Bocconi

WORKING PAPER SERIES

WORKING PAPER
N. 141
MAY 2020

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Pains, Guns and Moves: The Effect of the US Opioid Epidemic on Mexican Migration*

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May 26, 2020

Abstract

The opioid epidemic and migration along the US–Mexico border are two of the most-debated policy issues in recent US politics. We show how these two topics are interlinked: the US opioid epidemic generated large Mexican migration flows. We exploit the fact that in 2010, a series of reforms to the US health care system resulted in a shift in demand from legal opiates to heroin. This demand shock had considerable effects on Mexico, the main supplier of heroin consumed in the US. Violence and conflicts increased in Mexican municipalities suitable for opium production, as they became highly valuable to drug cartels. People migrated out of these municipalities to escape this violence, mostly to areas close to the US border and into the US. The rise in US demand for heroin increased internal migration by an estimated 90,000 individuals and migration across the border at least by 12,000.

Keywords: opioid crisis, migration, violence, organized crime, Mexico.

*We thank Diogo Britto, Gemma Di Poppa, Nicola Mastrorocco, Paolo Pinotti, Giuseppe Sorrenti, Hasin Yousaf and seminar participants at Bocconi University, the Deakin Conflict and Economic Development Workshop, and the Sydney Empirical Micro Workshop for their valuable comments.
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1 Introduction

The opioid epidemic is one of the deadliest health crises in modern US history. In 2017, opioid overdoses (legal or illegal) killed 47,600 people – more than guns or vehicle accidents.[1] This crisis originated in the mid-1990s, when opioid-based medications started to be prescribed as short-term treatment for severe pain. Over the next decade, opioid-based medications quickly spread, as they began to be prescribed to manage less severe pain as well, despite the high risk of addiction.[2] In 2010, enough opioids were prescribed to provide each American with more than 2 weeks of pain relief treatment.[3]

To reverse this trend, the federal government and several states began to implement a number of policies to curb the abuse of prescription opioids starting in 2010. These included a reformulation of the main legal opiate (Evans et al. 2018; Alpert et al. 2018), the introduction of prescription drug monitoring programs (Buchmueller and Carey 2018; Meinhofer 2018; Ayres and Jalal 2018; Mallatt 2017), and changes in controlled substance laws (Meara et al. 2016). These policies reduced individuals' ability to use legal opiates as pain relief medications, and ultimately increased the demand for (and use of) substitutes including heroin – an illegal opiate and a close substitute for legal opioid-based medications (Kolodny et al. 2015; Alpert et al. 2018; Evans et al. 2018).

While a growing literature has studied the negative impact of the legal opioid and heroin epidemic on life expectancy (Dowell et al. 2017), labor participation (Currie et al. 2018; Krueger 2017), and crime (Dave et al. 2018) in the US, much less is known about its effects abroad.

In this paper, we show that the increasing US demand for heroin fostered migration from Mexican areas more suitable for opium production. As a consequence of this demand shock, violence soared among drug cartels to control these more profitable areas. The increase in violence is followed by an increase in migration, which suggests that violence pushed people to migrate out of these areas (both within Mexico and to the US). Therefore, our main contribution is to assess the international spillovers of the opioid crisis and to highlight how a US domestic policy may have important consequences for a neighboring country, which ultimately increase migration into the US itself.

We start the analysis by creating and validating an index of suitability for the production of

[1] In 2017, 39,773 deaths were gun related and 37,133 involved a motor vehicle (CDC/NCHS 2018).

[2] Section 3.1 provides a detailed description of the determinants of the opioid over-prescription problem.

[3] The quantity of legal opioids sold peaked in 2010 at almost 250 billion morphine milligram equivalents (MME) (FDA 2018; Guy Jr et al. 2017). This constitutes up to 16 days of opioid prescription for every American, even at the highest recommended dose of 50 MME a day.

papaver somniferum (poppy) – the plant that produces opium, the active ingredient in heroin.[4] We then exploit the above-mentioned regulatory changes, which increased the US demand for Mexican heroin, the production of which is controlled by drug cartels: we expect municipalities that are suitable for growing poppy to experience a greater increase in cartel violence after 2010, and as a result, more out-migration.

A key identifying assumption is that changes in violence and migration around 2010 between places that are suitable and unsuitable for opium production would have been the same without the spike in US demand for heroin. The main threat to this identification is that Mexican municipalities that can produce opium are generally different from other municipalities independently of the shock of US heroin demand. For instance, drug cartels are much more likely to be active in these areas in order to exploit poppy cultivation (even before 2010). These places are also more rural and tend to be located in specific regions.

We address this problem by exploiting the fact that cannabis is also an important illegal drug produced in Mexico that heavily involves cartels. We first show that before 2010, the poppy-suitable and cannabis-suitable municipalities were comparable in many observable characteristics, most importantly those related to migration decisions and violence, as they are both likely to be infiltrated by drug cartels that are interested in drug production. After 2010, only municipalities that can cultivate poppies received a positive shock in the value of their potential drug production; municipalities suitable for growing cannabis but not poppies were unaffected.[5] Following this observation, we use a difference-in-differences (DID) estimation strategy, which compares municipalities suitable for cultivating poppy with those only suitable for growing cannabis. To avoid comparing municipalities located in very distant areas of Mexico, we exploit variation between municipalities within the same Mexican macro region.[6]

We first exploit individual-level Mexican census data to measure internal migration flows. Between 2010 and 2015, the heroin demand shock increased internal migration from poppy-suitable municipalities by 10% and inter-regional migration by 30%. This amounts to an extra 90,000 mi-

[4]While opium is also the main ingredient of legal opiates, Mexican farmers do not participate in this market. The legal cultivation of poppies to manufacture medicine is based on the UN Single Convention on Narcotic Drugs of 1961 and is supervised and strictly controlled by the International Narcotics Control Board (Transnational Institute 2018). The legal production of opium for the US market is heavily licensed; the main producers are Australia, India, and Turkey. The legal production of opium for other countries is often done locally. For example, the pharmaceutical company Sanofi Aventis directly produces the opium it needs in France, as does Shionogi Pharmaceutical in Japan, and Johnson Matthey in the UK (The Senlis Council 2005).

[5]We further discuss this point in Section 5.

[6]According to the Mexican National Institute of Statistics, Mexico can be divided into eight macro regions, which are shown in Figure A.8.

grants fleeing poppy-suitable municipalities due to the heroin demand shock. Of these migrants, 81,000 moved to a different Mexican region. We then show that internal migration from poppy-suitable municipalities increased especially towards municipalities on the US–Mexico border. The flow of migrants from these municipalities towards the border doubled after the 2010 demand shock.

To determine whether migrants actually moved to the US, we use data on the number of *Matrículas Consular de Alta Seguridad* (Matriculas) issued in the period 2007–2016, which are identification cards issued by the Mexican government through its consulate offices in the US. All Mexicans residing abroad can request a Matricula, including unauthorized migrants. We find that 12,000 additional Matriculas were issued to people coming from poppy-suitable municipalities after 2010. Since an average of 1 of every 2.5 Mexicans in the US holds a Matricula, this might imply an extra 30,000 Mexican migrants to the US potentially induced by the opioid epidemic.[7]

We then study the mechanism responsible for the large migration flows out of municipalities with land highly suitable for growing poppy. First, we focus on economic outcomes including GDP, local value added, and investment and consumption levels. We find that the heroin demand shock has no substantial effect on these outcomes. However, we do find an increase in different measures of violence, particularly those related to drug cartels.[8] This evidence supports the idea that violence induced by the heroin demand shock forced people to emigrate in search of safer places within and outside Mexico. Compared to municipalities that are only capable of growing cannabis, since 2010, those suitable for poppy cultivation have experienced an increase in homicides (6.9%), deaths (3.6%), confrontations between drug cartels and police (10.3%), executions between cartels (7.8%), and cartels' attacks on local institutions (6.4%).[9]

In Section 2 we start by highlighting the paper's contribution to the literature. In Section 3, we describe the institutional background. We present the data, estimation strategy, and our analysis in Sections 4, 5 and 6, respectively. Section 7 concludes.

[7]This is in line with the fact that Matriculas last for 5 years, and every 5 years around 4.7 million of the cards are issued. According to the 2010 US Census, this corresponds to 40% of the 11.7 million Mexicans living in the US.

[8]As discussed below, violence might increase due to either: i) conflicts' displacement from cannabis- to poppy-suitable areas or ii) a net increase in violence in poppy-suitable areas.

[9]Data on homicides and deaths are available until 2016. Data on confrontations between drug cartels and police, executions and cartels' attacks on local institutions are available until 2011.

2 Related literature

This paper relates to the recent strand of studies on the US opioid epidemic. The causes of the epidemic have been linked to several different characteristics of the demand and the supply sides of the pharmaceutical market, which led to a dramatic rise in painkiller prescriptions in the 2000s, and ultimately to a normalization of the use of opioids as a first-line remedy for a large set of pathologies and illnesses (Van Zee 2009; Fernandez and Zejcirovic 2017; Dasgupta et al. 2018; Lin et al. 2018; Currie and Schnell 2018). As highlighted above, this paper contributes to the literature on the effects of the opioid epidemic (Dowell et al. 2017; Currie et al. 2018; Krueger 2017; Dave et al. 2018) by studying its international consequences, which have thus far been overlooked.

The paper also adds to the literature on the determinants of migration decisions – specifically to studies that explore the link between income shocks and migration. Previous studies, which have mostly focused on income shocks in legal markets, show that migration responses to income shocks are highly dependent on the migrants' demographic characteristics (Orrenius and Zavodny 2005; Mckenzie and Rapoport 2007). On the one hand, an income increase (decrease) might reduce (increase) financial constraints, thus fostering (decreasing) the number of people who decide to migrate (Angelucci 2015). On the other hand, an improvement (deterioration) in the economic conditions at home makes migration less (more) appealing (Bazzi 2017). Our contribution is to show that an income shock in an illegal market might foster forced migration through the growth in violence and uncertainty. This idea is based on previous studies that: i) investigate the link between violence and income shocks (Miguel et al. 2004; Angrist and Kugler 2008; Brückner and Ciccone 2010; Dal Bó and Dal Bó 2011; Acemoglu et al. 2012; Dube and Vargas 2013; Castillo et al. 2018) and ii) document the effects of violence on migration (Alvarado and Massey 2010; Bohra-Mishra and Massey 2011; Adhikari 2013). In this paper, we merge these two lines of research by linking an income shock to violence, and in turn, to migration decisions.

This paper also contributes to the literature on the negative spillovers of drug-related violence in Mexico (Calderòn et al. 2015; Dell 2015; Gutiérrez-Romero 2015; Gutiérrez-Romero and Oviedo 2017; Dell 2018) and specifically to the investigation of the link between violence and migration in Mexico (Rios 2014; Basu and Pearlman 2017; Orozco-Aleman and Gonzalez-Lozano 2017). More closely related to our work, Sobrino (2019) studies the relationship between violence in Mexico and competition between cartels, by exploiting changes in heroin demand in the US. She finds that

i) the US opioid demand shock increased cartels' presence in municipalities that are well suited to grow poppy after 2010; and ii) as more cartels enter a municipality, homicide rates increase. On the one hand, our paper is different as we examine the effects of the opioid crisis on Mexican migration, while Sobrino (2019) studies drug cartels' conflicts in the presence of an exogenous shock (the opioid crisis). Therefore, her focus is on drug cartels' outcomes, while ours is on migration. On the other hand, Sobrino's (2019) analysis complements ours, as cartels' violence serves as a mechanism that links the opioid crisis to migration.[10]

3 Institutional background

3.1 The US opioid epidemic

Opioids include both natural and synthetic morphine-like drugs that relieve pain, slow the user's breathing and heart rate, and enhance feelings of relaxation and euphoria. While low and medium doses of opioids can be used as an effective painkiller, high doses can cause respiratory failure, unconsciousness, and death. Since the early 2000s the US has experienced an exponential increase in opioid painkiller prescriptions. This trend was sparked by a paradigm shift in the health community in the mid-1990s, which started emphasizing that pain is a symptom that needs to be treated (Max et al. 1995). Physicians began prescribing opioids even for non-cancer-related pain relief (Phillips 2000). Several factors have been found to have exacerbated the increase in painkillers' prescription and use across the general population over the last decade, including demographic trends (Dasgupta et al. 2018), limited coverage of alternative pain therapies by insurers (Lin et al. 2018), aggressive marketing campaigns by pharmaceutical companies (Van Zee 2009; Fernandez and Zejcirovic 2017), and physicians' ability (Currie and Schnell 2018). Recent studies have also shown that the economic downturn triggered by the 2008 financial crisis and the job losses incurred during that period contributed to the misuse of opioids (Carpenter et al. 2017; Hollingsworth et al. 2017).

