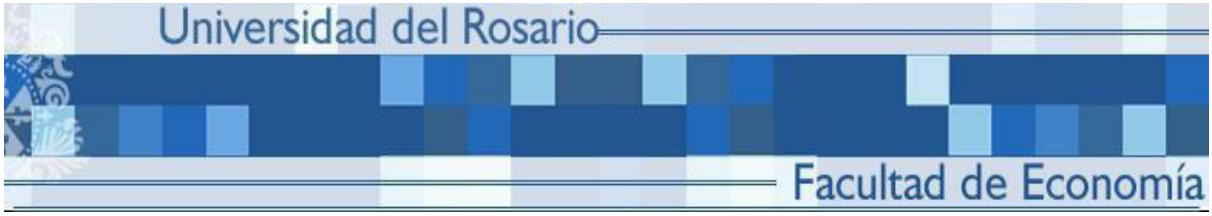

One Step Ahead of the Law: The Net Effect of Anticipation and Implementation of Colombia's Illegal Crops Substitution Program

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Abstract

Pre-announced policies often generate anticipation effects that may end up in unintended consequences. But little is known about the extent to which the actual implementation of the policy can offset these effects. Previous research have shown that the announcement of an illegal crop substitution program made coca cultivation increase substantially in Colombia, but the net effect of the policy has not been estimated. We use detailed data on both coca cultivation and substitution payments at $1km \times 1km$ grid squares to estimate the net effect of the policy. Our data also allows us to study the geographical spillovers of the program to non-targeted neighboring areas. Using a difference-in-differences empirical strategy, we find that program recipients reduced illegal crops by 94% with respect to the pre-program mean. Surprisingly, the reduction in neighboring (non-targeted) grid areas is of similar magnitude. However, these reductions are not enough to compensate for the large increase in coca growing that took place between the announcement and the implementation of the policy, and thus the net effect is negative. This suggest both that the early announcement was a mistake that led to a substantial one-time cost, but the ongoing substitution efforts will have the intended effects if continued.

JEL classification: D74, K42
KeyWords: Policy anticipation; Illegal Markets; Coca; Colombia

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1. Introduction

Governments want to discourage illegal activities with carrots and sticks. Carrots are preferred when poor households are involved in illegal activities out of necessity. But, if the carrot policy is pre-announced without fixing the baseline, it can have perverse incentives to increase the illegal activity and might render the policy ineffective. In this article we study policy anticipation in the context of coca cultivation in Colombia and the announcement, within negotiations with FARC guerrilla, that small farmers will be paid to eradicate coca crops. We then evaluate the policy once implemented to asses the net effect of the policy.

Malani and Reif (2015) mention that anticipation happens when individuals have: (i) access to information about future treatment, (ii) they can benefit from acting before treatment and, (iii) individuals are forward looking. These three conditions are met in our context, because FARC members could inform farmers of the advances in the negotiation and policymakers did not set a baseline before the announcement. The coca plant can provide initial harvest in six months (Dion & Russler, 2008), therefore the response to incentives can happen rapidly. To analyze anticipation and program effectiveness we use two difference-in-differences strategies: for anticipation we compare areas with and without FARC presence, before/after the first draft of the negotiation was released. To measure the effect of the program we compare areas that receive/ did not receive payments before/after the eradication payments.

The Global Drug Report (2018) produced by the United Nations Office on Drugs and Crime (UNODC), established that 67% of world's coca crops cultivated are in Colombia. Coca crops are the main input for the production of cocaine. Consequently, Colombia was the main producer of cocaine in the world (UNODC, 2018). Around 58% of coca growers expressed that poverty and unemployment lead them to plant coca leaf (Ministerio de Justicia y del Derecho, 2011).

Peace negotiations with FARC guerrilla started on 2012, with one of the points in the agenda

being to solve the problem of illicit drugs. On May 2014, a draft containing the National Program of Crop Substitution (PNIS) was released. PNIS seeks to decrease the hectares of coca crops by means of voluntary substitution of cultivations in exchange of benefits such as conditional cash transfers, productive projects grants, and technical assistance. The final agreement was signed on November 2016 and the first PNIS beneficiaries were registered that same month.

We have satellite data on the extent of coca cultivation for the years 2010-2018 at the 1 kilometer x1 kilometer grid square level. We also have the coordinates of the location of all PNIS beneficiaries, sign-up date and payments received. To measure FARC presence, we use data on selective killings and bellicose actions before 2014, the year just before PNIS announcement. We find that coca cultivation increased by 0.54 percentage points (91 % of the mean before the announcement) as an effect of anticipation to the PNIS program in FARC areas.

Grids that receive PNIS payments decreased cultivation by 1.05 percentage points (53% of the mean cultivation on 2017). Interestingly we find that on areas neighboring grids that received PNIS, there is also a reduction of 1.06 percentage points. Consequently we do not find evidence of a balloon effect at the local level. The reduction on neighboring grids could be due to the coca leaf buyers not coming to an area with less supply and increased state presence.

Although the program was effective on the areas where it was implemented, the overall anticipation is larger on this first year of implementation. Future research could measure the full scale implementation and longer term effects. We estimate the cost per hectare reduced at 46 million COP (around U$15,000). This is around a fifth of the cost of reducing a hectare by aerial spraying estimated by (Mejia, Restrepo, & Rozo, 2015). These estimates do not include the health costs of glyphosate or the benefits of PNIS productive projects.

Policy anticipation when there is a delay between announcement and implementation was

theoretically studied by Kremer and Willis (2016). Empirically, many papers have studied the announcement of policies before implementation in different contexts (Dong & Klaiber, 2019; Blundell, Francesconi, & van der Klaauw, 2011; Lueck & Michael, 2003). But most of the literature have been on bans or regulations, while we study anticipation to receiving subsidies.

In terms of illicit drugs policies, the literature have shown that forced eradication actions generate negative spillovers, or "balloon effects", which affects the net effectiveness of forced eradication efforts (Moreno-Sanchez, Kraybill, & Thompson, 2003; Reyes, 2014). Recently, Mejia et al. (2015) find that eradication by aerial spraying of one hectare of coca only reduces total coca area by 0.03 hectares. Bagley (2012) argues that to sustain a decline in coca crops funding for development programs are needed in addition to eradication efforts. In this paper we study a voluntary eradication policy and do not find "balloon effects" at the local level.

(Lopez, Guarin, Medina, & Zuleta, 2019) and (Mejia, Prem, & Vargas, 2019) have shown the increase in coca crops after the PNIS program announcement. We estimate the anticipation effect with another source of variation, and focus on the effectiveness of the PNIS program once implemented. Consequently, we can compare anticipation with effectiveness of the program. Another advantage of our research is that we do the analysis at the $1km \times 1km$ grid level, instead of municipality level. Municipalities have on average 1,000km^2 of area, therefore 1,000 of our grid squares. With this level of detail we can focus exclusively on areas prone to coca cultivation and can also study spillovers of the program.

