator for the presence of FARC and by the number of criminal gangs involved in violent events between 2000 and 2010. FARC had indeed gained substantial participation in the illicit market of cocaine, in particular in coca-growing areas. After the peace agreement in 2016 with the Colombian government, the void of power left by FARC might have raised the incentives for new competitors to exert violence for a higher share of earnings from coca production and trade. The information on the number of criminal gangs involved in violent events, that we derive from ViPAA data (Osorio et al., 2019) described in section 3, aims at controlling for the degree of competition among criminal actors in the period prior to the years under investigation.

Table 5 confirms, even after the inclusion of such a wide set of meaningful baseline controls, the positive and significant association between the predicted amount of cocaine trafficked through a municipality and the homicide rate. Compared to the baseline results in Table 4, point estimates turn out to be slightly lower, although not significantly different, across all specifications. The coefficients from OLS are less precisely estimated with a 10% significance level.

4.3.2 Placebo tests

Our empirical strategy relies on the assumption that narco-traffickers move cocaine along the shortest route by either roads or rivers as thoroughly described in section 3.1. However, narco-traffickers might choose to transport cocaine by randomly selecting a route to the nearest export point, or even one further away, in order to avoid detection by authorities along the shortest routes.

We try to resemble the random choice of trafficking routes and check whether this replicates our baseline findings by implementing a battery of placebo tests. We perform 100,000 simulations, for both OLS and 2SLS estimates, in which we reshuffle the treatment variable across municipalities but within the same year.

Table 6 collects the descriptive statistics from the placebo estimates. Regardless of estimation type and sample, the mean of the estimated coefficients across all simulations is equal to zero and the rejection rate, i.e. the percentage of simulations with p-value below 5%, never exceeds 5%. Moreover, the maximum of the placebo estimated coefficient is far below the corresponding baseline point estimates. Figure 7 displays the distribution of placebo-estimated effects for each type of estimation and sample with the indication of the corresponding baseline estimate coefficient.

5 Conclusion

In this study, we examine the effects of local exposure to illicit drug trafficking on violence and economic development in Colombian municipalities located along trafficking routes. Our analysis focuses on the period from 2011 to 2021 and combines confidential data on geolocalized coca crops and crime data provided by the Colombian Ministry of Defence. Relying on an optimized network of cocaine transportation routes and a measure of each municipality's exposure to drug trafficking, our empirical findings reveal a positive association between coca trafficking and homicide rate.

To address potential endogeneity arising from unobserved time-varying local factors that could simultaneously influence coca production in growing areas and the homicide rate along the trafficking routes, we exploit the quasi-experimental setting provided by the unanticipated announcement by the Colombian government in May 2014 of a crop substitution program (PNIS) offering material incentives to replace growing coca with legal crops, and which lead, as documented by Prem et al. (2023), to a sizeable increase in coca production in areas with higher suitability for coca cultivation. We exploit the PNIS announcement to construct an instrumental variable for the amount of coca produced in cultivation areas and then trafficked along the routes.

Our baseline specifications yield point estimates ranging from 1.12, in OLS estimate on the whole group of municipalities, to 3, in 2SLS estimate on the sample of municipalities in the proximity of trafficking routes, which indicates that a 1% increase in the amount of coca trafficked through a municipality is associated with a 0.03 increase in the homicides rate. Considering that the average yearly change in predicted trafficked coca corresponds to 42.1%, this impact amounts to about 1.1 additional homicides per 100,000 inhabitants every year. This corresponds to about 3.5% of the sample mean in the homicide rate over the whole period.

The results are robust to the inclusion of a large battery of control variables at the baseline. Moreover, we test whether narco-traffickers, to avoid detection by police authorities, randomly choose the routes to move coca from growing areas to destination points. We do so by performing a sequence of 100,000 iterations of placebo estimates where our predicted measure of trafficked coca is randomly reshuffled across municipalities. The placebo estimates never replicate our baseline findings based on the network of shortest routes.