The quantity of legal opioids sold peaked in 2010 when several federal and state laws were introduced to stop their over-prescription. One important change to the legal opioid market related to OxyContin, an extended-release formulation of oxycodone (a semi-synthetic opioid) that was the

[10] Our paper also differs on two methodological points. First, we employ a different methodology to calculate municipal suitability for poppy cultivation. Second, we use different definitions of the treatment (i.e. discrete vs. continuous) and control group (i.e. only cannabis-suitable municipalities vs. all Mexican municipalities.)

most popular opioid painkiller up to 2010 (Bartholow 2010). The US Food and Drug Administration (FDA) agreed on a reformulated anti-abuse version of OxyContin because crushing, inhaling, or injecting the drug released high doses of oxycodone all at once, instead of over 12 hours, leading to a very high risk of addiction and overdose death. The reformulation recommended by the FDA was effective at preventing abuse, but led to unintended effects, as consumers addicted to OxyContin started to substitute it with illegal opioid-based drugs, such as heroin and later fentanyl (Kolodny et al. 2015; Alpert et al. 2018; Evans et al. 2018). The switch from legal opioids to heroin was exacerbated by state laws, approved from 2010 onward, designed to restrict the use of opioids (Mallatt 2017; Meinhofer 2018).[11] Within a few years, the epidemic of overdose deaths from heroin abuse became a serious public health crisis in the United States. Appendix Figure A.1 provides descriptive evidence of how 2010 was a crucial year for the start of the US opioid crisis.

We show that the effects of this crisis were not limited to the US: the increased consumption of opioids represented a demand shock for heroin from Mexico, which was the main US supplier of heroin during this period. In the next section, we highlight our main hypothesis, connecting these events to Mexicans' migration decisions.

3.2 Mexican migration and the heroin demand shock

The US is by far the most popular destination for Mexicans moving abroad: as of 2017, an estimated 36.6 million people of Mexican origin lived in the US – only 31% of whom were foreign born; 50% have been in the US for more than 20 years (Noe-Bustamante et al. 2019). Of the foreign-born Mexicans living in the US, 4.9 million live there illegally (Passel and Cohn 2019). While the number of Mexicans living in the US has steadily increased since the late 1960s, over the last 15 years the net flows of migrants from Mexico to the US have been close to zero or even negative. For example, between 2005 and 2010 about 1.4 million Mexicans arrived in the US (about half entered illegally). During this period, roughly the same number of Mexicans returned to Mexico from the US (Passel et al. 2012).

Migration to the US represents only a minor share of overall Mexican migration; 6.4 million Mexicans (5.4% of the population) moved within the country from 2010 to 2015 (María Cristina

[11] For instance, in the period 2010–2014 several US states approved mandatory prescription drug monitoring programs to limit the supply of prescription opioids. In response, consumers turned to heroin as a substitute for prescription opioids (Mallatt 2017). Similarly, in 2010 government officials started cracking down on Florida's pain clinic suppliers, which reduced the supply of legal opiates and increased heroin consumption (Meinhofer 2018).

Díaz Pérez 2019). A recent Mexican government report (María Cristina Díaz Pérez 2019) suggests that internal migration flows linked to drug traffickers' violence peaked in 2012 with 419,000 individuals.

Our work connects the heroin demand shock starting in 2010 in the US with Mexican migration. This shock might have affected migration decisions in different ways. For instance, it could lead to an increase in opium production, which is a labor-intensive sector. In turn, employment might increase, reducing the incentives to migrate. Alternatively, a rise in labor income might increase the number of people who can afford to migrate, by making financial constraints less binding. The prevalent effect might depend on the role of wealth heterogeneity in determining migration decisions as income rises (Bazzi 2017).

At the same time, the demand shock for heroin implies higher rents for Mexican criminal groups, whose core business centers on smuggling narcotics into the US (Beittel 2015).[12] In recent years drug cartels have constantly fought to maintain territorial influence over large areas of Mexico (used to produce and transport illicit drugs), and the Mexican government has been unable to restrain the cartels.[13] In this context, the demand shock for heroin might imply stronger competition, conflicts, and violence between criminal groups to control areas suitable for poppy cultivation: this is generally the case when rents grow in an illegal sector, and violence to control this market peaks due to the absence of a central authority imposing the rule of law (Miguel et al. 2004; Angrist and Kugler 2008; Brückner and Ciccone 2010; Dal Bó and Dal Bó 2011; Acemoglu et al. 2012; Dube and Vargas 2013; Castillo et al. 2018; Gehring et al. 2018).

Drug traffickers' interest in poppy cultivation has indeed increased since 2010 (Beittel 2015). ONDCP (2018) documents that in 2017, Mexico supplied 91% of the heroin consumed in the United States. This is also confirmed by the descriptive evidence in Appendix Figure A.2, which displays the dramatic increase in the share of Mexican heroin in the US market and the share of Mexican land eradicated due to poppy cultivation since 2010.

In turn, the violence generated by the heroin demand shock – which targets civilians, political activists, and journalists as well as criminals (Calderón et al. 2019) – might represent a push factor that forces people to emigrate to safer places (Rios 2014; Basu and Pearlman 2017; Orozco-Aleman

[12] Mexican poppy cultivation, which is concentrated in the states of Sinaloa, Nayarit, Guerrero, and Oaxaca, channeled about $1 billion dollars in 2017, according to a recent estimate by Le Cour et al. (2019).

[13] In 2007, the Partido de Acciòn Nacional (PAN) candidate, Felipe Calderon, was elected president on a platform centered on the war against cartels. However, his policies resulted in an unprecedented increase in violence, as the targeted eliminations of cartel leaders sparked infra-cartel competition and fragmentation (Ríos 2013; Medel and Thoumi 2014).

and Gonzalez-Lozano 2017) within and outside Mexico, such as the US.[14]

4 Data

We compiled information from multiple sources into a new municipal-level panel dataset. The time intervals considered, as well as the number of observations included in the final sample, vary depending on the availability of each variable. The following subsections provide a detailed description of the variables and the data sources used to create them; Appendix Table A.1 reports the summary statistics for all our variables.

4.1 Outcome variables

4.1.1 Migration

We run the analysis on internal migration at the individual level using Mexican population census data provided by the National Institute of Statistics (INEGI). The census is run every 5 years, and we focus on the 2010 and 2015 waves. We use responses to the question on where an individual was living 5 years earlier. We adopt two separate definitions of internal migrants: i) individuals who were living in a different municipality 5 years earlier and ii) in a different macro region.

To measure the migration flows towards the US, we exploit data on the number of Matriculas issued by Mexican consulate offices in the US (Caballero et al. 2018). Matriculas are needed to open a bank account, to obtain a driving license or city/state services (e.g. medical services) or to rent an apartment.[15] Importantly, illegal migrants can also request them. From the original registry, we calculate the total number of Matriculas issued each year from 2007 to 2016 for each pair of Mexican municipalities of origin and state of arrival in the US.[16]

4.1.2 Local economy and violence

To disentangle the mechanisms underlying the main results, we use a further set of dependent variables that capture different determinants of migration that might have been affected by the

[14]The spike in violence across Mexico corresponded to an increase in new ways to spread fear among the population, such as leaving bodies or body parts in public spaces as a warning to citizens or fellow criminals.

[15]The relevance of Matriculas as unofficial identity cards varies across US jurisdictions. As of 2013, more than 371 counties, 356 financial institutions, and 1,036 police departments accepted them as a valid proof of identification (Mathema 2015).

[16]Appendix Figure A.3 reports the total number of Matriculas issued each year in the US. It shows a declining trend up to 2010, followed by a strong increase, which peaks in 2015 and suddenly declines the following year.

heroin demand shock.

First, from INEGI's economic census we retrieve information about GDP, investments, intermediate consumption, and gross value added at the municipal level for the years 2003, 2008, and 2013.[17]

Second, we focus on the level of violence, measured as the number of homicides, total number of deaths, and drug-trafficking-related violent episodes. We collect municipal-level data on the number of homicides for the period 2000–2016 from INEGI. To account for the possibility that homicides are misreported, especially in areas strongly controlled by drug cartels, we also collect municipal-level INEGI data on the total number of deaths for this period. Data on episodes of drug-trafficking-related violence are available from Atuesta et al. (2019) from December 2006 to November 2011. The data are classified as confrontations (i.e. clashes between cartels or cartels and police), executions (i.e. intentional homicide of a drug cartel member), and aggressions (i.e. criminal attacks on governmental institutions). These data are currently the best available measure of cartel-related violence.[18]

4.2 Suitability of Mexican soil for illegal crops

Our main explanatory variable is a given area's suitability to cultivate poppies. Unfortunately, the precise maps of crop suitability provided by FAO-GAEZ for many legal crops are unavailable for illegal ones. Thus, we create a novel measure of suitability by exploiting the biological characteristics of *papaver somniferum* (poppy), the plant from which opium is extracted and then heroin is derived. We collect information about the local characteristics needed for growing poppy from the FAO EcoCrop database (see Appendix Figure A.6). We define optimal poppy suitability in terms of temperature, rain, and soil pH. We then map these characteristics across Mexican municipalities using INEGI's *Conjunto de Datos de Perfiles de Suelos (Escala 1:250000 Serie III)* database, which divides Mexican territory into different units that have similar agricultural conditions, and gathers information on several characteristics.[19]

We create three dummies (temperature, rain, and soil pH) for each soil-unit in these data. Each dummy equals 1 if the value of a characteristic of a given soil falls within the optimal interval

[17] Appendix Figure A.4 illustrates increasing trends in the municipal average for all indicators.

[18] Appendix Figure A.5 depicts the violence data, including the sharp increase in homicides that corresponds to the launch of President Calderon's war on drugs in 2007.

[19] Appendix Figure A.7 shows an example of how an area is divided into different units, and how they are split across municipalities.

for growing poppy (and 0 otherwise). We then define soil as suitable for growing poppies if all three dummies are equal to 1. Finally, we aggregate soil at the municipal level by calculating the percentage of the total municipal surface that is suitable for cultivating poppies. In our main specifications, we define a municipality as suitable if it has at least 1% suitable surface.[20] Then, we repeat the same procedure to construct a measure of cannabis suitability that we use to define the control group in the baseline analysis, which includes municipalities that are unsuitable for growing poppies but suitable for cannabis.

Based on these measures, Figure A.8 maps the geographical distribution of municipalities suitable for poppy cultivation (red), and those unsuitable for poppies but suitable for cannabis (green). To validate the reliability of this map, Appendix Figure A.9 shows the map of poppy and cannabis production risk, as elaborated by the Secretary of National Defense of the Mexican government (SEDENA) in collaboration with the United Nation Office on Drugs and Crime (UNODC). This map is obtained by bringing together different sources of data, including historical information on eradication, natural and social characteristics favoring the production of illegal crops, as well as satellite data on actual production. This map is very similar to the one obtained using our procedure, which supports the validity of our measure of illegal crop suitability.