Through this research we complement the recent literature related to the effects of the peace agreement in Colombia. The peace agreement creates opportunities for development, like increased school attendance (Namen, Prem, & Vargas, 2019). But it also generates unintended consequences (Prem, Saavedra, & Vargas, 2018; Prem, Rivera, Romero, & Vargas, 2018). We find that in terms of illicit drugs, there were also unintended consequences too.

2. Context

The second half of the twentieth century in Colombia saw the birth of left-wing guerillas such as *Fuerzas Armadas Revolucionarias de Colombia* (FARC) and *Ejercito de Liberación Nacional* (ELN); and rigth-wing guerillas such as *Autodefensas Unidas de Colombia* (AUC). The clash between left-wing guerillas, AUC and the military forces of the government, accompanied by the strengthening of drugs traffick, aggravated the conflict in the country. For groups like FARC, illicit crops presented a source of income. In the Colombian case, the main illicit crop is coca, which serves as the primary input in the creation of cocaine hydrochloride.

Coca crops strengthen existing conflicts, since they serve as a funding source for insurgent group(Ross, 2004; Angrist & Kugler, 2008). On the other hand, geographic expansion of conflict generate the need for the insurgency to expand their funding sources too (Díaz & Sánchez, 2004). Households respond to the risk of violent attacks, changing the decisions about what to cultivate(Arias, Ibáñez, & Zambrano, 2014). Coca is easier to cultivate, since the crop can grow in low-quality soil; is resistant to changes in climate; can be harvested from three to six times a year; and requires low investment in infrastructure (Mansfield, 1999; Dion & Russler, 2008).

Before 1990, most coca crops were concentrated in Peru and Bolivia, however, the sudden decline in coca in Peru and Bolivia due to state interventions (Laserna, 2009; Thoumi, 2009), accompanied by factors such as the expansion of the armed conflict (Torres, Díaz, et al., 2005; Mejía & Posada, 2008) led Colombia to become the main coca leaf grower in the world (UNODC, 2018). In 1990, the country had approximately 40,000 thousand hectares of coca, however, coca crops increased to close to 163,000 by 2000.

Moreno-Sanchez et al. (2003) and Dion and Russler (2008) found that the forced eradication policy generated an increase in coca crops through the extension of crops in the territory and on account of more extensive crops as eradication activities intensified. As a result, by

2006, it had not been possible to eliminate all the coca from the country.

In 2012, the Colombian government and FARC, began peace negotiations in La Habana. The fourth item in the agenda was a solution to the "drugs problem" with programs to substitute illicit crops (Gobierno Nacional y FARC-EP, 2012). The negotiation team relaased on May 2014 a draft that contained the National Integral Program of Illicit Use Crop Substitution (PNIS). The proposed solutions were partly fueled by the demands made to the government by coca cultivators of the Catatumbo[1] region. Coca growers of that region striked on 2013, requesting support for the substitution of illicit crops in the form of cash transfers to mitigate the food crisis caused by forced eradication.

PNIS offers the following benefits to the farmers that voluntarily decide to erradicate their coca crops:

- Two million colombian pesos (COP) in cash after signing the voluntary agreement (around 2.5 times the minimun monthly wage).
- After eradication, five bi-monthly transfers of 2 million COP
- In-kind transfers of 20.8 million COP for productive projects
- Technical assistance for other crops (3.2 million COP value)

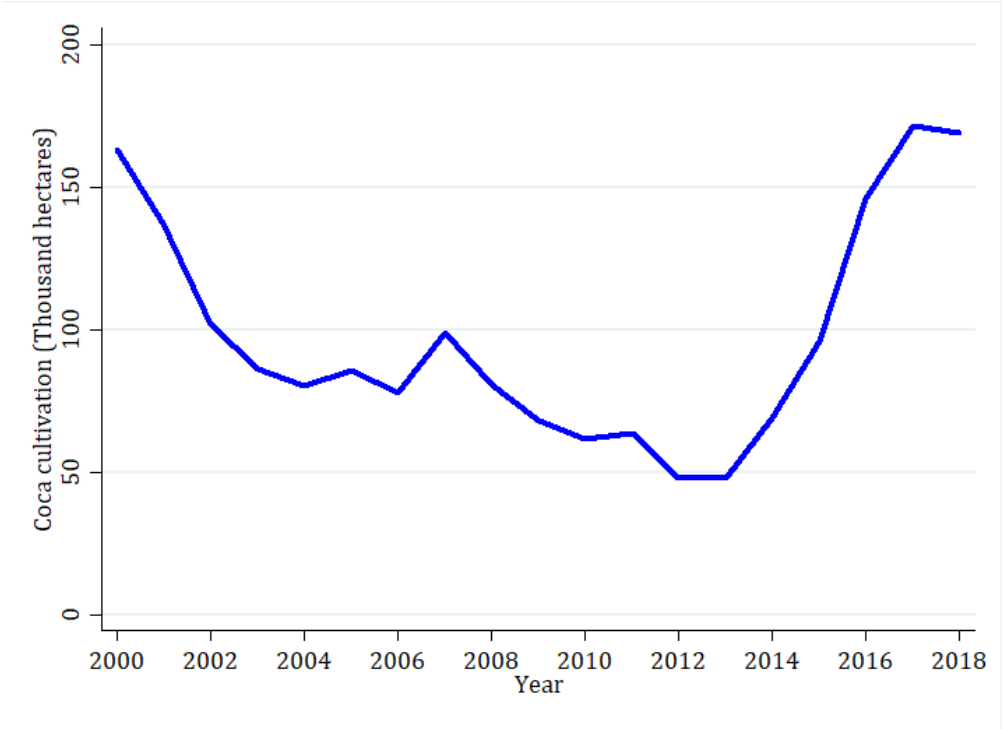
That is, in exchange for voluntarily eradicating illicit cultivation, each cultivator can receive up to 36 million COP in benefits from PNIS. The agreement that each farmer signs, includes also the signature of a FARC member as "signatory of the Peace Agreement, PNIS companion and promoter". However, a review of past experiences of voluntary substitution and international literature on the subject (Unlu & Kapti, 2012; Chouvy, 2013), indicate that, especially in the absence of baseline information that allows the characterization of the population, the introduction of conditional incentives in a context of illegality and low state

[1]Catatumbo is a subregion of Colombia, that includes various municipalities in Norte de Santander department, that historically has had coca crops. Tibú municipality, located in Catatumbo, is one of the areas with more coca crops in the country.

presence can generate just the opposite: an increase in illicit crops.

Figure 1 shows the evolution of coca cultivation in Colombia from 2000 to 2018. It can be seen that from 2014, year of the first announcement of PNIS, coca cultivation increased. This implied a retreat in the fight against drugs, taking into account that for 2013 the number of hectares of the illicit crop had decreased in 70% with respect of its value in 2000. On 2017 coca cultivation reached its maximum historical value of 171,000 hectares.

