Navarra Center for International Development

Working Paper nº 05/2024

Avocados: Mexico's green gold. The impact of the U.S. opioid crisis on Mexico's drug cartel violence

Itzel De Haro Lopez

University of Navarra

Avocados: Mexico's green gold.

The impact of the U.S. opioid crisis on Mexico's drug cartel violence*

Itzel De Haro Lopez†

June, 2024

Abstract

The growing global demand for avocados has drawn the attention of rent-seeking drug trafficking organizations (DTOs) in Mexico. As a result, farmers and packing houses have become targets of extortion by these organizations. This paper aims to answer whether declining drug revenues have incentivized cartels to target the avocado sector. By leveraging exogenous variation from the introduction of Fentanyl in the U.S., I analyze the impact of reduced heroin demand on homicides and cartel presence in avocado and poppy-growing municipalities between 2011 and 2019. Using municipal-level data, I show that the decline in the demand for heroin increased homicide rates, including those of agricultural workers, as well as truckload thefts in avocado-growing municipalities. Conversely, decreased heroin demand resulted in a reduction in homicides and violent thefts in poppy-growing municipalities. Furthermore, I find no evidence of changes in cartel presence in avocado and poppy municipalities. Consequently, the rise in homicides in avocado municipalities can be attributed to DTOs' increased use of violence against civilians rather than territorial expansion. Overall, this paper provides evidence of inter-sector spillovers resulting from drug demand changes.

Keywords: Crime diversification, Drug cartels, Avocado, Fentanyl, Heroin, Crime, Violence, Mexico
JEL Classifications: K42, O12, O13, O17, Q17

*I am very grateful to Laura Schechter, Dominic Parker, Priya Mukherjee, and Jaime Millán for their invaluable support and advice in this project. For highly valuable comments and suggestions, Paul Dower, Bradford Barham, Andrea Velazquez, Gaurav Doshi, Natalia Serna, Felipe Parra, and participants at the SEA 2023, AMIE 2022 Workshop, LACEA-2022, the 2023 RIDGE-LACEA Workshop on the Economics of Crime, SEA-2023, the IRP GRF Seminar, the UW AAE Development Seminar, the AAE Applied Economics Workshop, and the AAE Development Lab. I also thank the MCO project, Fernanda Sobrino, and Esteban Quiñones, for generously sharing their data. All errors are my own.

†Navarra Center for International Development, University of Navarra. Email address: ideharo@unav.es.

1 Introduction

"It's not only avocados. Mexican organised crime has long mutated away from 'just' drugs trafficking [...]. Today, the model is this: you control a given territory, and within in it you exploit whichever commodity is locally available. That includes avocados [...]" - Falko Ernst, International Crisis Group.[1]

"Where there's money, that's where the bad guys go. With all the publicity that it's going so well for us — this will be the sixth year that Mexican avocados have [been] advertised in the Super Bowl — it draws attention to us"
- Avocado farmer from Michoacán, Mexico.[2]

Drug trafficking has ceased to be the only source of income for many drug cartels in Mexico, with some of them resorting to other criminal activities, such as extortion, kidnapping, illegal mining, and fuel theft (Herrera and Martinez-Alvarez, 2022; Jones and Sullivan, 2019). One of the most prominent sectors that has attracted the attention of drug trafficking organizations (DTOs)[3] is the avocado industry, whose exports have contributed over 2.5 billion U.S. dollars every year since 2016.[4] DTOs target avocado farmers and packinghouses through extortion and avocado theft (Linthicum, 2019; de Cordobá, 2014). In 2014, the municipality of Tancítaro–known as the leading producer of avocados in Michoacán– reported an estimated loss of $150 million due to extortion fees in the avocado sector, equivalent to 10% of the national avocado exports for that year (de Cordobá, 2014). Additionally, between 7 and 10 avocado truckloads are stolen every week in the state of Michoacán, contributing to annual losses ranging from $3.6 - 5.2 million (Agren, 2019).[5]