To further validate our measures of suitability, we test whether suitability for poppy and cannabis correlate with the average eradication of each type of crop from 2010 to 2016. Eradication is undertaken by the Mexican military, which first identifies individual fields and then destroys illegal crops.[21] To measure eradication, we use data provided by SEDENA, which records the yearly quantity of poppy and cannabis destroyed by the Mexican army in each municipality, both in terms of the number of plantations and hectares eradicated. We construct separate yearly measures of eradication for poppy and cannabis that reflect (1) the total number of hectares eradicated each year as a percentage of the municipal area and (2) the number of plantations per capita eradicated each year. As expected, we find that poppy suitability strongly correlates with poppy (but not cannabis) eradication, while the opposite is true for cannabis suitability. The percentage of hectares eradicated in municipalities that are suitable for growing poppy is four times the percentage destroyed in unsuitable municipalities (0.4% vs 1.6%), and 6.5 times more plantations per

[20] In Section 6.1 we validate the choice of this threshold and test our main findings using different thresholds.

[21] While illegal crop eradication is directly linked to actual cultivation, its variation, both in space and time, may also reflect many other characteristics not strictly linked to the latter, such as the political willingness to carry out eradication campaigns in a particular year, or in a given municipality. This motivates our decision to use a suitability index and not the eradication data in our main analysis.

capita are eradicated (1.2 vs 7.9).[22]

5 Estimation strategy

The treatment group (T) of this analysis includes 423 Mexican municipalities suitable for poppy cultivation. The control group (C) contains 456 municipalities that are suitable for growing cannabis but not poppies. We expect that before 2010 these two types of municipalities would be similar as they are both likely controlled by cartels for the production of illegal drugs (we test this assumption in the next paragraph). We then expect only municipalities suitable for poppy cultivation to be affected by the heroin demand shock in the US.

We exploit this variation by estimating the following DID model:

$$y_{i,t} = \beta_0 + \beta_1 Poppy_i * Post_t + \gamma X_{i,t} + \eta_i + \delta_{t,m} + \epsilon_{i,t} \, , \tag{1}$$

where i and t describe the cross-sectional and time dimensions, respectively. Depending on the data source used, the cross-sectional dimension is an individual (individual census data), a Mexican municipality (economic census and violence data), or a Mexican municipality/US state pair (Matriculas).

The time dimension unit is 5 years for the individual level and the economic census data, and yearly for the other dependent variables (i.e. Matriculas and violence data).

We apply to the dependent variables $y_{i,t}$ the inverse hyperbolic sine transformation,[23] except for the individual-level data (dummy variable).

$Poppy_i$ is equal to 1 if municipality i is suitable for poppy cultivation. For individual-level data it is equal to 1 if an individual was living 5 years earlier in a municipality suitable for poppy cultivation. $Post_t$ is a dummy equal to 1 for any observation after 2009, and 0 otherwise.[24]

Concerning the specifications using individual-level data and Matriculas, the set of controls $\gamma X_{i,t}$ includes the interaction between the distance to the US border and the dummy $Post_t$, as well

[22] Estimates can be found in Appendix Table A.2.

[23] This transformation approximates the natural logarithm of the variables and allows retaining zero-valued observations (Burbidge et al. 1988; Bellemare and Wichman 2020).

[24] Our findings remain unchanged if we use 2010 as the first pre-treatment year. The OxyContin reformulation took place in April 2010 and was completely effective from August 2010 (Alpert et al. 2018; Evans et al. 2018). Similarly, anti-abuse state laws were adopted throughout that year. Moreover, it is plausible to observe a lag between the US demand shock and its effects in Mexico. In other words, from a theoretical point of view, it is unclear whether the effects in Mexico were observable as early as 2010.

as controls for individual-level characteristics in the specifications regarding internal migration.[25]

We always control for municipality fixed effects (η_i) and macro-region-year fixed effects ($\delta_{m,t}$). Standard errors (ϵ_{jt}) are robust to heteroskedasticity and clustered at the Mexican state-year level, or Mexican state-US-state-year level in the case of Matriculas.

Regardless of the specific model estimated, a crucial assumption of the DID approach concerns the absence of trends in potential outcomes between the treated and control units. We provide evidence of this fact using two empirical tests. First, Appendix Table A.3 shows that before 2010, the treatment and control municipalities were comparable in many observable characteristics. The standardized differences between them are indistinguishable from each other even at the conservative 25% level (Imbens and Wooldridge 2009). Second, we test whether there are pre-existing differential levels and trends on the dependent variables in Appendix Table A.4. It shows the differences in dependent variables between the treated and control municipalities for: i) their average values before 2010 and ii) the trend between the last and the first years of the pre-treatment period. In all cases, we control for Mexican state fixed effects. These tests show that there are no significant differences in outcomes between the treated and control municipalities in either average levels or pre-trends during the pre-treatment period.[26]

6 Results

6.1 Internal migration and migration to the US border

Table 1 reports our findings on internal migration, defined as living in a different municipality than 5 years earlier (using data from the 2010 and 2015 waves of the Mexican census). This estimation compares how the migration decisions of individuals living in treated and control municipalities change differently between the 2005–2010 period and the 2010–2015 period.

Columns (1) and (2) show the overall results, while columns (3) and (4) focus on migrants to a different macro region. Between 2010 and 2015, we find an increase in the probability of migrating to another municipality of about 0.43 p.p., which is equal to an increase of around 10% over the baseline probability of migrating before 2010. The effects of migration to another macro region are

[25] We control for age, age^2, age^3, gender, and education.

[26] In Table A.5 we show that model 1 predicts eradication. In poppy-suitable places, the percentage of land eradicated *and* the number of plantations eradicated almost doubled after 2009. This provides further credibility to our estimation strategy.

Table 1: Poppy Suitability and Migration across Mexico

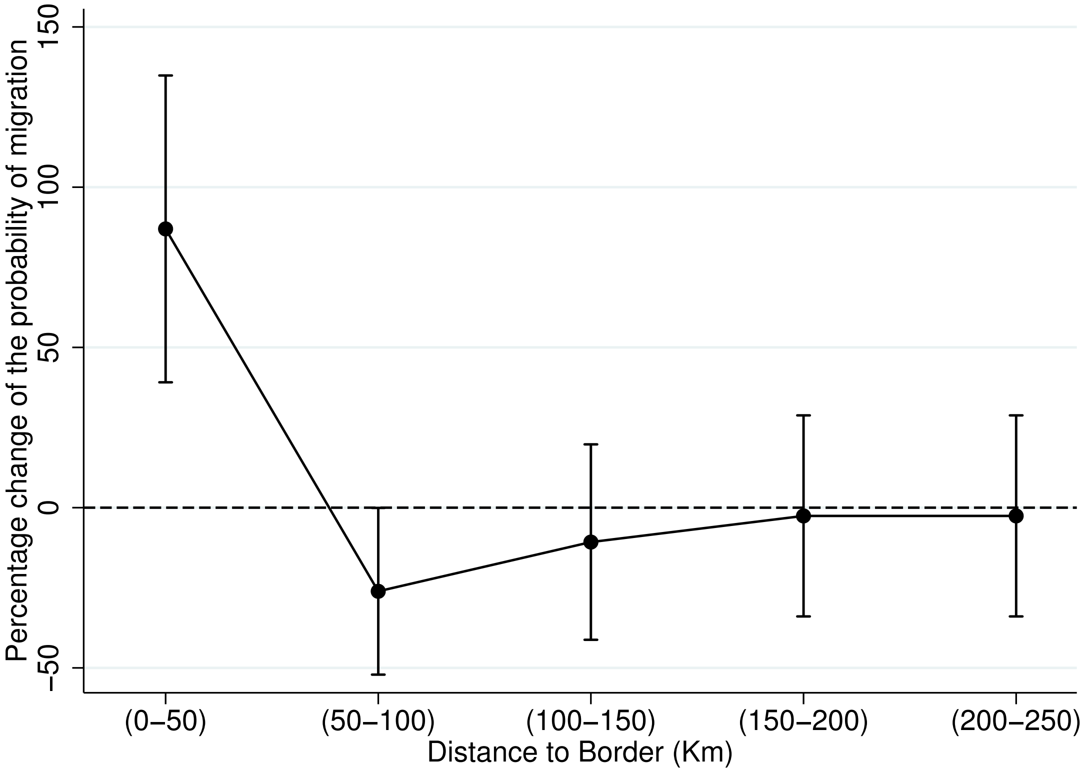
	(1) Any mun.	(2) Any mun.	(3) Across reg.	(4) Across reg.
Poppy * 2015	0.0043***	0.0041***	0.0039***	0.0038***
	(0.0015)	(0.0014)	(0.0011)	(0.0011)
Observations	10,909,124	10,845,651	10,909,124	10,845,651
R-squared	0.0252	0.0322	0.0173	0.0197
Individual controls	NO	YES	NO	YES
Dist. US border X $Post_t$	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Macro-region X Year FE	YES	YES	YES	YES
Base value (Btw. 2005-2010)	0.0431	0.0431	0.0130	0.0130

Note: This table shows the effect of poppy suitability on migration to any Mexican municipality (columns 1–2) or to another macro region (columns 3–4). *Poppy * 2015* is the interaction between the dummy *Poppy*, which is equal to 1 if the municipality where individuals were living 5 years earlier has at least 1% of its area suitable for poppy cultivation and 0 otherwise, and the dummy *2015*, which is equal to 1 for the 2015 census. All specifications include individual controls (i.e. age, age^2, age^3, gender, and education), the interaction between the distance to the US border and the dummy *2015*, municipality fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

even higher when compared to the baseline. Between 2010 and 2015, we find an increase in the probability of migrating to another macro region of about 0.38 p.p., which is equal to an increase of around 30% over the baseline probability of migrating to another macro region before 2010. Given the large number of people living in treated areas, these estimates translate into large movements of Mexicans within the country. Our estimates imply that between 2010 and 2015 there were an extra 90,000 migrants, 81,000 of whom were inter-region migrants moving out of poppy-suitable areas.

These results represent a first estimate of the overall effects of the US heroin demand shock on Mexican migration. In Figure 1 we further explore the effects on migration by studying where in Mexico migrants from poppy-suitable municipalities moved to. In particular, we explore whether migrants moved close to the US border. To do so, we estimate model 1, where the dependent variable is a dummy variable equal to 1 if a person migrated within the last 5 years and moved a specific distance from the US border. Figure 1 plots the results of this regression for individuals who migrated to a municipality less than 50 km from the US border, 50–100 km, 100–150 km, and 150–200 km. To make them comparable, we divided each coefficient by the baseline probability of moving to an area that distance from the border (and multiplied by 100). Therefore, each coefficient represents the percentage increase in the probability of migrating to that specific distance.

Figure 1: Poppy Suitability and Migration towards the US Border



Note: The figure shows the change in the probability of migrating between the two census waves (in 2005–2010 and 2010–2015), depending on the distance to the US border of the arrival municipality. The vertical bars represent the 90%-confidence intervals

Figure 1 shows that most of the increase in migration estimated in Table 1 is driven by individuals moving close to the US border. The probability of migrating at less than 50 km from the border doubled for individuals living in poppy-suitable municipalities. We believe this signals a significant share of internal migrants attempting to cross the US border.

To directly test levels of migration to the US, we exploit the number of new Matriculas issued: the results are reported in Table 2.[27] As these are yearly data, we can differentiate between the years right after the shock (i.e. 2010–2013) and those more distant from the initial shock (i.e. 2014–2016). We only find an increase in the number of Matriculas issued in the period 2014–2016: in treated municipalities we observe a yearly average increase of 1%, which corresponds to a total of about 12,000 additional Matriculas in the 2014–2016 period. These results are compatible with

[27] Here, we specifically control for municipality-US state fixed effects.

a lag of a few years between the US heroin demand shock and its effects on Mexican migration to the US. We discuss this interpretation further in the next section.

Note that this number represents a conservative estimate of the number of migrants to the US, as we expect only 1 in 2.5 Mexicans living in the US to have a Matricula. This estimate is based on the fact that a Matricula is valid for 5 years, and every 5 years a total of 4.7 million Matriculas are issued – equivalent to 40% of the Mexican population living in the US.[28] Therefore, 12,000 additional Matriculas issued imply nearly 30,000 extra migrants to the US.