Overall, our study holds substantial relevance in the ongoing debate concerning the interplay between illicit drug production and economic development in South America. It provides compelling evidence of the substantial impact of drug production on heightened violence. Further research is needed to investigate the causal effects of the illicit drug market on additional outcomes such as economic development, labor market participation, and education. Finally, these findings underscore the necessity for government policies to account for the unintended and spillover effects of crime policies, even in areas not explicitly targeted, including trafficking areas.

Figures and Tables

Table 1 *Descriptive Statistics (2011-2021)*

	(1) Mean	(2) Std. Dev.	(3) Min	(4) Max	(5) Mean	(6) Std. Dev.	(7) Min	(8) Max
PANEL A: Coca crops (Grid Level) - 2011-2020								
	All Grids				Grids in Growing Areas			
Hectares of coca per grid	0.10	0.90	0.00	83.74	0.96	2.72	0.00	83.74
Observations	11,533,600				1,145,080			
Number of grids	1,153,360				114,508			
PANEL B: Municipality Characteristics - 2012-2021								
	All Municipalities				Municipalities on the routes			
Coca Trafficked (hectares of coca)	672.7	2,885.012	0	50,888.9	1,233.243	3,816.946	0	50,888.95
Homicide Index (100k inhabitants)	25.50	32.26	0.00	494.95	31.08	35.73	0.00	494.95
Observations	11,150				6,070			
Number of municipalities	1,115				607			
PANEL C: Road network characteristics								
Length routes (Km)	449.07	307.11	8.7	1,405.548				
Number of routes	1,000							

Table 2 *Substitution program announcement and coca production*

	(1)	(2)
	Dependent variable: Hectares of coca	
Post-announcement × Coca suitability	0.0671***	0.0356***
	(0.0113)	(0.0067)
Observations	11,533,600	11,533,600
Mean hectares of coca at baseline	0.031	0.031
Grid cell FE	Yes	Yes
Department-by-Year FE	Yes	
Municipality-by-Year FE		Yes

Notes: Conley's standard errors, accounting for spatial clustering up to 100 km and serial correlation until $t-2$, in parentheses. Asterisks denote statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The outcome variable is the number of hectares of coca grown in a grid-cell. $Post - announcement$ is an indicator for post-crop substitution program announcement years, i.e., from 2014 onward. *Coca suitability* is a coca suitability index at the grid-cell level. All specifications include grid-cell fixed effects. Columns 1 features department-by-year fixed effects, while column 2 municipality-by-year fixed effects.

Table 3 *First stage estimates*

	(1)	(2)
	Dep. var.: hect. of coca on trafficking routes	
	All municipalities	Municipalities on the routes
Hectares of coca on trafficking routes IV	0.429***	0.709***
	(0.020)	(0.035)
Observations	11,150	6,070
F-stat	465.49	419.46
Municipality FE	Yes	Yes
Department-by-Year FE	Yes	Yes

Notes: Standard errors in parentheses are clustered at the municipality level. Asterisks denote statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The outcome is the predicted amount of cocaine trafficked through the municipality, which is defined in section 3.1, while the main explanatory variable is the instrumental variable constructed by exploiting the 2014 PNIS announcement described in section 4.1. All specifications include municipality and department-by-year fixed effects.