Figure 1: Historical evolution of coca crops



3. Data

We combine data from different sources to create a panel dataset at the 1kmx1km grid level to study the effect of PNIS announcement on the increase of coca crops and the effectiveness of the program once implemented.

Data on coca cultivation is from the *Integrated System of Illicit Crops Monitoring* (SIMCI)

of the United Nations Office on Drugs and Crime. SIMCI annually produces data on coca cultivation through manual inspection of satellite imagery. We have information from 2010 to 2018 at the 1kmx1km grid level. We have the number of hectares of coca crop in each grid. Given that the area of a grid square is $1km^2 = 100ha$, the numberof hectares on a grid can also be interpreted as a percentage.

We also have data at the PNIS benefitiary level with sign-up date, payments received, hectares of coca at first monitoring and eradicated hectares on the second monitoring. Importantly we have a point coordinate of the coca plot. We identify the 1kmx1km grid square where each PNIS benefitiary is located and declare it a PNIS plot. Given that we do not have the exact shape of the PNIS benefitiary's plot, it is possible that the plot is also part of the neihboring grid.

In order to construct a measure that approximates FARC presence, we have municipal data from the *National Center of Historical Memory of Colombia* (CNMH) on violent actions in which FARC was involved[2]. Specifically, we use information for selective killings (SK) and bellicose actions (BA). The former are defined by CNMH as the intentional killing of three or less people in a state of defenselessness, in the same place and time, perpetrated by FARC. The later, are defined as killings during war actions. Also, to complement data on conflict, we have municipal data of FARC actions related to violation of human rights, coded by Osorio, Mohamed, Pavon, and Brewer-Osorio (2019), based on publications of narratives of conflict in *Noche y Niebla* (NN) magazine created by the non-governmental organization *Research and Popular Education Center* (CINEP).

A dummy variable was created for grids inside municipalities affected by FARC SK, FARC BA or FARC NN if at least one violent episode ocurred between 2010 and 2013. Since the FARC presence measures we construct use information before the announcement, we avoid strategic movements post-announcement.

[2]Prem, Rivera, et al. (2018) states that, while using past violent actions is an imperfect proxy for presence and may underestimate the real influence o an armed group, territorial control is unlikely to occur without violence inflicted in the past, then past violent actions translates into certain influence in the territory.

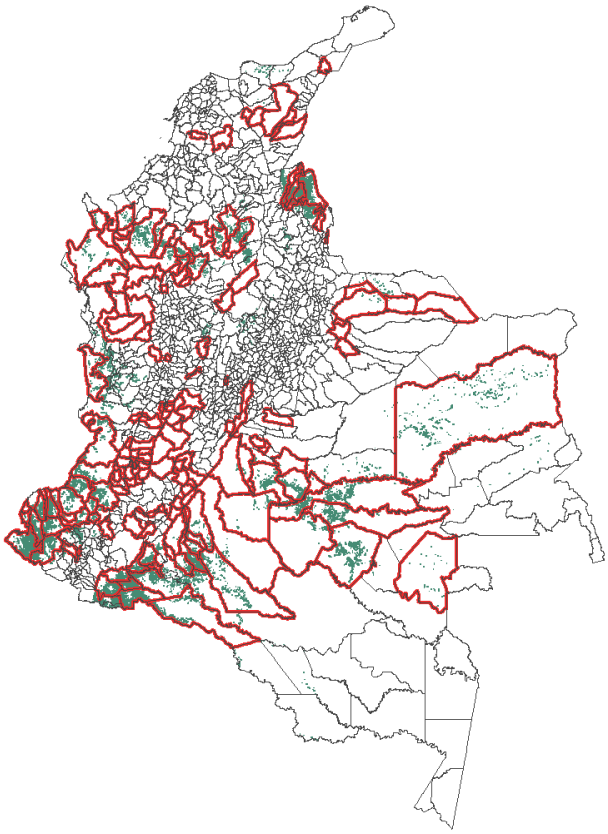
For the main FARC presence measure, we use selective killings, considering that these kind of violent action may be associated with the territorial control through fear, in which the killing is used as mechanism to send a message of presence and control againts the population or other armed gruoups. Bellicose actions and NN reports, on the other hand, imply direct clashes between more than one armed group. Nevertheless, we report robustness to these definition of FARC presence.

Figure 2 presents the geographical distribution of coca cultivation and FARC municipalities. Out of the 1,120 Colombian municipalities, 276 (24.6%) have coca crops ever in the period of analysis. Of the coca municipalities, 92 (33.9%) have FARC presence defined by selective killings, 139 (51.3%) have FARC presence defined by bellicose actions and 103 (37.3%) have FARC presence defined by NN. Within the municipalities that grow coca ever, only 6,372 districts (veredas) out of 33,348 districts grow coca (19.1%). Finally, within coca districts, only 84,242 grid squares out of 533,762 had some coca or neighbor a coca grid during our study period (15.9%). Consequently these are the 84,252 grids that enter our regression analysis.

Table 1 presents summary statistics for our sample of 84,252 coca grids. Approximately, 70% of grids have FARC SK presence, while 86% have FARC BA presence and 62% have FARC NN presence. In terms of coca area measured in hectares, the mean and standard deviation have increased from 2010 to 2018 . 16% of the coca grids joined PNIS during our study period

Table 2 presents summary statistics for PNIS grids. On 2017, 8.8% of the grids received PNIS payments. From the grids that receive PNIS ever, 76% have FARC SK presence. On the other hand, coca hectares in 2016 measured remotely (*SIMCI*) have a higher mean than the base line coca hectares measured on the field. That is not all the plots were enrolled within a grid. Mean eradicated area is 1.3, just below both means of cultivated area in 2016. Finally, the mean payment is 20 million COP, with a standard deviation of 28 million COP.

Figure 2: Coca crops and FARC municipalities



Notes: This figure presents a map of Colombian municipalities. On green we show the location of coca crops in 2013. On red we highlight the municipalities with FARC presence based on selective killings.

Figure 3 presents coca cultivation on grids with and without FARC SK presence. After the 2014 announcement, the area with coca crops in FARC grids, increased more than in grids without FARC presence. Also, it can be observed that apparently, before PNIS announcement, coca crops evolved in a similar way in both FARC and no FARC grids. This is important since "parallel trends" is a main assumption for the validity of our difference-in-differences strategy. We test this assumption formally in the following section.