Table 2: Poppy Suitability and Migration to the US

	(1) Matriculas	(2) Matriculas
Poppy * Post 2009	0.003	
	(0.004)	
Poppy * 2010-2013		-0.001
		(0.004)
Poppy * Post 2013		0.010**
		(0.004)
Observations	448,290	448,290
R-squared	0.909	0.909
Dist. US border X $Post_t$	YES	YES
Mun. X US State FE	YES	YES
Macro-region X Year FE	YES	YES
Base value (Avg. 2007-2009)	256,051	256,051

Note: This table shows the analysis of the effect of poppy suitability on the Matriculas issued in the US from 2007 to 2016, from each Mexican municipality to each US state. *Poppy * Post-2009* is the interaction between the dummy *Poppy*, which is equal to 1 if a municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise, and the dummy *Post-2009*, which is equal to 1 for the years 2010–2016 and 0 otherwise. *Poppy * 2010–2013* is the interaction between the dummy *Poppy* and the dummy *2010–2013*, which is equal to 1 for the years 2010–2013 and 0 otherwise. *Poppy * Post-2013* is the interaction between the dummy *Poppy* and the dummy *Post-2013*, which is equal to 1 for the years 2014–2016 and 0 otherwise. Column (1) includes the interaction between the distance to the US border and the dummy *Post-2009*, while column (2) the interactions of the former separately with *2010–2013* and *Post-2013*. All specifications include municipality-US state fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-US state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The availability of Matriculas data for different years before and after 2010 allows us to implement an event study approach to provide further evidence of the absence of pre-trends in migration

[28] According to the 2010 US Census, almost 11.7 million Mexicans live in the US. A summary of the Census data is accessible at `https://www.census.gov/newsroom/pdf/cspan_fb_slides.pdf`.

to the US as well as further insights on the dynamics of the effect since 2010. Appendix Figure A.10 confirms the absence of pre-trends and the presence of an effect in the last years of the panel.

6.2 Robustness Tests

This section describes the results of two tests we conducted to check the robustness of our main findings. First, we change how we define when a municipality is poppy and cannabis suitable. Appendix Tables A.6 and A.7 report how the baseline results on migration change depending on how we define poppy-suitable municipalities (i.e. higher than 0%, 2%, and 3%).[29] In all cases the results are in line with those of the baseline analysis, which demonstrates their robustness with respect to this concern.

Second, we explore a different definition of control municipalities. In our main analysis we consider control municipalities those suitable for cannabis but not poppy. To estimate the effects of the heroin demand boom on migration, we assume that cannabis-suitable areas were not affected by any specific shock during the period of interest. However, this might not be the case if the profitability of cannabis-suitable areas also changed during this time. For instance, the process of cannabis legalization in the US, which accelerated after 2014, might have decreased the demand for illegal cannabis, which in turn could have reduced the migration from cannabis-suitable areas.

However, we do not consider the legalization of cannabis in the US to be a potential threat to our identification strategy for three reasons. First, the effects on internal migration are measured for the period 2010–2015, which mostly preceded the shock in the cannabis market.[30] Second, the effects on migration to the US were already visible in 2014. Third, cannabis was only legalized in two small states in 2014 (Oregon and Washington); their production of cannabis was unlikely to crowd out the illegal supply of Mexican cannabis, especially in the short run. The first big US state to legalize was California in 2018 (DEA 2017) – 2 years after our study period.

To further decrease concerns that our definition of control municipalities is affecting our results, we re-estimate model 1 using a different control group. While the treated group is the same as in the baseline analysis, the control includes only neighboring municipalities, regardless of their suitability for cannabis production. This specification allows us to explicitly control for

[29] We select these values since above 3%, there is a sharp decrease in the correlation between being classified as poppy suitable and poppy eradication. Figure A.11 shows the average percentage of land eradicated from 2010 to 2016 for municipalities unsuitable for growing poppy as defined using thresholds from 1–6%.

[30] The 2015 Mexican Census is updated to March 15, 2015.

cannabis-related trends by including a further control in the regressions: the interaction between the indicator for cannabis suitability and the dummy $Post_t$. To check if the alternative control group is comparable to the treated group, Table A.8 provides the standardized differences in several observable characteristics between the two groups. In Table A.9 we test the absence of differences between the two groups in the level and trends of the migration outcome variables before 2010. In both cases, the results suggest a strong comparability between municipalities that are suitable for growing poppy and their neighbor municipalities. The results of this robustness test, reported in Tables A.10 and A.11, confirm the main findings of the baseline analysis.

6.3 Mechanisms

What are the drivers of these migration patterns? One potential explanation concerns the effect of the heroin demand shock on the local economies of Mexican municipalities. Indeed, an increase in migration flows is compatible with an improvement in local economic conditions. Since poppy cultivation is labor intensive, an increase in the demand for heroin might raise employment and labor income within poppy-suitable municipalities, thus making migration financially affordable for more individuals. To check whether this is the case, we analyze a set of local economic indicators (i.e. GDP, value added, investment and consumption levels) reported in Table 3 and find no substantial impact of the heroin demand shock on the economic performance of treated municipalities since 2010, thus discarding the economy-related mechanism as a driver of our main results. The null effects can be explained by the fact that there are both positive and negative effects on the local economy and/or due to the small effect of this shock on the legal economy. We also complement the pre-trends analysis of Table A.4 with an event study approach in Figure A.12 in the Appendix.[31]

A second compatible explanation is an increase in the levels of violence, as the heroin demand shock might foster conflicts among cartels to control valuable areas. This might in turn affect individuals' willingness to migrate. Table 4 shows that the heroin demand shock increased homicides, deaths, and drug cartels' violence, in terms of confrontations between cartels and authorities, criminals' executions, and aggression towards government institutions.

Our estimates show that the boom in US heroin demand generated 201 extra homicides (i.e. 6.9%) and 3,487 extra deaths (i.e. 3.6%) each year between 2010 and 2016. Similarly, in the

[31] Unfortunately, we cannot directly test for changes in employment, since employment rates in Mexico are only available at the state level.

Table 3: Poppy Suitability and Economic Performance

	(1) GDP	(2) Val. Ad.	(3) Invest.	(4) Int. Cons.
Poppy * Post 2009	0.013	0.019	0.089	0.004
	(0.039)	(0.048)	(0.076)	(0.031)
Observations	2,425	2,425	2,425	2,425
R-squared	0.980	0.973	0.929	0.980
Municipality FE	YES	YES	YES	YES
Macro-region X Year FE	YES	YES	YES	YES
Base value (Avg. 2007-2009, 1000s pesos)	387,450	168,018	18,495	219,433

Note: This table shows the analysis of the effect of poppy suitability on economic performance. Column (1) shows the effect on GDP (2003, 2008, 2013), column (2) on total value added (2003, 2008, 2013), column (3) on investment (2003, 2008, 2013) and column (4) on intermediate consumption (2003, 2008, 2013), all in logarithmic scale. *Poppy * Post-2009* is the interaction between the dummy *Poppy*, which is equal to 1 if a municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise, and the dummy *Post-2009*, which is equal to 1 for the year 2013 and 0 otherwise. All specifications include municipality fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4: Poppy Suitability and Violence

	(1) Homicides	(2) Deaths	(3) Confrontations	(4) Executions	(5) Aggressions
Poppy * Post 2009	0.069***	0.036***	0.103***	0.078*	0.064***
	(0.025)	(0.010)	(0.025)	(0.044)	(0.014)
Observations	14,943	14,889	5,274	5,274	5,274
R-squared	0.812	0.972	0.521	0.726	0.419
Municipality FE	YES	YES	YES	YES	YES
Macro-region X Year FE	YES	YES	YES	YES	YES
Base value (Avg. 2007-2009)	2,898	97,762	89	1,031	23

Note: This table shows the analysis of the effect of poppy suitability on homicides and cartel-related violence depending on the presence of cartels. *Poppy * Post-2009* is the interaction between the dummy *Poppy*, which is equal to 1 if the municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise, and the dummy *Post-2009*, which is equal to 1 for the years 2010 onward, and 0 otherwise. Column (1) shows the effect on the number of homicides (2000–2016), column (2) on the number of deaths (2000–2016), column (3) on the number of confrontations between cartels and the authorities (2006–2011), column (4) on the number of executions between cartels (2006–2011), and column (5) on number of aggressions by cartels to authorities (2006–2011). All the dependent variables are in logarithmic scale. All specifications include municipality fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

period 2010–2011 the shock generated nine extra confrontations (i.e. 10.3%), 80 extra executions (i.e. 7.8%), and one extra aggression (i.e. 6.4%) per year. The above analysis complements the pre-trends check of Table A.4, with an event study approach in Figure A.13.[32]

Overall, this set of results shows that the heroin demand shock had an immediate effect on violence in Mexico, and that migration started to grow a few years later. These findings suggest that migration might have increased due to the cumulative effect of the violence generated by the heroin demand shock. In other words, violence levels have to be consistently high for an extended period of time in order to affect individuals' willingness to move.

Two possible mechanisms may explain the increase in violence in treated municipalities: i) drug cartels are moving their military power from cannabis- (the control group) to poppy-suitable municipalities (the treated group); ii) drug cartels are using local manpower to control poppy-suitable municipalities, without moving their gunmen from cannabis-suitable areas. The first mechanism implies that part of our estimated effect might be due to a decrease in violence across control municipalities, as drug cartels move their gunmen to more profitable poppy areas. This mechanism assumes that drug cartels have a high level of centralization and organizational capacity.[33] The second mechanism implies more fragmented and fluid conflicts, in which cartels rely on local thugs to run illegal businesses. We refrain from distinguishing between these two mechanisms, as both appear plausible in this context. Note also that both channels are compatible with the results of Sobrino (2019), which shows how violence erupts in poppy-suitable areas especially when more than one cartel is active in the same municipality.

7 Conclusions

This paper studies the effects of the opioid crisis outside the US. We exploit the fact that in 2010, a series of reforms to the US health system resulted in a shift in demand from legal opiates to heroin. This shock affected the demand for heroin from Mexico, the main supplier of heroin consumed in the US. Mexican municipalities suitable for opium production became highly valuable to Mexican

[32]Figure A.13 shows a spike in homicides in 2009, the baseline year, which explains why post-treatment years do not appear different from zero. Indeed, the coefficients of the years 2011–2014 are statistically different from most of the pre-treatment years. The spike in 2009 is probably due to a differential effect of the ongoing war on drugs. Note also that we observe a sharper effect when looking at drug related homicides (confrontations and aggressions) as these closely measure drug cartels violence, differently from the overall number of homicides and deaths.

[33]Note, however, that the effect cannot be entirely due to a decrease in violence within the control group: if violence decreases in the area of origin after gunmen are moved, then violence should (symmetrically) increase in their new location.

cartels, which led to more conflict and violence. In turn, people fled these municipalities, in particular to areas close to the US border and into the US.

This paper focuses only on the production process, i.e. the first step of the drug's supply chain. Future research could explore whether violence and migration dynamics have been affected along drug smuggling routes.