Table 4 *Coca trafficking and violence - OLS and 2SLS estimates*

	Dependent variable: Homicides index			
	(1)	(2)	(3)	(4)
			2SLS estimates	
	OLS estimates		Announcement IV	
	All municipalities	Municipalities on the routes	All municipalities	Municipalities on the routes
Trafficking routes coca (log)	1.126***	1.588***	1.833*	3.008***
	(0.430)	(0.553)	(1.109)	(1.040)
Observations	11,150	6,070	11,150	6,070
Mean dep. var.	25.504	31.216	25.504	31.216
Avg yearly growth in exp. var ($\bar{g}$)	23%	42.1%	23%	42.1%
Effect at avg growth rate: $\hat{\beta} \times ln(1 + \bar{g})$	0.23	0.58	0.37	1.06
Municipality FE	Yes	Yes	Yes	Yes
Department-by-Year FE	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses are clustered at the municipality level. Asterisks denote statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The outcome variable is the homicide rate per 100,000 inhabitants. The main explanatory variable is the predicted amount of cocaine trafficked through the municipality, which is defined in section 3.1. Odd columns consider the sample of all municipalities while even columns the sample of municipalities situated along the drug trafficking routes. Columns 1 and 2 collect the OLS estimates, columns 3 and 4 the 2SLS estimates using the PNIS announcement IV defined in section 4.1. All specifications include municipality and department-by-year fixed effects.

Table 5 *Coca trafficking and violence - control for baseline characteristics*

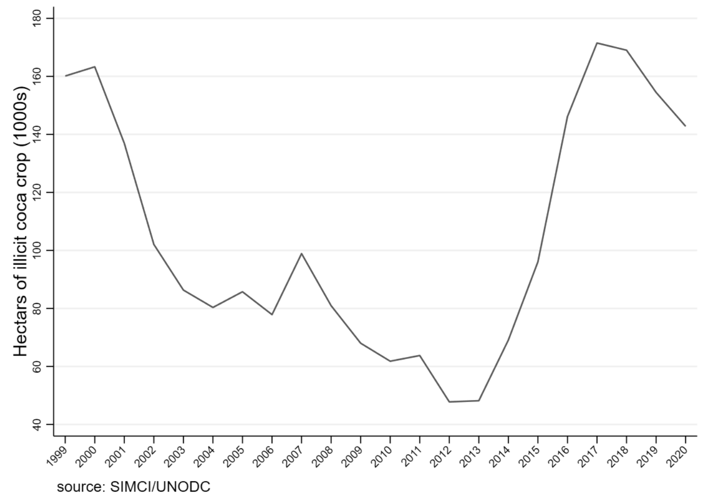
	Dependent variable: Homicides index			
	(1)	(2)	(3)	(4)
			2SLS estimates	
	OLS estimates		Announcement IV	
	All municipalities	Municipalities on the routes	All municipalities	Municipalities on the routes
Trafficking routes coca (log)	0.694*	0.930*	1.544**	2.235**
	(0.398)	(0.504)	(0.763)	(0.979)
Observations	11,100	6,020	11,100	6,020
Mean dep. var.	25.504	31.216	25.504	31.216
Municipality FE	Yes	Yes	Yes	Yes
Department-by-Year FE	Yes	Yes	Yes	Yes
Baseline mun. contr.-by-Year FE	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses are clustered at the municipality level. Asterisks denote statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The outcome variable is the homicide rate per 100,000 inhabitants. The main explanatory variable is the predicted amount of cocaine trafficked through the municipality, which is defined in section 3.1. Odd columns consider the sample of all municipalities while even columns the sample of municipalities situated along the drug trafficking routes. Columns 1 and 2 collect the OLS estimates, columns 3 and 4 the 2SLS estimates using the PNIS announcement IV defined in section 4.1. All specifications include municipality and department-by-year fixed effects. All specification feature a set of municipality controls at the baseline interacted with year dummies. The set of baseline controls includes: population (log), poverty index, and average night-time lights intensity (log) in 2010; share of employment in agriculture in 2005; distance from department capital (log); homicides rate in 2011; indicator for the presence of FARC; number of criminal gangs involved in violent events between 2000 and 2010.