Table 1: Summary statistics - grid level

	Mean	Median	Std. Dev.	Min	Max	N
FARC (SK)	.7	1	.46	0	1	84,252
FARC (BA)	.86	1	.34	0	1	84,252
FARC (NN)	.62	1	.48	0	1	84,252
Coca area 2010 (ha)	.59	0	1.3	0	37	84,252
Coca area 2013 (ha)	.57	0	1.5	0	62	84,252
Coca area 2016 (ha)	1.7	0	4.4	0	90	84,252
Coca area 2018 (ha)	2	0	4.4	0	61	84,252
PNIS payments ever	.16	0	.37	0	1	84,252

Notes: An observation is a $1km \times 1km = 100$ hectares grid square. FARC dummies are equal to one if the grid is in a municipality in which a violent action took place before 2014. SK, refers to selective killings; BA, to belicose actions; and NN, to violation of human rights. PNIS payments ever is a dummy that equals 1 if the grid received PNIS payments.

Figure 4 presents coca crops evolution separating grids that have received payments for eradication in 2017. It can be observed that the area with coca crops in grids defined as PNIS, decreased, while coca crops area in no PNIS grids keep increasing. This suggest that there is a relationship between PNIS and the decrease of coca crops. Also, it can be observed that both groups follow a similar trend before PNIS implementation, giving support to the "parallel trends assumption".

4. Empirical Strategies

Our identification relies on two difference-in-differences strategies. To estimate anticipation we compare areas with and without FARC presence, before/after the first draft of the negotiation was released on 2014. To measure the effect of the program we compare areas that receive/ not receive PNIS payments before/after the eradication payments. In both cases, the outcome of interest will be coca hectares as percentage of grid area. As each grid square is $1km \times 1km = 100hectares$, the results can also be interpreted in number of hectares.

Table 2: Summary statistics - PNIS

	Mean	Median	Std. Dev.	Min	Max	N
PNIS (2017)	.088	0	.28	0	1	84,252
PNIS (2018)	.092	0	.29	0	1	84,252
FARC SK (if PNIS ever)	.76	1	.43	0	1	13,633
Coca area 2016 (ha)	1.6	.27	3.6	0	65	7,227
Base line coca (ha)	1.4	.75	2.2	.0024	50	7,227
Erradicated coca (ha)	1.3	.67	2.1	0	50	7,227
Payments (Million COP)	20	11	28	0	503	7,227

Notes: An observation is a $1km \times 1km = 100$ hectares grid square. PNIS is a dummy equal to one if the grid received PNIS payments on the indicated year. Coca area 2016 measured in hectares is based on *SIMCI*'s satellite measurements. Base line coca is measured on field verification by program implementers.One million Colombian pesos (COP) is around 300 dollars.

4.1. Anticipation effect

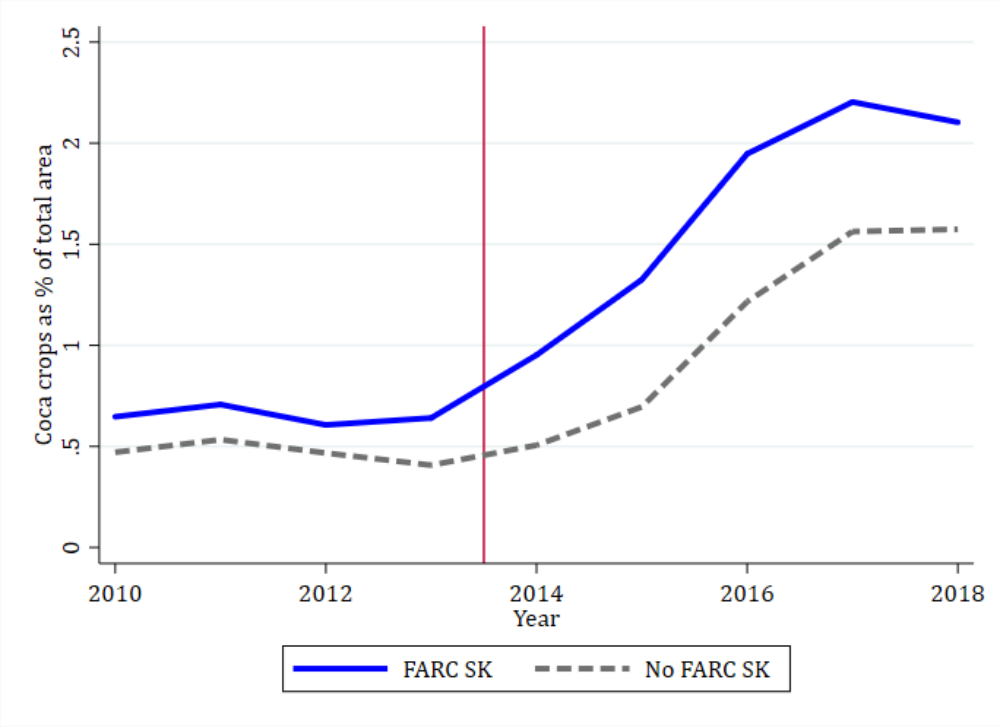
Thia estimation strategy exploits the timing in the announcement of PNIS on 2014, during the peace negotiations, and the spatial distribution of FARC prior to the announcement year. Formally, the equation to be estimated is:

$$y_{imdt} = \beta(PostAnnouncement_t \times FARC_m) + \alpha_i + \lambda_{dt} + \varepsilon_{imdt} \tag{1}$$

Where y_{imdt} is the percentage of coca area on grid i, of municipality m, from department d on year t. $PostAnnouncement_t$ is a dummy that indicates if year $t \geq 2014$, the year of the PNIS draft announcement. $FARC_m$ is a dummy that measure presence of FARC on municipality m before 2014, either through selective killings (SK), bellicose actions (BA) or attack reports (NN). α_i and λ_{dt} are grid and department/time fixed effects, respectively. The α_i capture any time invariant characteristics of the grid, like elevation and soil type; and λ_{dt} department level yearly shocks, like weather. ε_{imdt} is the error term that we cluster at the municipality level. The difference-in-difference coefficient, β, captures the differential increase in coca cultivation in FARC grids after the program announcement.

To claim causal effects, it is necessary to evaluate the parallel trends assumption. This

Figure 3: Evolution of coca crops in FARC/No FARC municipalities



Notes: The x-axis represents time in years and the vertical axis the percentage of coca crops in the grid. The solid blue line is for areas with FARC presence based on selective killings. While the gray dashed line is for areas without FARC SK presence. The red line represents the PNIS announcement.