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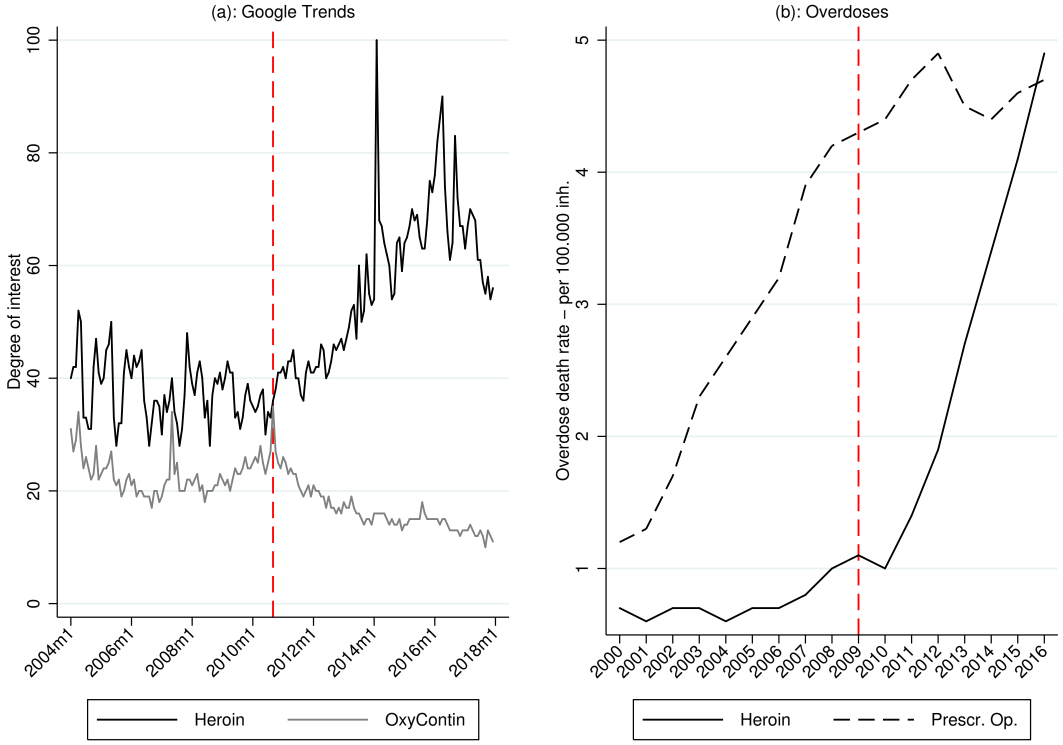
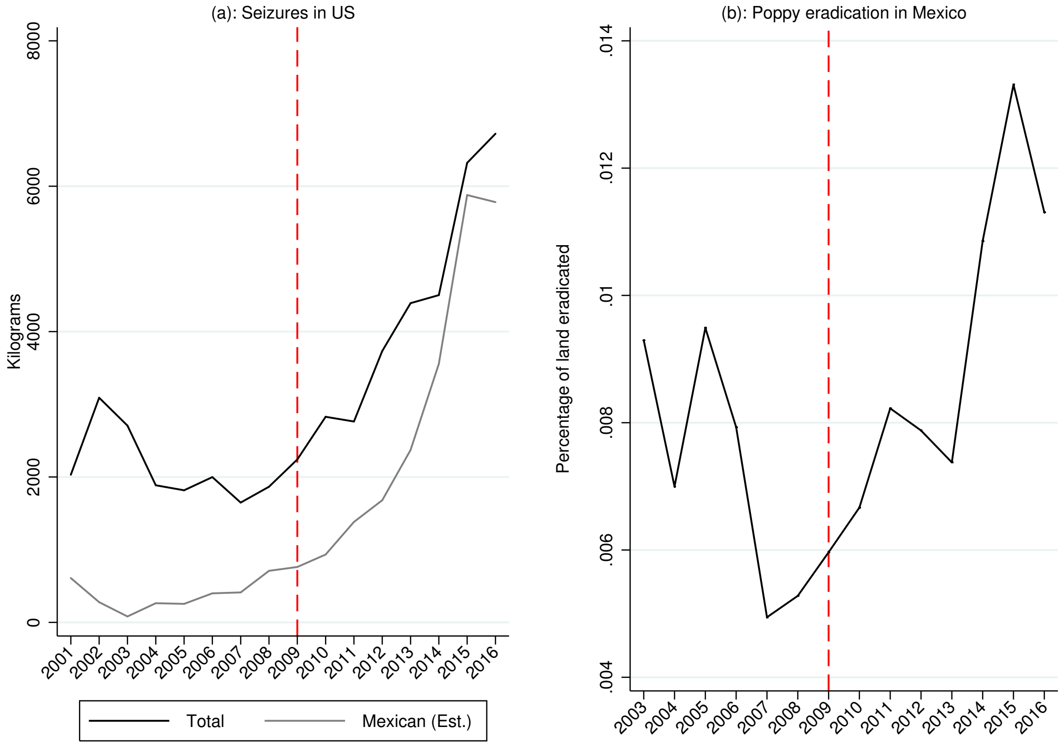
Appendix

Figure A.1: Dynamics of Opioid Epidemic



Note: Panel (a) shows the degree of interest over time in heroin (black line) and OxyContin (gray line) across the US according to the number of searches for these words on *Google Search Engine*. Panel (b) shows the yearly number of overdose deaths due to heroin per 100,000 inhabitants, as retrieved from the National Institute on Drug Abuse .

Figure A.2: Dynamics in the Market for Heroin



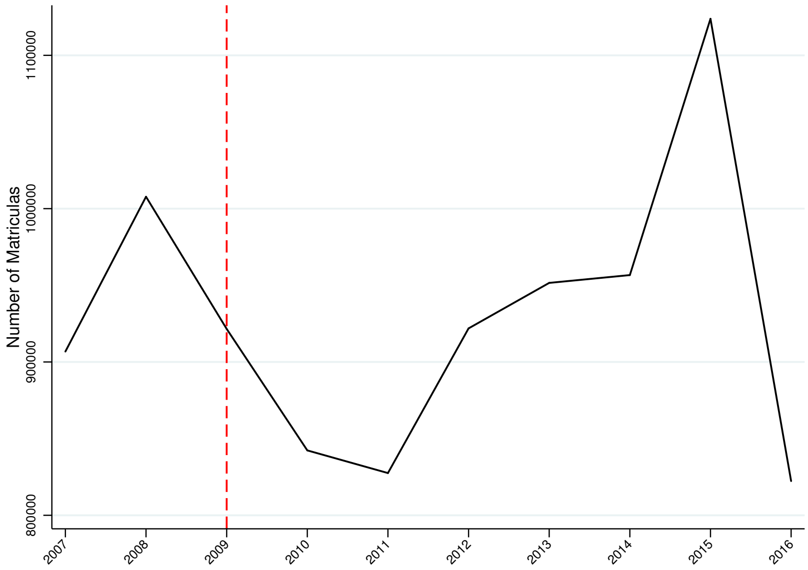
Note: Panel (a) shows the yearly total number of heroin seizures across the US (black line), as well as an estimation of the number of seizures of Mexican heroin (dashed line), both obtained using information provided by the US Drug Enforcement Administration. Panel (b) shows the evolution over the period 2003–2016 in the average percentage of land eradicated at the Mexican municipal level using information provided by the Secretary of National Defense of the Mexican government.

Table A.1: Summary Statistics of the Outcome Variables

	N.Obs.	Mean	Std. Dev.	Min	Max
Matriculas	448,290	10	104	0	17,564
Internal migration (Any mun.)	10,909,124	0.0389	0.1933	0	1
Internal migration (Across reg.)	10,909,124	0.0108	0.1032	0	1
GDP (millions of pesos)	2,425	2,577	13,935	0	224,985
Value added	2,425	1,047	5,639	0	115,732
Investments (millions of pesos)	2,425	117	653	0	12,890
Int. consumption (millions of pesos)	2,425	1,529	8,736	0	152,074
Homicides	14,943	8	34	0	1,271
Deaths	14,889	202	794	1	19,807
Confrontation	5,274	0	1	0	39
Executions	5,274	2	16	0	639
Aggressions	5,274	0	1	0	28

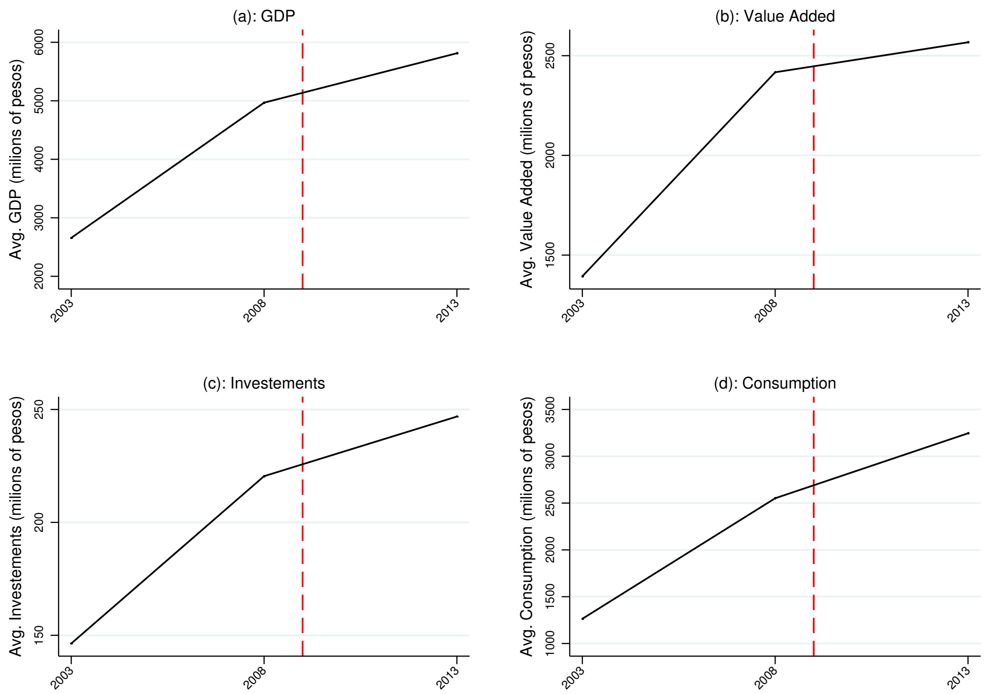
Note: The table shows the summary statistics for all dependent variables employed in our analysis, including the number of observations, mean, standard deviation, minimum, and maximum, all rounded to the closest integer.

Figure A.3: Number of Matriculas Issued by Year



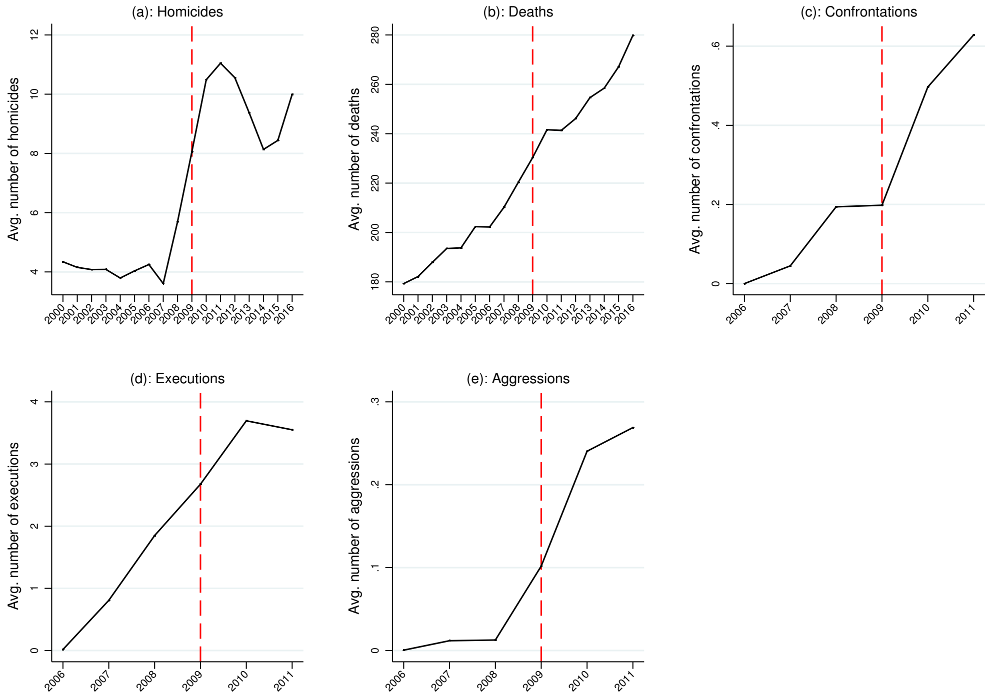
Note: This figure shows the trend in the total number of *matriculas consulares* issued in the US.