This paper analyzes the impact of declining drug revenues on violent crimes in avocado- and poppy-growing municipalities. I hypothesize that, as the demand for Mexican heroin in the U.S. has declined, cartels have shifted their efforts to target other businesses, such as the avocado sector. In fact, the headline of a 2020 article points this out:

"Avocado crime soars as Mexican gangs turn focus from opium to 'green gold' "
- *Financial Times (2020)*

[1] Financial Times (2020).
[2] The Guardian (2019).
[3] In this paper, I use drug cartel and drug trafficking organizations (DTOs) as interchangeable terms.
[4] Source: Own estimates based on information from the Mexican Secretariat of Agriculture and Rural Development (SAGARPA).
[5] Own estimates based on the 2019 value per ton of avocado.

The fall in opium revenues has been attributed to a decreased demand for Mexican heroin, driven by the introduction of Fentanyl in the U.S., a readily available cheap synthetic opioid, 50 to 100 times more potent than morphine, typically used in treating severe pain (Le Cour Grandmaison et al., 2019; Financial Times, 2020; CDC, 2021a). Fentanyl has become increasingly popular among drug consumers and dealers as a potent and inexpensive alternative to other drugs (Felter, 2022). Dealers use Fentanyl to dilute other drugs such as heroin, to enhance these drugs' potency while lowering the dealer's costs (DEA, 2020b; NIDA, 2021). This is of foremost importance to Mexico, the third major producer of heroin and the leading supplier to the U.S., where over 90% of the heroin available in the market comes directly from Mexico (Le Cour Grandmaison et al., 2019). The fall in the U.S. demand for heroin has led to an opium crisis in Mexico, with opium farmers reporting a decline in revenues of around 50% between 2017 and 2018 (Le Cour Grandmaison et al., 2019).

Therefore, as Fentanyl becomes more available in the U.S. market and heroin less profitable, cartels may have diversified into other lucrative sectors. This paper analyzes the effect of the introduction of Fentanyl on violent crimes in avocado- and poppy-growing municipalities in Mexico. By combining geographically referenced data on avocado and poppy suitability with detailed information on homicides, thefts, and cartel presence, this paper aims to answer the following questions: i) Did the introduction of Fentanyl increase the number of murders in avocado-suitable municipalities?, ii) Did the opioid crisis increase cartel presence in avocado-suitable municipalities? and iii) What was the impact on poppy-producing municipalities?

Changes in the prices of commodities have been used to measure the impact of shifts in the demand for a good on violent outcomes (Brückner and Ciccone, 2010; Berman et al., 2017; Dube et al., 2016; Sobrino, 2019). However, using this strategy has several problems in this context. For instance, heroin prices measured through undercover purchases are susceptible to measurement error (Horowitz, 2001), are likely to be endogenous to violence in Mexico, and may not reflect changes in the prices perceived by cartels. Instead, I use Fentanyl overdoses as a proxy for the availability of Fentanyl in the U.S. market and rely on overdoses of Fentanyl being exogenous to violence in Mexico for identification.

For this analysis, I study the period between 2011 and 2019, which corresponds to the third wave of the opioid crisis in the U.S. Specifically, I use information on the top eight avocado-producing states in Mexico. The sample encompasses the state of Michoacán, the leading producer and exporter of avocados in Mexico, and Guerrero, the country's primary producer of opium (Le Cour Grandmaison et al., 2019; The Associated Press, 2021).

The results indicate that the decrease in the demand for heroin increased murders in avocado-growing municipalities, particularly among agricultural workers and the general population. This shift also resulted in a higher incidence of truckload thefts and thefts with violence in these areas. Contrary to what would be expected, there is no evidence of changes in the number of cartels present in these municipalities and no impact on potentially inter-cartel-related murders. This suggests violence has mainly arisen from cartels targeting civilians rather than from territorial conflict between cartels.