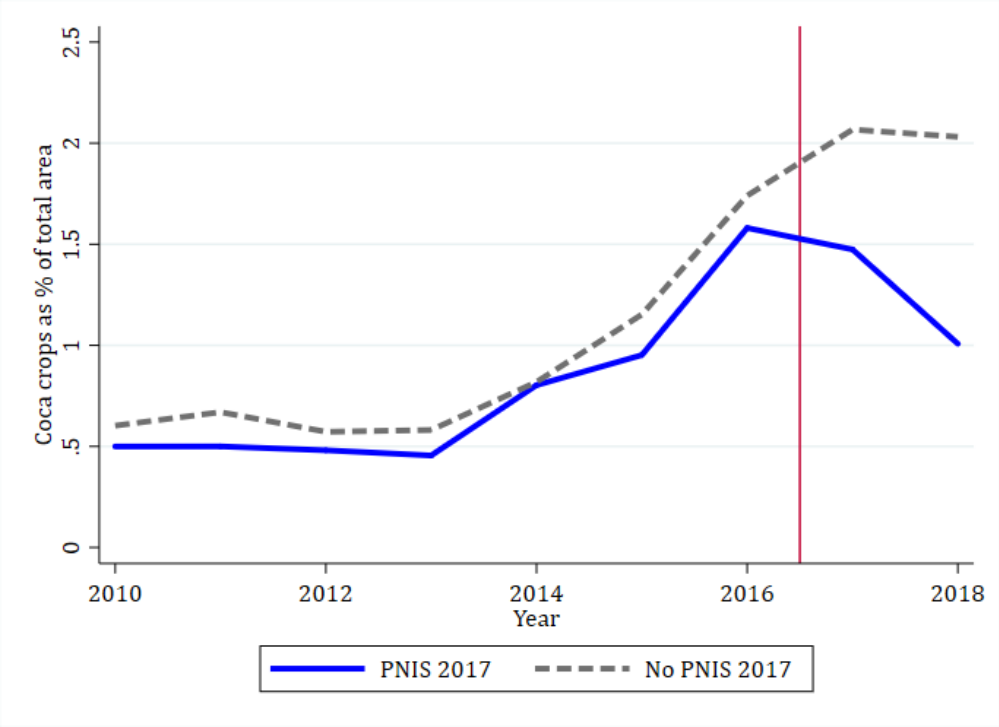
assumption implies that, absent the program announcement, coca crops would have evolved similarly in grids affected and no affected by FARC. To test this assumption, following Abadie (2005), a semi-parametric version of (1) will be estimated:

$$y_{imdt} = \sum_{t \in T} (\beta_t \times FARC_m) + \alpha_i + \lambda_{dt} + \varepsilon_{imdt} \tag{2}$$

Where T includes all periods in the sample except 2013, the year prior to the program announcement. β_t can be interpreted as the differential coca cultivation in municipalities affected by FARC in year t, relative to the year prior the announcement.

The above specification also allows to analyze an event study of the differential increase in coca cultivation in FARC grids with respect to no FARC grids year by year. This is important since PNIS first announcement was made in 2014, but modifications and details

Figure 4: Evolution of coca crops in PNIS/No PNIS grids



Notes: The x-axis represents time in years and the vertical axis the percentage of coca crops in the grid. The solid blue line is for grids that receive PNIS payments on 2017. While the gray dashed line is for areas that did not receive the program that year. The red line represents the first PNIS payments.

were added on the following years.

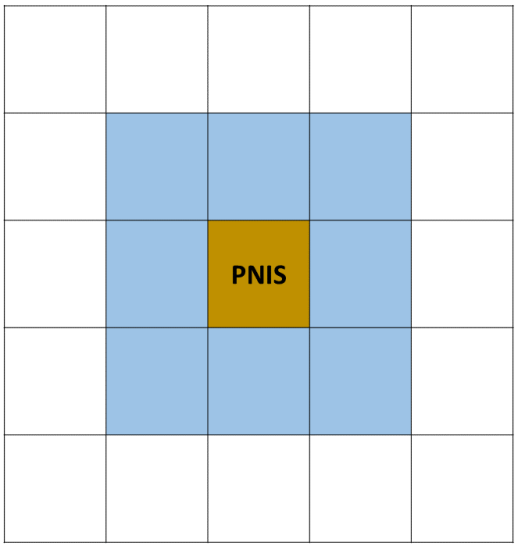
4.2. PNIS payments effects

To study the effect of PNIS payments, the difference-in-differences strategy compares areas that receive/ did not receive payments before/after the eradication payments. In addition, we look for spillover effects at the grid level, for grids neighboring the PNIS grids. The neighbors are defined as those grids that do not received PNIS payments, but surround one PNIS grid, as Figure 5 illustrates. The white squares that are not direct neighbors, but surround the neighbors, will be called second ring of neighbors ("2nd ring").

Formally, the equation to be estimated is:

$$y_{it} = \beta(PNIS_i \times Post_t) + \delta(NeighborPNIS_i \times Post_t) + \alpha_i + \lambda_t + \varepsilon_{it} \tag{3}$$

Figure 5: Neighbor definition



Notes: The dark yellow squares receives PNIS payments. And we define the eight neighboring light blue squares as neighbors. The white squares that are not direct neighbors will be called the second ring of neighbors ("2nd ring").

y_{it} is the percentage of coca crops on grid i during year t. $Post_t$ is a dummy variable that equals one after the grid receives eradication payments. $NeighborPNIS_i$ is a dummy that equals one if the grid does not receive PNIS payments and is surrounding a grid that receives PNIS payments. α_i, λ_t are grid and time fixed effects. ϵ_{it} is the error term. The difference-in-difference coefficient that capture the effect of the program is β. On the other hand, δ captures the spillover effect of being a neighbor of a PNIS grid.

Since we are also using difference-in-difference as identification strategy, we estimate the following equation to test for parallel trends in the effect of the program:

$$y_{it} = \sum_{t \in T} (\beta_t \times PNIS_i) + \alpha_i + \lambda_t + \varepsilon_{it} \tag{4}$$

Given that PNIS started at the end of 2016, the dynamic specification allows us to analyze an event study for the short term effect of the program and test the parallel trends assumption before hand.

5. Results

5.1. Anticipation effect

Figure 6 presents the estimation of the dynamic difference-in-differences described in equation (2). Each point represents the coefficient of a year and associated 95% confidence interval. For this estimation, the measure of FARC presence by selective killings (SK) is used. No coefficient before the PNIS announcement is statistically signicant different from zero. Then, the parallel trends assumption is empirically satisfied.