Figure A.4: Trends in Economic Indicators



Note: This figure shows the evolution over time of several economic indicators, averaged at the municipal level. The indicators include GDP (panel (a)), value added (panel (b)), investments (panel (c)), and intermediate consumption (panel (d). The data employed to plot the figure are retrieved from the Mexican National Institute of Statistics.

Figure A.5: Trends in Violence



Note: This figure shows the evolution over time of several measures of violence, averaged at the municipal level, including homicides (panel (a)), deaths (panel (b)), confrontations between cartels and authority (panel (c)), executions between cartels (panel (d)), and aggressions by cartels to authorities (panel (e). The data employed to plot the figure are retrieved from the Mexican National Institute of Statistics and Atuesta et al. (2019).

Figure A.6: Example of the Information Contained in the FAO EcoCrop Database

Papaver somniferum

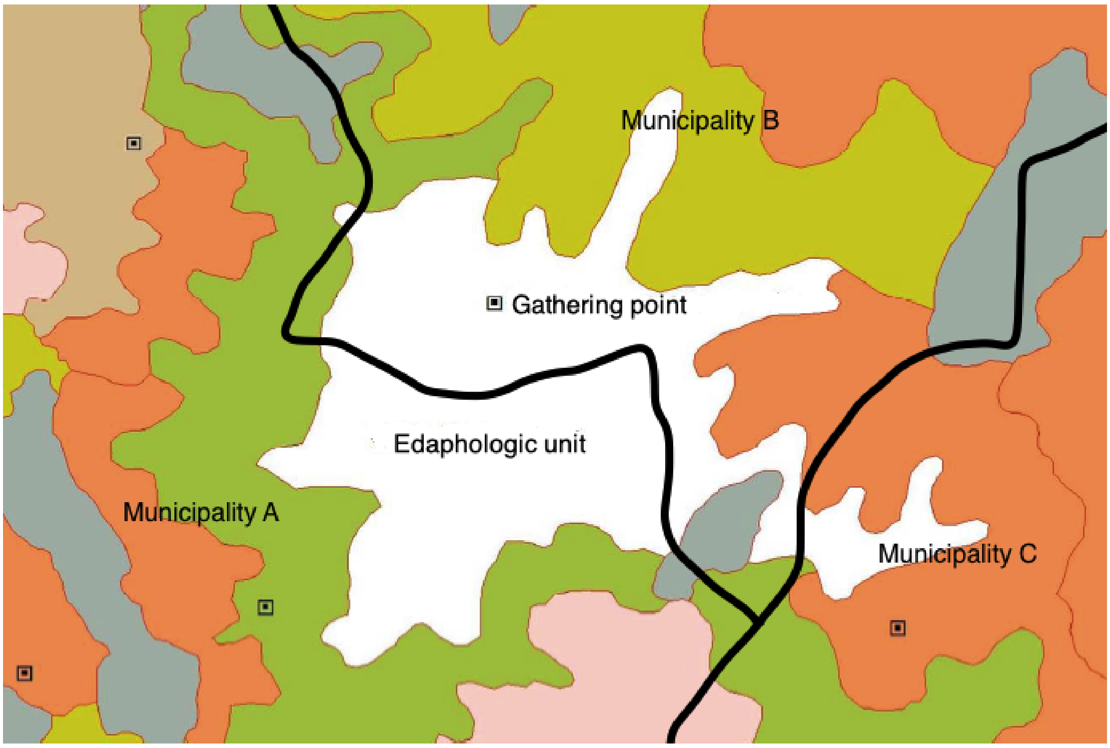
Description			
Life form	herb	**Physiology**	
Habit	erect	**Category**	medicinals & aromatic
Life span	annual	**Plant attributes**	grown on large scale

Ecology							
	Optimal		**Absolute**			**Optimal**	**Absolute**
	Min	Max	Min	Max	**Soil depth**	medium (50-150 cm)	shallow (20-50 cm)
Temperat. requir.	15	24	3	28	**Soil texture**	medium	medium
Rainfall (annual)	800	1200	300	1700	**Soil fertility**	high	moderate
Latitude	15	10	55	60	**Soil Al. tox**		
Altitude	---	---	-	2400	**Soil salinity**	low (<4 dS/m)	low (<4 dS/m)
Soil PH	6.5	7.5	6	8.3	**Soil drainage**	well (dry spells)	well (dry spells)
Light intensity	very bright	clear skies	very bright	cloudy skies			

Climate zone	tropical wet & dry (Aw), tropical wet (Ar), steppe or semiarid (Bs), subtropical dry summer (Cs), temperate oceanic (Do), temperate	**Photoperiod**	long day

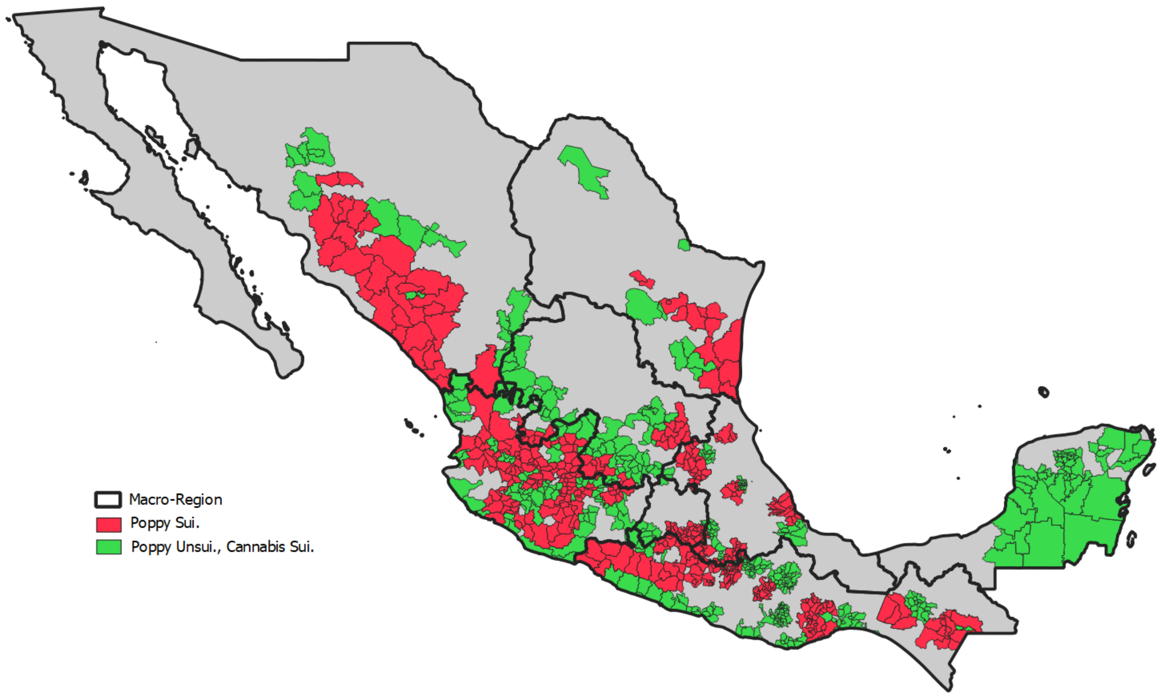
Note: This figure shows the information on the characteristics of *papaverum somniferum* (poppy) available from the FAO EcoCrop database.

Figure A.7: Diagram for Data Collection of Soil Characteristics



Note: This figure shows an example of how the information about soil characteristics is collected by the Mexican National Institute of Statistics. Areas filled with the same color represent the same edaphologic units, while the black lines define the borders between municipalities.

Figure A.8: Illegal crops Suitability Across Mexico



Note: This figure shows the geographical distribution of municipalities suitable for opium production (i.e. municipalities with at least 1% of their area suitable for poppy cultivation, red) and those that are suitable for cannabis but not poppy (i.e. municipalities with at least 1% of their area suitable for cannabis cultivation, green).

Figure A.9: Risk of Illegal Crop Cultivation Across Mexico

Note: This figure shows the risk of illegal crop cultivation across Mexico, as calculated by SEDENA and UNODC using data on historical eradication, natural and social characteristics favoring the production of illegal crops, and satellite data. More intense red corresponds to a higher associated risk. Source: *Mexico-Monitoreo de Cultivos de Amapola 2014-2015*, pg. 97.

Table A.2: Illegal Crop Eradication: Cross-Sectional Analysis

	(1) % Land Poppy	(2) Poppy Plant. Rate	(3) % Land Can.	(4) Can. Plant. Rate
Poppy	1.621***	7.906***	-0.080	1.434
	(0.515)	(2.478)	(0.177)	(1.313)
Cannabis	-0.271	0.420	0.517***	2.901**
	(0.297)	(1.343)	(0.190)	(1.157)
Observations	2,454	2,441	2,454	2,441
R-squared	0.033	0.044	0.029	0.047
Macro-region FE	YES	YES	YES	YES
Base value (Pop.=0/Can.=0)	0.404	1.192	0.165	1.047

Note: This table shows the cross-sectional analysis of the effect of illegal crop suitability on the average eradication of poppy (columns 1–2)) and cannabis (columns 3–4)) at the municipal level during the period 2010–2016. The dependent variables are the percentage of municipal area eradicated (columns 1–3) and the number of plantations per 1,000 inhabitants eradicated (columns 2–4). *Poppy* is a dummy equal to 1 if the municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise. *Cannabis* is a dummy equal to 1 if the municipality has at least 1% of its area suitable for cannabis cultivation and 0 otherwise. All specifications include macro region fixed effects. Standard errors are robust to heteroskedasticity. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A.3: Treated vs Control: Standardized Differences on Observable Characteristics

	Control		Treated		
	Mean or N	SD or (%)	Mean or N	SD or (%)	Std Diff
Population	34,336	97,307	44,478	122,729	-0.092
Surface (Km2)	771	1,604	788	1248	-0.012
Dist. to the US border (Km)	800	196	759	188	0.216
Altitude (meters)	1,179	804	1,252	620	-0.101
Temperature (Celsius)	20.77	3.744	20.26	2.850	0.153
Dense vegetation	0.424	0.385	0.380	0.372	0.117
Pipeline	0.081	0.273	0.095	0.293	-0.047
Near pipeline	0.136	0.343	0.167	0.374	-0.087
PAN mayor	0.268	0.443	0.186	0.390	0.195
Ever cartel	0.140	0.348	0.189	0.392	-0.132
Num. cartels	0.093	0.177	0.122	0.213	-0.151

Note: This table separately shows the average value (or N if the variable is discrete), and standard deviation (or % if the variable is discrete), of several observable characteristics of the control and treated municipalities, together with the standardized difference between the two groups. The treated group includes all municipalities suitable for opium production (i.e. municipalities with at least 1% of their area suitable for poppy cultivation), while the control group includes those not suitable for poppy but suitable for cannabis (i.e. municipalities with at least 1% of their area suitable for cannabis cultivation). Data for constructing *Population*, *Surface*, *Distance to the US border*, *Altitude*, *Temperature*, and *Dense vegetation* are retrieved from the INEGI. *Pipeline* and *Near pipeline* are two dummies constructed using data from PEMEX (i.e. the Mexican public oil company), coded 1 if a pipeline transporting gasoline passes through the municipality or an adjacent municipality, and 0 otherwise. *PAN mayor* is a dummy equal to 1 for municipalities in which PAN (i.e. Partido de Acciòn Nacional) won the municipal electoral round of 2007–2010, and 0 otherwise. The data on electoral results are retrieved from the web page of each state electoral committee. *Ever cartel* is a dummy equal to 1 if the municipality ever registered the presence of a drug cartel by 2010, and 0 otherwise, while *Num. cartels* is the average number of cartels observed in the municipality by 2010. Both variables rely on information provided by Rios and Coscia (2012).