In contrast, poppy-growing municipalities show significant decreases in homicide rates among agricultural workers and the general population, as well as lower theft rates. Additionally, I find a negative but small and not statistically significant relationship between Fentanyl and cartel presence in poppy-growing municipalities. The lack of evidence for cartel movement, suggests that cartels still have incentives to maintain control over these areas.

This paper contributes to the literature on crime by providing further evidence of the relationship between income and crime. While several papers have looked into the relationship between income and civic conflict, and others have looked into the effect of changes in commodity prices, empirical evidence of this relationship remains ambiguous. On the one hand, a positive income shock can reduce conflict by increasing individuals' opportunity cost to participate in criminal activities (Berman and Couttenier, 2015; Brückner and Ciccone, 2010; Chassang and Padró i Miquel, 2009; Dube et al., 2016; Miguel et al., 2004). On the other hand, more income increases the returns to appropriation (Angrist and Kugler, 2008; Berman et al., 2017; Chimeli and Soares, 2017; Dube and Vargas, 2013; Idrobo et al., 2014; Parker and Vadheim, 2017). In other words, increased income raises individuals' incentives to tap into avocado revenues by engaging in criminal activities. In this paper, I provide evidence of the second mechanism, where declining drug revenues have increased incentives for criminal organizations to tap into another sector.

Theoretical models and empirical evidence show that the relationship between income and violence can depend on the commodity type. Dal Bó and Dal Bó (2011) and Dube and Vargas (2013) find a negative relationship between income shocks and violence in labor-intensive industries and a positive correlation in capital-intensive industries. This study contributes to this literature by providing empirical evidence of this relationship by looking into the effects of a change in the demand for heroin on violence in two labor-intensive sectors. Moreover, the findings of this paper provide evidence of a positive relationship between income and violence in a labor-intensive industry. This aligns with growing recent literature showing that raising prices of agricultural goods can lead to increased rapacity from criminal organizations in the presence of weak property rights and illegal institutions (Bandiera, 2021; Kenny et al., 2022; Millán-Quijano and Pulgarín, 2023; Dimico et al., 2017).

This paper also complements the growing literature on the diversification of criminal organizations, such as the Italian mafia, which is involved in a wide range of sectors. Similar to Mexico, the presence of weak institutions has provided leeway for the Italian mafia to exploit legal industries through extortion. The mafia's control also extends to the agricultural sector, as illustrated by their involvement in the trade of oranges, lemons, and tomatoes (Buonanno et al., 2012; Bandiera, 2003; Dimico et al., 2017; Jones and Awokoya, 2019). This study also provides evidence as to why Mexican cartels diversify. So far, the literature has explained this diversification as a byproduct of increased cartel competition resulting from the Mexican government's kingpin strategy between 2006 and 2012 (Herrera and Martinez-Alvarez, 2022; Jones, 2013; Magaloni et al., 2020).[6] Although this explains earlier diversification, it does not fully account for more contemporary changes in cartels' behavior, as the government's strategy has significantly changed since 2012.

To the best of my knowledge, this paper is the first to study the effect of Fentanyl on violence in Mexico, and more specifically, its effect on the avocado sector. While Sobrino (2019) has also investigated how changes in the U.S. demand for heroin affect violence in Mexico, this paper differs substantially from hers in three main ways. First, this study analyzes the post-2013 period when the introduction of Fentanyl reduced the demand for heroin, known as the third wave of the U.S. opioid crisis. Meanwhile, Sobrino (2019) studies the preceding period, corresponding to the second wave of the U.S. opioid crisis, where the reformulation of OxyContin increased the demand for heroin.[7] Second, my empirical strategy relies on using the availability of Fentanyl in the market (using Fentanyl overdoses as a proxy) for identification, rather than changes in the prices of heroin.

[6] The kingpin strategy consisted of targeting the heads of criminal organizations. The capture or killing of the cartel leaders led to the internal instability and subsequent fragmentation of cartels (Jones, 2013).

[7] More information on the timeline of the U.S. opioid crisis can be found in Section A.2.3.