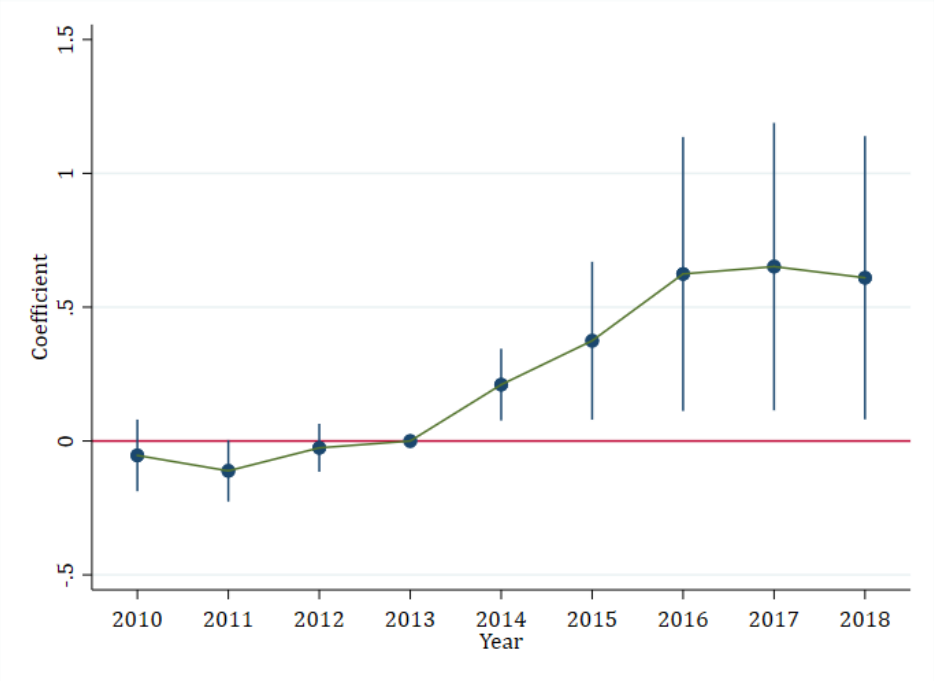
In terms of the evolution of the effect, the event study shows that, since PNIS announcement, the cultivated coca area in FARC areas becames differentially higher year to year with respect to no FARC areas. The effect stabilizes on 2018. The fact that the effect of the announcement on coca crops increases, highlights importance of fixing the baseline, to avoid perverse incentives to increase illegal activity.

Table 3, presents the results for the difference-in-differences specification for the anticipation effect presented in equation (1). We present the results for four definitions of FARC presence. The first, third and fourth column, show the results of the estimation using selective killings (main), bellicose actions and attacks definitions respectively, as described in the Data section. The second column shows the results for FARC selective killings presence equal to one only when the number of cases is above the 10th percentile. Thus, we generate a more demanding FARC presence definition, to control for municipalities where low number of violent cases may be related with isolated actions.

We find that after the announcement, coca crops as percentage of the grid area increased by 0.54 ppts in FARC SK areas with respect to no FARC areas. When restricting presence by those areas above the 10th percentile for SK, the effect increases to 0.80 ppts. Similar coefficients are obtained when using BA and NN definitions.

As robustness to the previous specification, Table A.1 includes a control variable of aerial eradication as percentage of the municipal area. This tests for an alternative explanation

Figure 6: Event study differential coca cultivation in FARC/No FARC areas before/after announcement



Note: This figure illustrates the event study for coca cultivation on FARC/No FARC areas. The x-axis plots years and the y-axis plots the coefficients of year interacted with the FARC dummy. The segment containing each point is the 95% confidence interval

that the increase in coca cultivation might be due to decreased forced eradication efforts by the government. In general, the coefficients are pretty similar to those of Table 3. For example, for FARC SK the effect diminishes by 0.02 its magnitude, from 0.54 to 0.52.

Table A.2 in the Appendix present results using as coca sample only the grids that reported coca crops before the announcement. The sample restriction serves to test if the increase in coca crops was mainly driven by new growing areas. The results are within the confidence interval of the ones estimated in Tables 3 and A.1. The magnitude of the coefficient is larger, because in these grids they already have the know how of cultivation. The previous results of anticipation confirm the findings of Lopez et al. (2019) and Mejia et al. (2019), which also found significative effects of the announcement on the increase of coca crops.

Table 3: PNIS announcement and coca cultivation on FARC areas

Dependent Variable:	% grid area with coca			
	(1)	(2)	(3)	(4)
Post X FARC (SK)	0.54**			
	(0.24)			
Post X FARC (SK-P10)		0.80***		
		(0.27)		
Post X FARC (BA)			0.70***	
			(0.21)	
Post X FARC (NN)				0.54***
				(0.19)
N. of obs.	758,272	758,272	758,272	758,272
Municipalities	274	274	274	274
Mean of Dep. Var. Before	0.60	0.60	0.60	0.60
R^2	0.57	0.57	0.57	0.57

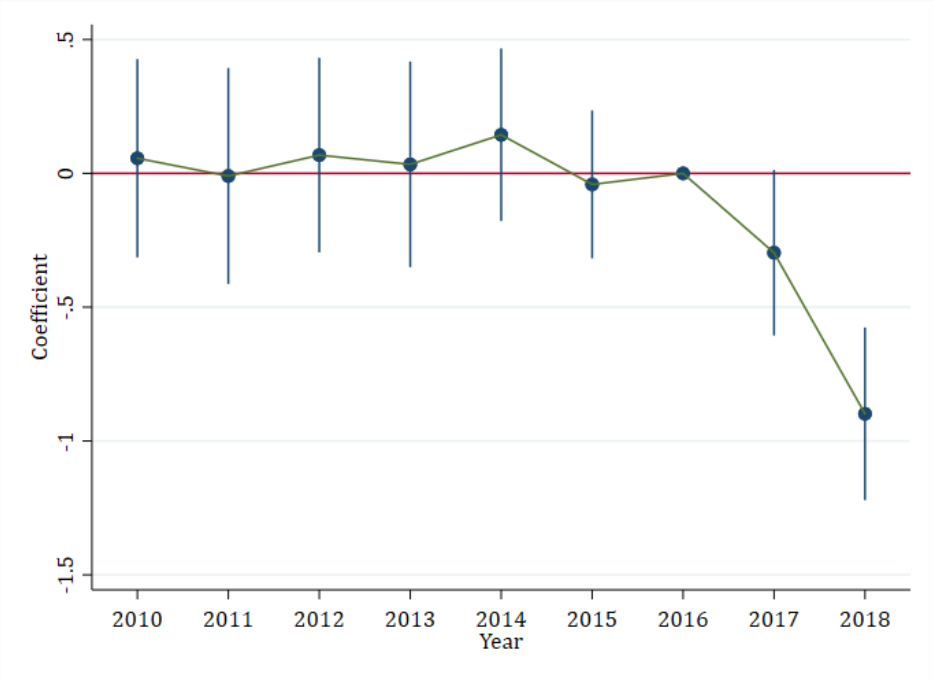
Notes: SK, refers to selective killings; SK-P10 exclude the lowest decile of selective killings; BA, refers to belicose actions; and NN to violation of human rights. All regresion include grid and department-year fixed effects. Standard errors, clustered by municipality are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.2. PNIS payments effects

Figure 7 presents results from the estimation of the dynamic difference-in-differences of equation (4) to test for parallel trends, using 2016 as base year (just before PNIS implementation). We find that no coefficient before PNIS implementation is significant, giving support for parallel trends before implementation. In terms of the evolution of the effect, the estimation shows that after PNIS implementation there is a immediate effect of decrease in coca area.