Table A.4: Treated vs Control: Balancing Tests on Levels and Trends of the Outcome Variables

	Difference - Avg. Level	Difference - Trend
Matriculas	0.022	-0.007
	(0.014)	(0.007)
Internal migration (Any mun.)	.	0.009
		(0.007)
Internal migration (Across reg.)	.	0.003
		(0.002)
Homicides	0.027	0.035
	(0.073)	(0.065)
Deaths	0.079	0.034
	(0.077)	(0.029)
Confrontations	0.004	0.030
	(0.005)	(0.028)
Executions	0.018	0.058
	(0.014)	(0.058)
Aggressions	-0.005	- 0.023
	(0.003)	(0.025)
GDP	-0.119	-0.082
	(0.147)	(0.156)
Value added	-0.106	–0.087
	(0.141)	(0.152)
Investements	-0.016	-0.027
	(0.122)	(0.138)
Int. consumption	-0.122	-0.097
	(0.147)	(0.159)

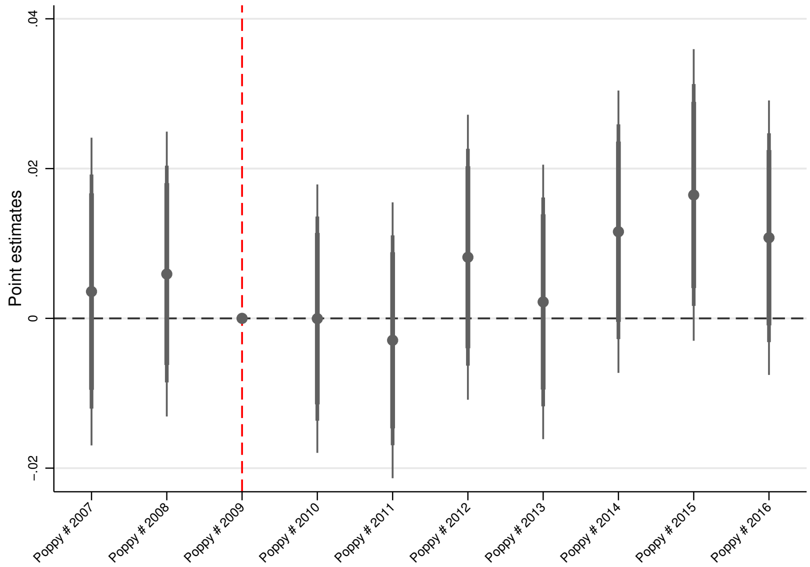
Note: The table shows the differences in outcome variables between treated and control groups before 2010, conditioned to Mexican state fixed effects, with respect to both their average level and the trend between the last and the first years of the pre-treatment period for each variable. The treated group includes all municipalities suitable for opium production (i.e. municipalities with at least 1% of their area suitable for poppy cultivation), while the control group includes those not suitable for poppy but suitable for cannabis (i.e. municipalities with at least 1% of their area suitable for cannabis cultivation), . All outcome variables are taken in logarithmic scale and the standard error are robust to heteroskedasticity. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A.5: Poppy Suitability and Poppy Eradication

	(1) % Land	(2) Plant. Rate
Poppy * Post 2009	1.052***	3.795***
	(0.294)	(1.234)
Observations	12,306	12,250
R-squared	0.565	0.502
Municipality FE	YES	YES
Macro-region X Year FE	YES	YES
Base value (Avg. 2007-2009)	1.096	4.537

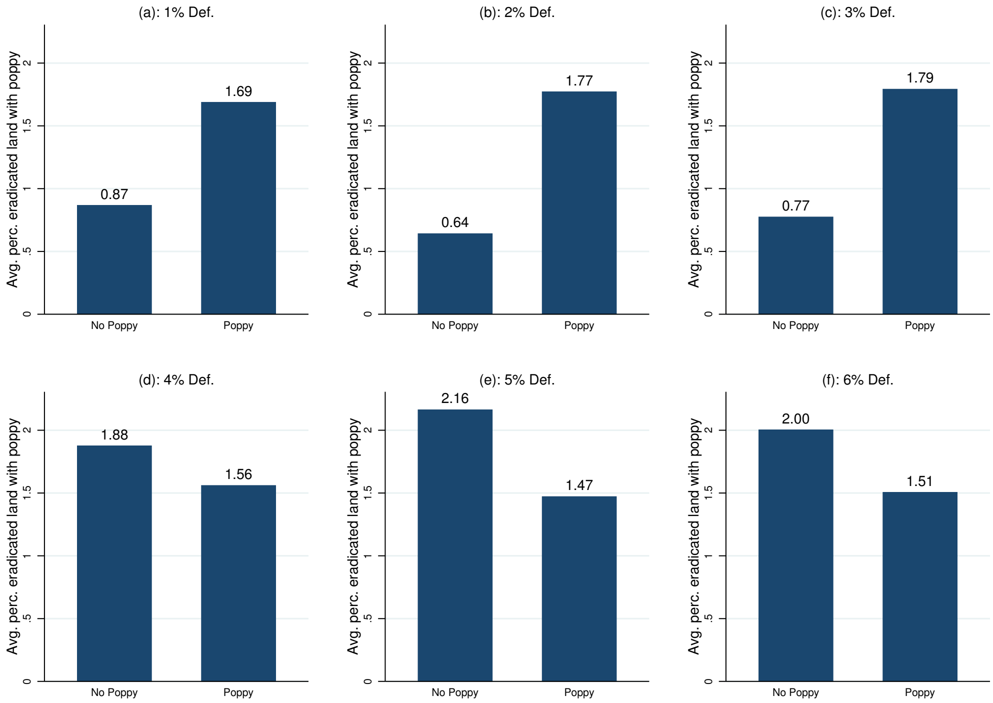
Note: This table shows the panel analysis of the effect of poppy suitability on the yearly eradication of the crop during the period 2003–2016. The dependent variables are the percentage of municipal area eradicated (column 1) and the number of plantations per 1,000 inhabitants eradicated (column 2). *Poppy * Post-2009* is the interaction between the dummy *Poppy*, which is equal to 1 if the municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise, and the dummy *Post-2009,* which is equal to 1 for the years 2010–2016 and 0 otherwise. All specifications include municipality fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Figure A.10: Poppy Suitability and Migration to the US: Event Study



Note: This figure shows the evolution over time of the effect of poppy suitability on the number of Matriculas issued in the US each year during the period 2007–2016, from each Mexican municipality to each US state. The variable *Poppy#year* denotes interaction terms of *Poppy* – a dummy equal to 1 if the municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise –with indicator variables for each year. The red vertical dashed line separates the pre-treatment and post-treatment periods. All specifications include distance to the US border-year fixed effects, municipality of origin-US state of arrival fixed effects, and macro-region-year fixed effects. The vertical gray lines represent confidence intervals at 90% (i.e. least-wide spikes), 95% (i.e. medium-wide spikes), and 99% (i.e. widest spikes). Confidence intervals are based on standard errors clustered at the Mexican state-US state-year level.

Figure A.11: Illegal Crop Eradication and Different Definitions of Poppy-Suitable Municipalities



Note: This figure shows the average percentage of poppy-cultivated land eradicated during the period 2010–2016, for municipalities suitable and unsuitable for growing poppy, as defined using different thresholds of the percentage of municipal area suitable for poppy cultivation: 1% (panel (a)), 2% (panel (b)), 3% (panel (c)), 4% (panel (d)), 5% (panel (e)), and 6% (panel (f)). Municipalities above the threshold are considered suitable for poppy cultivation, while those below the threshold, but greater than 0, are considered unsuitable.

Table A.6: Poppy Suitability and Internal Migration: Sensitivity Analysis

	(1) Any mun.	(2) Across reg.	(3) Any mun.	(4) Across reg.	(5) Any mun.	(6) Across reg.
Poppy * 2015	0.0038***	0.0034***	0.0048***	0.0039***	0.0036**	0.0036***
	(0.0013)	(0.0011)	(0.0016)	(0.0012)	(0.0015)	(0.0012)
Observations	11,452,988	11,452,988	10,569,195	10,569,195	10,294,326	10,294,326
R-squared	0.0317	0.0194	0.0327	0.0198	0.0327	0.0198
Poppy threshold	0%	0%	2%	2%	3%	3%
Individual controls	YES	YES	YES	YES	YES	YES
Dist. US border X $Post_t$	YES	YES	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES	YES	YES
Macro-region X Year FE	YES	YES	YES	YES	YES	YES
Base value (Btw. 2005-2010)	0.0426	0.0127	0.0433	0.0128	0.0414	0.0124

Note: This table shows the analysis of the effect of poppy suitability on migration to any Mexican municipality (columns 1, 3, and 5) or to another macro region (columns 2, 4, and 6). *Poppy * 2015* is the interaction between the dummy *Poppy* and the dummy *2015*, which is equal to 1 for the 2015 census. In columns (1) and (2) *Poppy* is equal to 1 if the municipality where individuals were living 5 years earlier had part of its area suitable for poppy cultivation and 0 otherwise; in columns (3) and (4) this area was equal to or greater than 2%, while in columns (5) and (6) the threshold is 3%. All specifications include individual controls (i.e. age, age^2, age^3, gender, and education), the interaction between the distance to the US border and the dummy *2015*, municipality fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A.7: Poppy Suitability and Migration to the US: Sensitivity Analysis

	(1) Matriculas	(2) Matriculas	(3) Matriculas	(4) Matriculas	(5) Matriculas	(6) Matriculas
Poppy * Post 2009	0.001		0.004		0.006	
	(0.004)		(0.004)		(0.004)	
Poppy * 2010-2013		-0.004		-0.001		0.001
		(0.004)		(0.004)		(0.004)
Poppy * Post 2013		0.008*		0.009**		0.012***
		(0.004)		(0.004)		(0.005)
Observations	478,380	478,380	435,540	435,540	424,830	424,830
R-squared	0.909	0.909	0.909	0.909	0.909	0.909
Poppy threshold	0%	0%	2%	2%	3%	3%
Dist. US border X $Post_t$	YES	YES	YES	YES	YES	YES
Mun. X US State FE	YES	YES	YES	YES	YES	YES
Macro-region X Year FE	YES	YES	YES	YES	YES	YES
Base value (Avg. 2007-2009)	274,090	274,090	242,823	242,823	230,605	230,605

Note: This table shows the analysis of the effect of poppy suitability on the Matriculas issued in the US during the period 2007–2016, from each Mexican municipality to each US state. *Poppy * Post-2009* is the interaction between the dummy *Poppy* and the dummy *Post-2009*, which is equal to 1 for the years 2010–2016 and 0 otherwise. In columns (1) and (2) *Poppy* is equal to 1 if the municipality has part of its area suitable for poppy cultivation and 0 otherwise; in columns (3) and (4) this area was equal to or greater than 2%, while in columns (5) and (6) the threshold is 3%. *Poppy * 2010–2013* is the interaction between the dummy *Poppy* and the dummy *2010–2013*, which is equal to 1 for the years 2010–2013 and 0 otherwise. *Poppy * Post-2013* is the interaction between the dummy *Poppy* and the dummy *Post-2013*, which is equal to 1 for the years 2014–2016 and 0 otherwise. All specifications include municipality-US state fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-US state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A.8: Treated vs. Alternative Control: Standardized Differences on Observable Characteristics

	Control		Treated		
	Mean or N	SD or (%)	Mean or N	SD or (%)	Std Diff
Population	38,355	103,569	45,910	125,670	-0.066
Surface (Km2)	710	1,197	788	1,248	-0.063
Dist. to the US border (Km)	750	218	759	188	-0.043
Altitude (meters)	1,337	760	1,252	620	0.122
Temperature (Celsius)	19.64	3.75	20.26	2.85	-0.185
Dense vegetation	0.349	0.378	0.380	0.372	-0.083
Pipeline	0.095	0.293	0.095	0.293	0.000
Near pipeline	0.175	0.380	0.167	0.374	0.020
PAN mayor	0.263	0.441	0.186	0.390	0.183
Ever cartel	0.158	0.365	0.189	0.392	-0.082
Num. cartels	0.204	0.336	0.232	0.360	-0.081

Note: This table separately shows the average value (or N if the variable is discrete), and standard deviation (or % if the variable is discrete), of several observable characteristics of the control and treated municipalities, together with the standardized difference between the two groups. The treated group includes all municipalities suitable for opium production (i.e. municipalities with at least 1% of their area suitable for poppy cultivation), while the control group includes their neighboring municipalities. Data for constructing *Population*, *Surface*, *Distance to the US border*, *Altitude*, *Temperature*, and *Dense vegetation* are retrieved from the INEGI . *Pipeline* and *Near pipeline* are two dummies constructed using information provided by PEMEX (i.e. the Mexican public oil company), indicating whether a pipeline transporting gasoline passes through the municipality or an adjacent municipality, and 0 otherwise. *PAN mayor* is a dummy equal to 1 for municipalities in which PAN (i.e. Partido de Acciòn Nacional) won the municipal electoral round of 2007–2010, and 0 otherwise. The data on electoral results are retrieved from the web page of each state electoral committee. *Ever cartel* is a dummy equal to 1 if the municipality ever registered the presence of a drug cartel by 2010, and 0 otherwise, while *Num. cartels* is the average number of cartels observed in the municipality by 2010. Both variables rely on information provided by Rios and Coscia (2012).