Finally, our studies differ in how we estimate poppy suitability. Sobrino (2019) employs a machine-learning approach to build an index based on opium yield data and conditions from Afghanistan. Meanwhile, I use a well-established crop suitability model that combines climate data with agro-climatic requirements for poppy growing from the UN Food and Agriculture Organization (FAO).

2 Background

2.1 Cartel violence in the avocado sector

As the nutritional benefits of avocados have become more widely known, their popularity has surged in many parts of the world, leading to a significant increase in demand. (Srivastava, 2019). This has important implications for Mexico, the world's largest producer and exporter of avocados, and the main supplier to the U.S. [8]

The increasing profitability of avocados has also attracted criminal organizations seeking to extract revenue through extortion and theft. Avocado farmers are often the target of extortion from cartels, who demand payment in exchange for "protection" (Linthicum, 2019; de Cordobá, 2014; Padgett, 2013; Rainsford, 2019). While there is no consensus on the amount, reported annual extortion fees range between $150 to $250 per hectare (de Cordobá, 2014; Linthicum, 2019).[9] As a result, the avocado sector has sustained significant losses due to extortion. For instance, in 2014, the municipality of Tancítaro–the largest avocado producer in the country– reported annual losses of up to $150 million due to extortion (de Cordobá, 2014).

Besides extortion, DTOs also engage in avocado theft. On average, 7 to 10 truckloads of avocados are stolen weekly in Michoacán. Each truck carries about 8 tons of avocados destined for export, with an average value $10,000 per truckload (García Tinoco, 2019; Agren, 2019).[10] Moreover, increasing violence in the region has disrupted international trade, as evidenced by the temporary suspension of USDA avocado inspection programs in 2019 and a temporary U.S. ban on Mexican avocado imports due to security concerns for USDA inspectors in 2022 (Linthicum, 2019;

[8] Mexico produces more than a third of the world's avocados, with over 75% of its exports going to the U.S.(Hansen, 2017).

[9] DTOs are sophisticated and can charge differentiated prices to farmers. They charge specific quotes for every avocado plant bought in a greenhouse and higher fees per hectare for farmers who export. They also impose fees based on the number of avocado trees planted and the size of the fields (Padgett, 2013).

[10] Estimates based on an exchange rate of 20 Mexican pesos per U.S. dollar.

The Associated Press, 2022).

Tired of the increasing levels of violence and extortion, farmers in some communities of Michoacán armed themselves and formed self-defense groups called *autodefensas*. These groups emerged in 2013 in direct response to the Knights Templar cartel, which targeted civilians through extortion, kidnapping, and murder (Ornelas and Gutiérrez, 2017). The arming of civilians quickly became a concern for the government and, in January 2014, negotiations commenced between government officials and *autodefensas* leaders. The government proposed their disarming and integration into a new state security force. Despite initial resistance, by 2015, most of the *autodefensas* had agreed to the government's proposal (Felbab-Brown, 2016).

2.2 The effect of the U.S. opioid crisis in Mexico

Mexico is the third-largest producer of opium in the world, following Afghanistan and Myanmar. It contributes to 6% of the global opium production. Most of Mexico's heroin is produced in the northern states of Chihuahua, Sinaloa, Durango (referred to as the Golden Triangle), Guerrero, and Nayarit. Guerrero alone accounts for over 60% of the country's opium production (Le Cour Grandmaison et al., 2019).[11] Detailed information on Mexico's heroin production and distribution can be found in Section A.2.2 of the Appendix.

Mexico is also the main exporter of heroin to the U.S., responsible for supplying 90% of the heroin consumed in the country (Le Cour Grandmaison et al., 2019). Consequently, fluctuations in heroin demand in the U.S. can impact opium production in Mexico, cartel competition, and even violence. Sobrino (2019)'s study shows evidence that the increase in the demand for heroin in the U.S., following the reformulation of OxyContin in 2010,[12] increased cartel presence in Mexico's suitable poppy municipalities and contributed to a rise in homicides.