Table 4, presents the results of the main regression for the effect of PNIS on coca crops (equation 3) to analyze the effectiveness of the program. The first and second column present the results without including the term for neighbor grids. The first column includes all the grids, while the second column includes just grids which receive PNIS payments ever. We include the second column for completeness, but the parallel trend assumption is not

Figure 7: Event study differential coca cultivation in PNIS/No PNIS areas before/after implementation



Notes: This figure illustrates the event study for coca cultivation on PNIS/No PNIS grids. The x-axis plots years and the y-axis plots the coefficients of year interacted with the PNIS dummy. The segment containing each point is the 95% confidence interval.

cleanly satisfied for comparing early versus late PNIS grids.

The third and fourth columns include the dummy for PNIS neighboring grids, to account for spillover effects in nearby grids. *SIMCI* is the satellite information about coca crops. Due to the PNIS program, on 2016 the *UNODC* used field verifiers to set up a baseline for the implementation. Disparities were found between the official data of *SIMCI* and the data collected in field (Wiesner et al, 2019). While Column 3 uses both sources of information, Column 4 restricts only to grids on *SIMCI*. Column 5 includes an additional dummy for the second ring of PNIS neighbors (neighbors of PNIS neighbors). This is included to measure possible spillover effects areas further from PNIS grids.

Overall we find a one percentage point reduction on PNIS grids. Note that this is slightly lower than the 1.3 hectares eradication reported on the field (Table 2). Significant spillover

effects of a reduction of 1.06 percentage points are found. The previous result indicates that for voluntary eradication there are no balloon effect to neighbor grids. A possible explanation for this spillover is that the coca leaf buyer is not visiting these locations, given the reduced supply. The effects found in Column 3 are robust to the restriction of the sample to *SIMCI* grids (Column 4). Finally, in column 5 no significant spillover effects are found for PNIS neighbors in the second ring, showing that the spillover effects are mainly concentrated in direct PNIS neighbors.

One possible concern is that we are miss-classifying as neighbor, grids that actually received PNIS payments. For example, due to measurement error on the point coordinates of the PNIS benefitiaries. Although global position systems (GPS) receivers are within 5 meters accuracy, it can go down to 100 meters under clouds.[3] On Table A.4 we exclude neighbor grids whose center is close to a PNIS benefitiary location. The coefficients are still significant and within the confidence intervals of those of Table 4.

PNIS heterogeneity

Table A.3 on the Appendix presents heterogeneous effects of the quantity of area eradicated, payments for eradication, distance of the PNIS grid to the closest river and road, the presence of additional public programs derived from peace process[4] and an index for state capacity.

Column 1 shows that there are no differential effects of additional payments. This is expected because payments beyond the signing transfer are conditional on eradication. Surpisingly, Column 2 shows no differential effect of additional reported eradicated area. While column 3 shows that there are no differential effects by distance to the closest navigable river, column 4 shows larger reductions on areas further from roads. Finally, we do not find differential effects for municipalities with higher state presence or part of the peace process development programs (PDET) (columns 5 and 6).

[3] https://lotadata.com/blog/how-precisely-accurate-is-your-geo-intelligence/

[4] PDET (*Plan de Desarrollo con Enfoque Territorial*) are programs for territorial development derived from peace process. See http://especiales.presidencia.gov.co/Documents/20170718-pdet/que-son-pdet.html

Table 4: Effect of PNIS on coca cultivation

Dependent Variable:	% grid area with coca				
	(1)	(2)	(3)	(4)	(5)
Post X PNIS	-0.88***	-0.97***	-1.05***	-1.05***	-1.05***
	(0.23)	(0.25)	(0.26)	(0.26)	(0.26)
Post X PNIS neighbor			-1.06***	-0.82***	-0.96***
			(0.17)	(0.19)	(0.19)
Post X PNIS neighbor (2nd ring)					-0.12
					(0.15)
Sample	Coca	PNIS	Coca	Simci	Coca
N. of obs.	758,272	122,749	758,272	686,619	758,272
Municipalities	274	70	274	274	274
Mean of Dep. Var.	1.12	1.40	1.12	1.23	1.12
R^2	0.53	0.52	0.53	0.53	0.53

Notes: Column (2) includes only grids that received payments for eradication on 2017 or 2018. Column (4) includes only the pixels that ever appear on the satellite monitoring, and consequently excludes neighbors that never had coca. All regresion include grid and year fixed effects. Standard errors, clustered by municipality, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.3. Net effect of PNIS

After estimating the anticipation effect of the PNIS announcement and the effectiveness of the implementation of the program, we can estimate the net effect. That is, if the decrease on coca cultivation with PNIS payments is larger or smaller than the increase generated by the announcement. For calculating this difference, we will use the main coefficients of Table 3 of anticipation (Column 1, 0.54 ppts). And for effectiveness, Table 4 (Column 3, direct effect = -1.05 ppts, spillover effect = -1.06 ppts). Note that this is the most conservative estimate of the anticipation and the largest of the effectiveness of the program.

Coca cultivation area increased by 0.54 percentage points on 60,735 km2 of coca grids on FARC municipalities. Multiplying we get a 328 km^2 increase, or 32,797 hectares. For the effectiveness of PNIS, coca crops decreased by 1.05 ppts on 6,384 km^2 direct beneficiaries and decreased by 1.06 ppts in neighboring grids on 12,533 km^2. Both effects account for a decrease of 6,703 and 13,284 hectares respectively. Adding up, we get a total decrease of

19,987 hectares of coca crops. Subtracting both quantities, we end up with a net increase of 12,810 hectares of coca crops, which means that at the moment, the anticipation increase is higher than the implementation decrease.

However, this result must be interpreted carefully. At the moment, we are just able to estimate short term effects of the program, as it is only been a year since the implementation. The current analysis is missing long term effects on PNIS grids and the full geographic implementation of PNIS. The net increase can not be interpreted as a failure of the program itself, and rather show the potential future benefits that PNIS can deliver if the program reaches all areas of the country.

6. Conclusions

We studied the anticipation and effectiveness of coca substitution payments in Colombia. We find that cultivation decreased by one percentage point on areas that receive substitution payments. But it had increased by half a percentage points in anticipation to the program in FARC areas. Given that there are more areas that anticipated receiving the program, the net effect is an overall increase.

This result is another reminder of the importance of setting a baseline when announcing a policy. However given previous costly experiences with aerial spraying, this substitution payments program illustrates an avenue forward to reduce coca cultivation.