Table A.9: Treated vs. Alternative Control: Balancing Tests on Levels and Trends of the Migration Variables

	Difference - Avg. Level	Difference - Trend
Matriculas	0.029	0.002
	(0.019)	(0.010)
Internal migration (Any mun.)	.	0.004
		(0.007)
Internal migration (Across reg.)	.	0.001
		(0.002)

Note: The table shows the differences in outcome variables between the treated and control groups before 2010, conditioned to Mexican state fixed effects and cannabis suitability, with respect to both their average level and the trend between the last and first years of the pre-treatment period for each variable. The treated group includes all municipalities suitable for opium production (i.e. municipalities with at least 1% of their area suitable for poppy cultivation), while the control group includes their neighboring municipalities. The variable *Matriculas* is taken in logarithmic scale. The standard errors are robust to heteroskedasticity. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A.10: Poppy Suitability and Migration Across Mexico: Alternative Definition of the Control Group

	(1) Any mun.	(2) Any mun.	(3) Across reg.	(4) Across reg.
Poppy * 2015	0.0043*	0.0040*	0.0035*	0.0034*
	(0.0024)	(0.0023)	(0.0019)	(0.0018)
Observations	11,409,651	11,334,937	11,409,651	11,334,937
R-squared	0.0285	0.0368	0.0160	0.0191
Individual controls	NO	YES	NO	YES
Dist. US border X $Post_t$	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Macro-region X Year FE	YES	YES	YES	YES
Base value (Btw. 2005-2010)	0.0431	0.0431	0.0130	0.0130

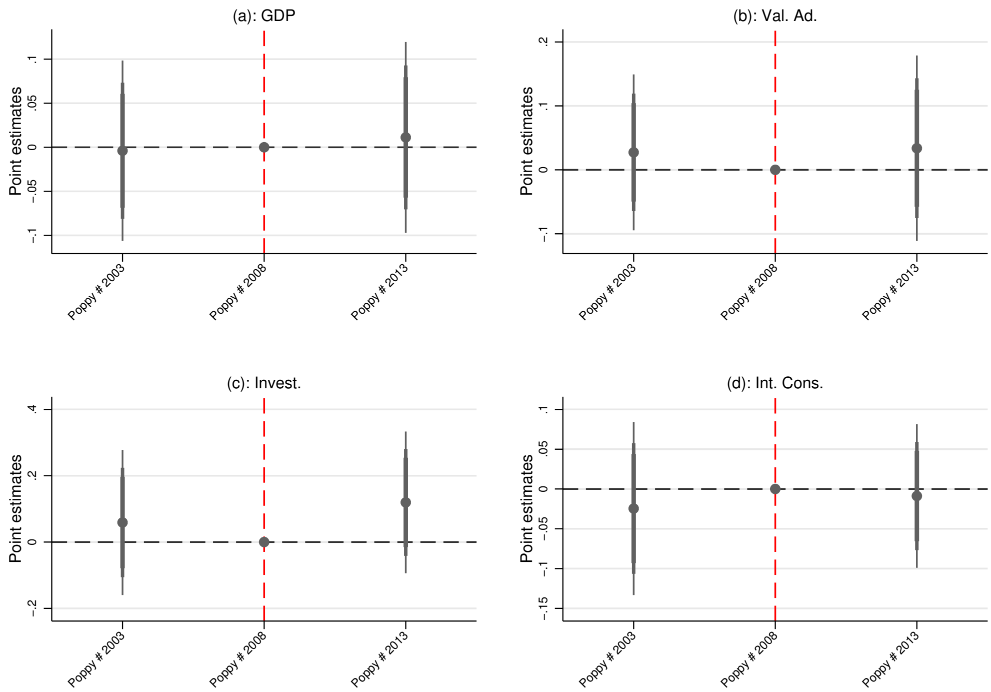
Note: This table shows the analysis of the effect of poppy suitability on migration inflows from any Mexican municipality (columns 1–2) or from another macro region (columns 3–4). *Poppy * 2015* is the interaction between the dummy *Poppy*, which is equal to 1 if the municipality where individuals were living 5 years earlier live has at least 1% of its area suitable for poppy cultivation and 0 otherwise, and the dummy *2015*, which is equal to 1 for the 2015 census. All specifications include individual controls (i.e. age, age^2, age^3, gender, and education), the interaction between the distance to the US border and the dummy *2015*, municipality fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the municipal level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A.11: Poppy Suitability and US Migration: Alternative Definition of the Control Group

	(1) Matriculas	(2) Matriculas
Poppy * Post 2009	0.011**	
	(0.005)	
Poppy * 2010-2013		0.008*
		(0.005)
Poppy * Post 2013		0.015***
		(0.005)
Observations	464,100	464,100
R-squared	0.904	0.904
Can. sui. X $Post_t$	YES	YES
Dist. US border X $Post_t$	YES	YES
Mun. X US State FE	YES	YES
Macro-region X Year FE	YES	YES
Base value (Avg. 2007-2009)	256,051	256,051

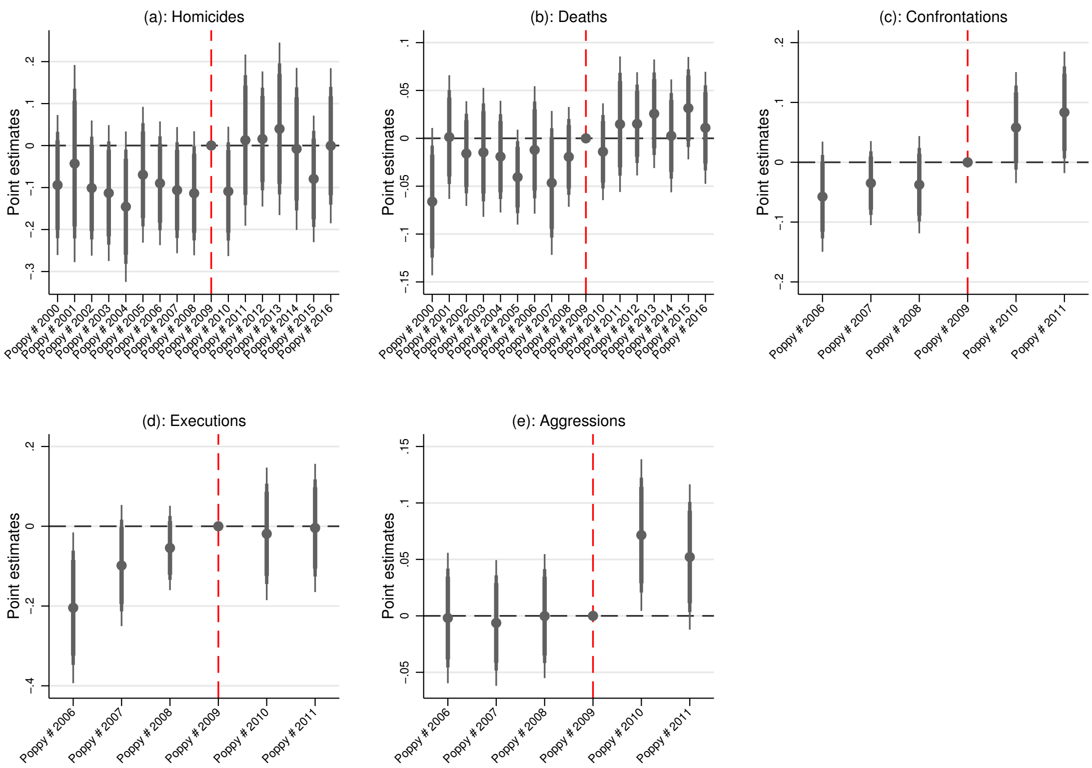
Note: This table shows the analysis of the effect of poppy suitability on the number of Matriculas issued in the US during the period 2007–2016, from each Mexican municipality to each US state. *Poppy * Post-2009* is the interaction between the dummy *Poppy*, which is equal to 1 if the municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise, and the dummy *Post-2009*, which is equal to 1 for the years 2010–2016 and 0 otherwise. *Poppy * 2010–2013* is the interaction between the dummy *Poppy* and the dummy *2010–2013*, which is equal to 1 for the years 2010–2013 and 0 otherwise. *Poppy * Post-2013* is the interaction between the dummy *Poppy* and the dummy *Post-2013*, which is equal to 1 for the years 2014–2016 and 0 otherwise. Column (1) includes the interaction between the distance to the US border and the dummy *Post-2009*, and between the latter and *Cannabis*, which is equal to 1 if the municipality has at least 1% of its area suitable for cannabis cultivation and 0 otherwise. Column (2) includes the interactions of the distance to the US border separately with *2010–2013* and *Post-2013*, as well as the interactions of *Cannabis* with *2010–2013* and *Post-2013*. All specifications include municipality-US state fixed effects and macro-region-year fixed effects. Standard errors are robust to heteroskedasticity and clustered at the Mexican state-US state-year level. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Figure A.12: The Effect of Poppy Suitability on Economic Performance: Event Study



Note: This figure shows the evolution over time of the effect of poppy suitability on GDP (panel (a)), total value added (panel (b)), investment (panel (c)), intermediate consumption (panel (d)), number of employed (panel (e)), average school grade (panel (f)), deaths (panel (g)), and number of homicides (panel (h)), all in logarithmic scale. The variable *Poppy#year* are interaction terms of *Poppy* – a dummy equal to 1 if the municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise – with indicator variables for each year. The red vertical dashed line separates the pre-treatment and post-treatment periods. All specifications include municipality fixed effects and macro-region-year fixed effects. The vertical gray lines represent confidence intervals at 90% (i.e. least-wide spikes), 95% (i.e. medium-wide spikes) and 99% (i.e. widest spikes). Confidence intervals are based on standard errors clustered at the Mexican state-year level.

Figure A.13: Poppy Suitability and Violence: Event Study



Note: This figure shows the evolution over time of the effect of poppy suitability on the yearly number of homicides (panel (a)), yearly number of deaths (panel (b)), yearly number of confrontations between cartels and the authorities (panel (c)), yearly number of executions among cartels (panel (d)), and the yearly number of aggressions by cartels on authorities (panel (e)), all in logarithmic scale. The variable *Poppy#year* are interaction terms of *Poppy* – a dummy equal to 1 if the municipality has at least 1% of its area suitable for poppy cultivation and 0 otherwise – with indicator variables for each year. The red vertical dashed line separates the pre-treatment and post-treatment periods. All specifications include municipality fixed effects and macro-region-year fixed effects. The vertical gray lines represent the confidence intervals at 90% (i.e. least-wide spikes), 95% (i.e. medium-wide spikes) and 99% (i.e. widest spikes). Confidence intervals are based on standard errors clustered at the Mexican state-year level.