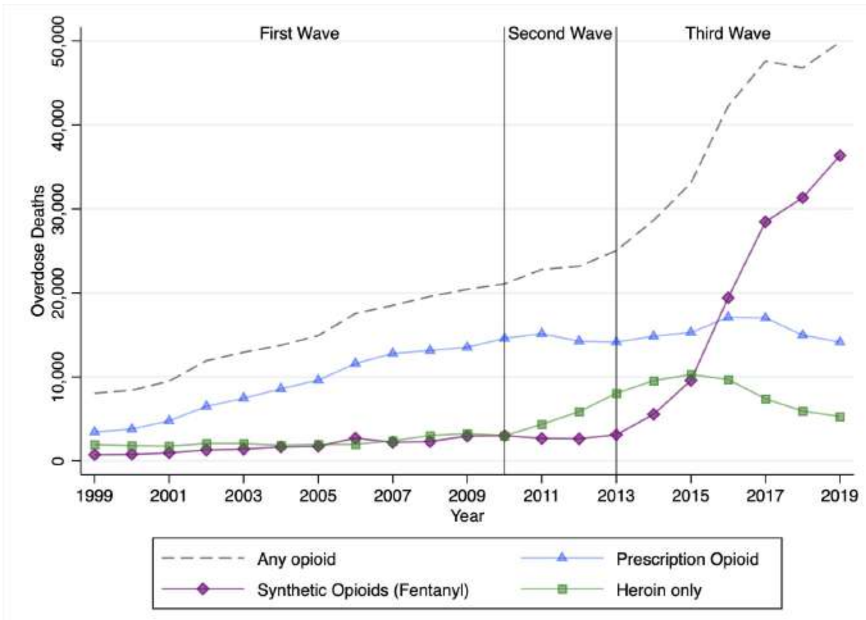
Starting in 2013, the U.S. experienced a surge in overdose deaths related to Fentanyl, as it became popular among drug users and dealers as a cheaper alternative to other drugs. Dealers often lace heroin with fentanyl because it provides a similar high to unlaced heroin at a lower cost (NIDA, 2021). This substitution led to a surge in fentanyl-related overdose deaths, which increased

[11] Figure A1 in the Appendix shows the geographical distribution of poppy cultivation.

[12] The reformulation of OxyContin in 2010 was part of stricter measures to reduce the abuse of prescribed opioids. This reformulation made OxyContin pills harder to crush (Coplan et al., 2016). As a result, individuals consuming opioids switched to less expensive and more readily available options, such as heroin. Further details on the U.S. opioid crisis can be found in Section A.2.3 of the Appendix.

from 3,105 to over 36,300 between 2013 and 2019 (see Figure 1). Moreover, it resulted in a decrease in the demand for heroin (Le Cour Grandmaison et al., 2019), reflected in a lower incidence of unlaced heroin-related overdoses starting in 2015.

Figure 1: Opioid overdose deaths in the U.S. 1999-2019



Notes: This figure depicts the three waves of the U.S. opioid crisis. Data obtained from the National Center for Health Statistics (NCHS). Fatalities from synthetic opioids are primarily due to fentanyl and exclude overdoses from methadone. The first wave consists of an increase in overdoses from prescribed opioids. This was followed by a rise in heroin-related overdose deaths (the second wave) due to stricter regulations on prescribed opioids. The third wave is marked by a shift to fentanyl, a cheaper opioid alternative, leading to a surge in fentanyl-related overdose deaths and a decline in heroin-related overdoses (CDC, 2021b). More information on each wave can be found in Section A.2.3 in the Appendix.

The decrease in the U.S. demand for heroin directly affected the demand for raw opium paste used to produce heroin. As a result, prices of opium paid by drug cartels to opium farmers in Mexico decreased significantly, falling 50% to 80% between 2017 and 2019 (Le Cour Grandmaison et al., 2019; Semple, 2019). For instance, surveyed farmers in Guerrero reported prices dropping from $950-$1,050 per kg in 2017 to $420 in 2018, corresponding to a 50% decrease.