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A Additional tables and figures

Table A.1: PNIS anticipation controling for aerial eradication

Dependent Variable:	% district area with coca			
	(1)	(2)	(3)	(4)
Post X FARC (SK)	0.52**			
	(0.22)			
Post X FARC (SK-P10)		0.73***		
		(0.23)		
Post X FARC (BA)			0.67***	
			(0.18)	
Post X FARC (NN)				0.50***
				(0.17)
Aerial eradication (% muni area)	-0.61***	-0.58***	-0.61***	-0.60***
	(0.19)	(0.17)	(0.20)	(0.20)
N. of obs.	758,272	758,272	758,272	758,272
Municipalities	274	274	274	274
Mean of Dep. Var. Before	0.60	0.60	0.60	0.60
R^2	0.57	0.57	0.57	0.57

Notes: SK, refers to selective killings; SK-P10 exclude the lowest decile of selective killings; BA refers to belicose actions; and NN to violation of human rights. All regresion include grid and department-year fixed effects. Standard errors, clustered by municipality are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: Effect of announcement on coca cultivation on FARC areas - Coca grids before announcement

Dependent Variable:	% district area with coca			
	(1)	(2)	(3)	(4)
Post X FARC (SK)	0.63**			
	(0.31)			
Post X FARC (SK-P10)		0.97***		
		(0.35)		
Post X FARC (BA)			0.84***	
			(0.26)	
Post X FARC (NN)				0.71***
				(0.25)
N. of obs.	531,414	531,414	531,414	531,414
Municipalities	252	252	252	252
Mean of Dep. Var. Before	0.85	0.85	0.85	0.85
R^2	0.57	0.57	0.57	0.57

Notes: Coca sample is definined as grids that cultivate coca ever before the announcement. SK, refers to selective killings; SK-P10 exclude the lowest decile of selective killings; BA refers to belicose actions; and NN to violation of human rights. All regresion include grid and year fixed effects. Standard errors, clustered by , are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.3: Heterogeneous effects

Dependent Variable:	% grid area with coca					
	(1)	(2)	(3)	(4)	(5)	(6)
Post X PNIS	-1.05***	-1.05***	-1.20***	-0.84***	-1.25***	-1.03***
	(0.26)	(0.26)	(0.30)	(0.32)	(0.17)	(0.24)
Post X PNIS neighbor	-1.06***	-1.06***	-1.05***	-1.28***	-1.01***	-1.13***
	(0.17)	(0.17)	(0.15)	(0.19)	(0.17)	(0.20)
Post X PNIS X Payments	0.0037					
	(0.0049)					
Post X PNIS X Erradicated area		0.028				
		(0.032)				
Post X PNIS X Dist. River			0.0043			
			(0.0072)			
Post X PNIS X Dist. Road				-0.011***		
				(0.0041)		
Post X PNIS X State pres.					0.31	
					(0.37)	
Post X PNIS X PDET						-0.15
						(0.36)
N. of obs.	758,272	758,272	758,272	758,272	758,272	758,272
Municipalities	274	274	274	274	274	274
Mean of Dep. Var.	1.12	1.12	1.12	1.12	1.12	1.12
R^2	0.53	0.53	0.53	0.53	0.53	0.53

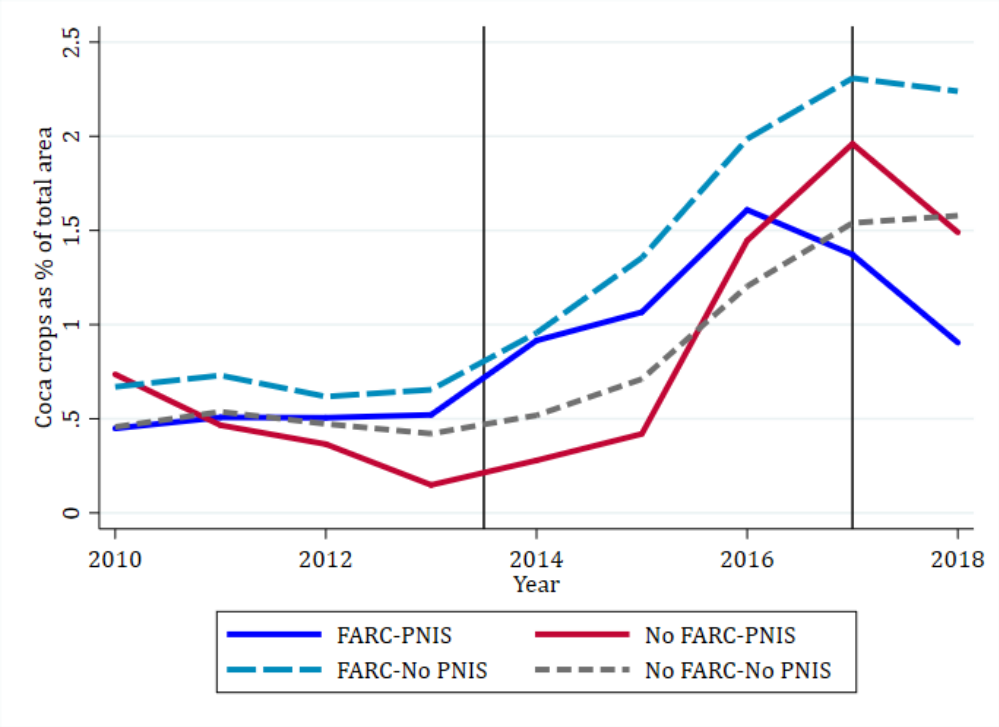
Notes: Distances to Rivers and Roads measured in kilometers. State capacity is an index equal to 1 if the grid is in a municipality with a number of governmental offices above the median. PDET is equal to 1 if the grid is in a municipality that receives additional programs derived from peace agreement. All regressions include grid and year fixed effects. Standard errors, clustered by , are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4: Robustness to neighbor definition

Dependent Variable:	% grid area with coca			
	(1)	(2)	(3)	(4)
Post X PNIS	-1.04***	-1.04***	-1.05***	-1.05***
	(0.26)	(0.26)	(0.26)	(0.26)
Post X PNIS neighbor	-1.13***	-1.19***	-0.81***	-0.98***
	(0.18)	(0.19)	(0.19)	(0.22)
Distance	1km	1.5km	1km	1.5km
Sample	Coca	Coca	Simci	Simci
N. of obs.	755,066	753,770	683,413	682,117
Municipalities	274	274	274	274
Mean of Dep. Var.	1.12	1.12	1.24	1.24
R^2	0.53	0.53	0.53	0.53

Notes: This Table repeats the specification of Table 4 but exclude neighboring pixels within an indicated distance, that could also be PNIS due to coordinates measurement error. Columns (3) and (4) includes only the pixels that ever appear on the satellite monitoring (Simci), and consequently excludes the neighbors that never had coca. All regresion include grid and year fixed effects. Standard errors, clustered by municipality, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A.1: Evolution of coca crops in FARC/No FARC PNIS/ No PNIS areas



Notes: The x-axis represents time in years and the vertical axis the percentage of coca crops in the grid. The solid blue line is for areas with FARC presence based on selective killings (SK) which also receive PNIS payments. The red solid line is for areas without FARC SK presence that receive PNIS payments. The light blue dashed line is for areas with FARC SK presence that have not received PNIS payments. Finally, the gray dashed line is for areas without FARC SK presence that do not receive PNIS payments.