Table 6 *Placebo estimates statistics - 100,000 simulations*

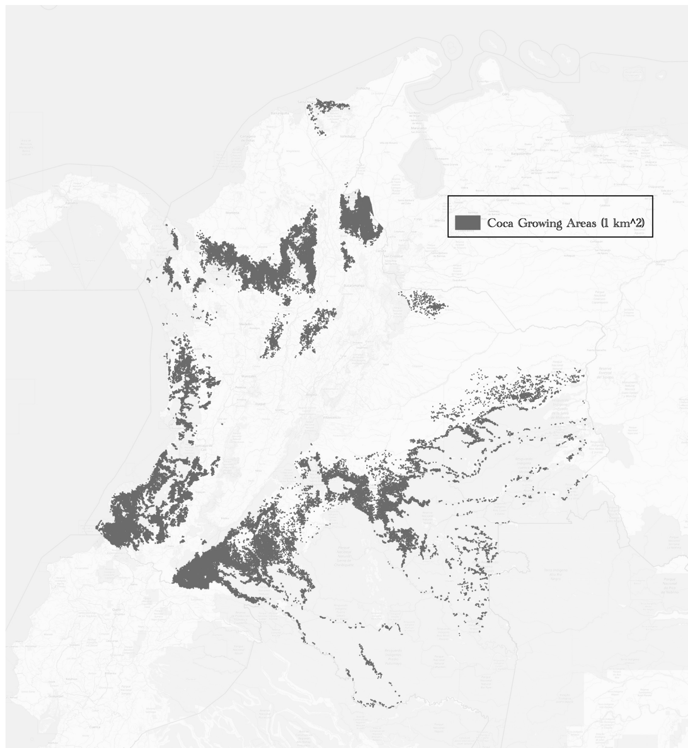
Estimation	Sample	Baseline est. coefficients	Placebo coefficients: Mean	Min	Max	Rejection rate (%) [pval < 0.05]
OLS	All municipalities	1.13	0.00	-0.33	0.34	4.93
OLS	Trafficking routes mun.	1.59	0.00	-0.50	0.46	4.94
2SLS	All municipalities	1.83	0.00	-0.36	0.42	4.99
2SLS	Trafficking routes mun.	3.01	0.00	-0.61	0.49	4.83

Figure 1 Coca cultivation trend in Colombia (1999-2020)



Source: Calculations conducted by the authors based on UNODC data. To compute the overall quantity of coca cultivated in Colombia, we aggregated the coca amounts from each grid across the country.

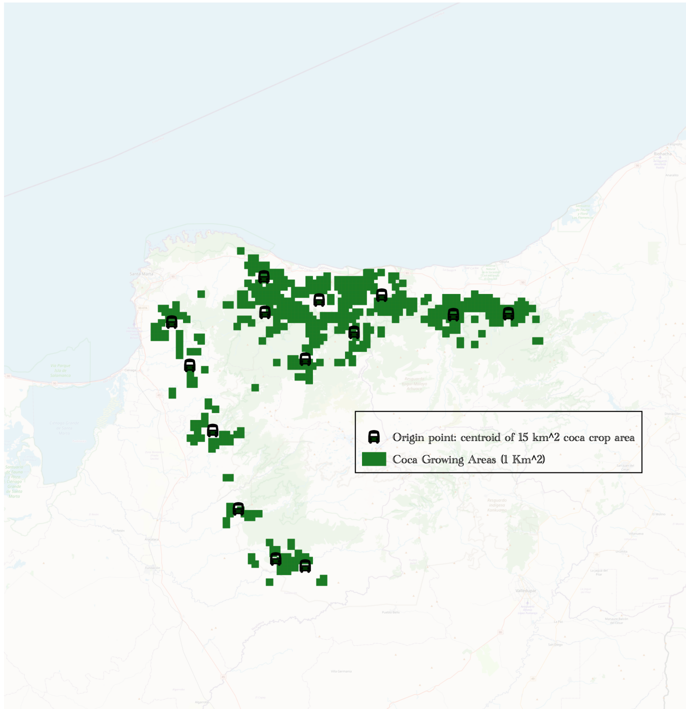
Figure 2 Coca Growing Areas (1 km^2 Grid-Level)



Source: Calculations conducted by the authors utilizing data from the United Nations Office on Drugs and Crime (UNODC) for coca crop information, and OpenStreetMap data for identifying roads, rivers, and ports.

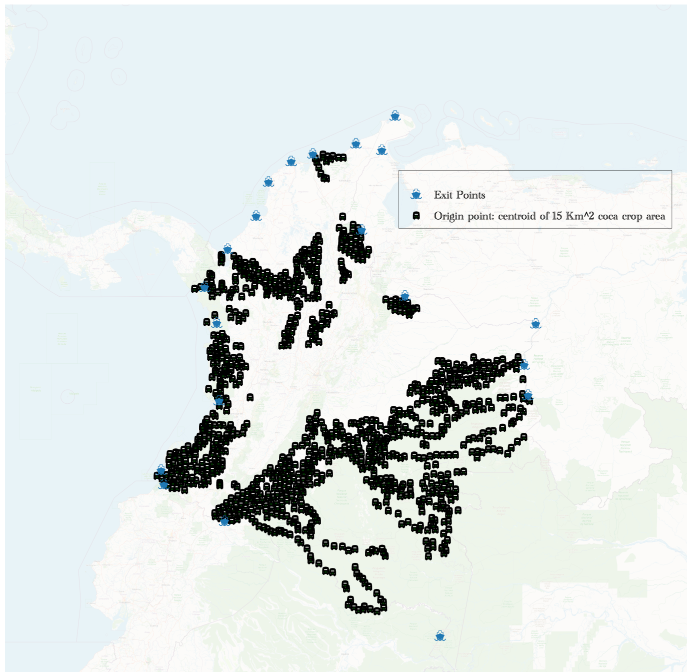
Notes: This figure illustrates the grid areas that experienced coca cultivation at least once between 2010 and 2021.

Figure 3   Creation of Coca Origin Clusters



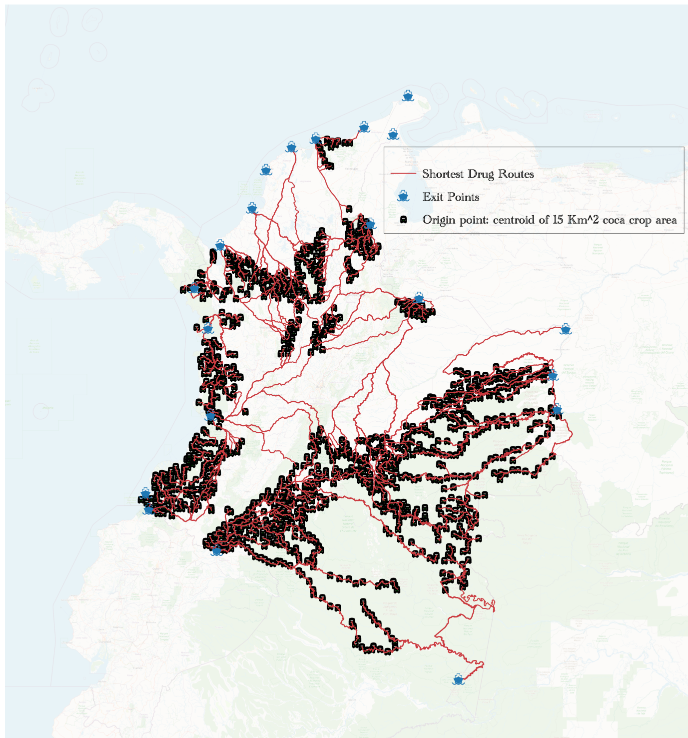
Notes: This figure depicts the process of constructing the 1000 coca clusters, with the largest cluster covering an area of 15 km^2.

Figure 4 Coca Clusters and Export Points



Notes: This figure displays the 1000 coca clusters alongside the 16 designated export points.

Figure 5 Predicted Trafficking Routes



Notes: This figure showcases the 1000 predicted trafficking routes.

Figure 6 Substitution program announcement and coca production: dynamic specification

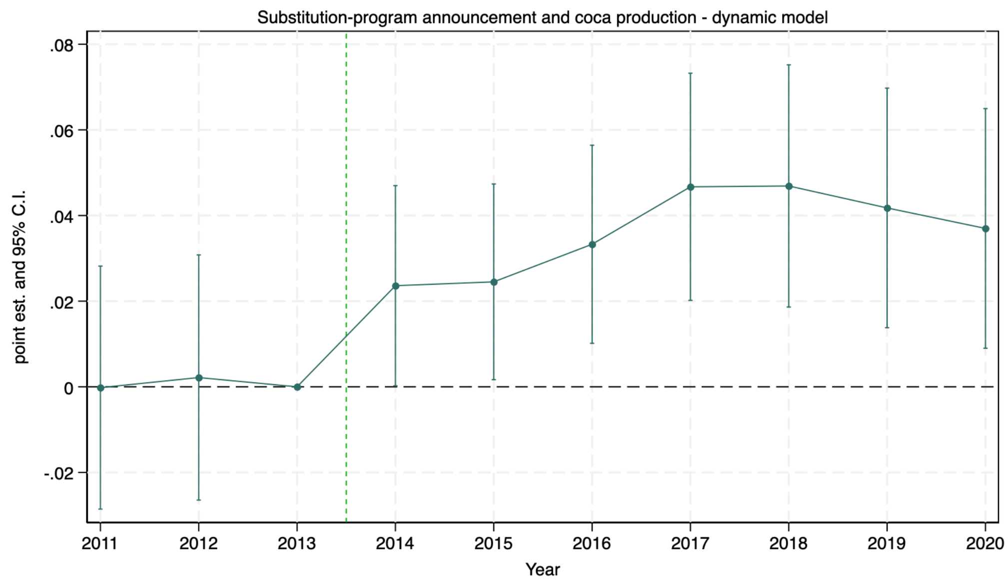
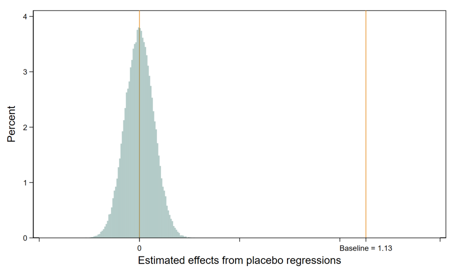
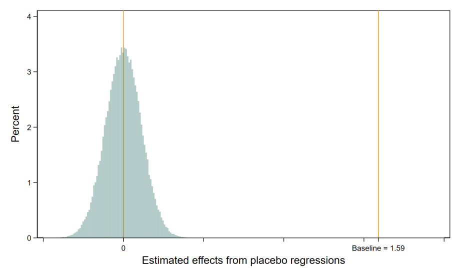


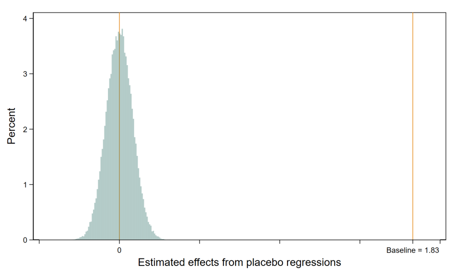
Figure 7 Distribution of placebo effects



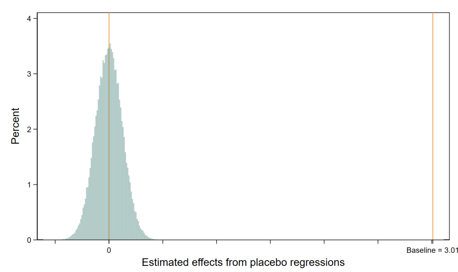
(a) OLS - All municipalities



(b) OLS - Mun. on trafficking routes



(c) 2SLS - All municipalities



(d) 2SLS - Mun. on trafficking routes

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