The decline in the demand for heroin also led to a reduction in the area of poppy cultivated. UN estimates based on satellite imagery revealed that from 2017-2018, 28,000 hectares of poppy were cultivated as opposed to 30,600 ha in 2016-2017, corresponding to a 9% decrease (UNODC, 2020). The White House Office of National Drug Control Policy (ONDCP) also estimated a 24%

decline between 2019 and 2020, with an overall drop of 47% compared to 2017 (see Figure A2 in the Appendix, ONDCP (2021)).In summary, the introduction of fentanyl in the U.S. led to a decrease in the demand for heroin, resulting in lower opium prices and a reduction in the poppy cultivated in Mexico.

3 Conceptual Framework

In Section A.3 of the Appendix, I provide a simplified version of the model developed by López Cruz and Torrens (2023) on crime diversification and spatial diffusion of violence to help guide the interpretation of my results. In this section, I summarize the main models' predictions.

In the model, DTOs behave as profit-maximizing firms that operate across multiple locations and are mainly involved in the production and distribution of illegal drugs. It is assumed that DTOs have been engaged in this activity for a while and, therefore, do not pay a fixed cost for this activity. Additionally, DTOs have the opportunity to engage in an extractive activity, such as extortion. This activity directly targets the legal sector. In contrast to drug trafficking, DTOs must pay a fixed cost to engage in an extractive activity. The production and distribution of illegal drugs and the extractive activity are disputable among DTOs, who resort to the use of force to compete, thus, leading to a rise in violence in the locations where they operate.[13]

Consider an economy with only two goods: poppies, used in the production of heroin, and avocados, a legal crop targeted by DTOs through extortion and theft. Locations are heterogenous in their value for each activity, with some best suited for poppy cultivation (drug trafficking) and others for avocado growth (the extractive activity). Additionally, DTOs vary in their ability to exploit and protect each location from their rivals. Taking these factors into consideration, DTOs strategically allocate capital and deploy armed labor (hitmen) for each activity and location. In other words, the market structure is modeled as an oligopoly with multiple products, and markets, where DTOs allocate capital and armed labor across markets and products to maximize their expected profits. The model endogenously yields predictions on the spatial distribution of DTOs'

[13] In López Cruz and Torrens (2023)'s original model criminal organizations can also participate in a non-contestable activity for which DTOs do not need to exert territorial control and, therefore, it does not lead to violent competition (e.g. telephonic fraud). In this model, I focus on the case where the value of the non-disputable activity is considerably lower compared to the alternative options, and, therefore, DTOs decide not to participate in this activity. Instead, DTOs produce and distribute drugs and decide whether to also engage in an extractive activity.

criminal activities and violence.

As profit-maximizing firms, DTOs prioritize allocating resources to the activities that generate the highest revenues and to the locations that offer the greatest return on their investment. For instance, DTOs specializing in drug trafficking funnel a larger portion of their capital and armed labor to the regions most suitable for poppy cultivation. Moreover, as with multi-product firms, a decline in the expected value from one of the DTO's activities (i.e. heroin trafficking) can lead to increased effort in the alternative activity (i.e. the extortion of avocado farmers) (Bernard et al., 2010). Given the fixed costs of the extractive activity, DTOs will only diversify whenever their expected profit from doing so is higher than the profit from specializing in drug trafficking. Therefore, as the value of heroin decreases, compared to the value of the extractive activity, drug trafficking becomes a less attractive activity for DTOs, and the extractive activity becomes more appealing. For DTOs specialized in drug trafficking, this may entail entering the extortion business, while DTOs, already engaged in both activities, will intensify the effort put towards the extractive activity.

Violence. As the profitability of heroin decreases relative to avocados, cartels are increasingly motivated to invest in extractive activities within avocado-suitable municipalities. To capture a larger market share, they escalate their investment in armed labor, which in turn leads to heightened levels of violence. This violence may be in the form of increased homicides and/or violent thefts, as armed labor is frequently used to fight rival cartels, in thefts, and as a coercive tool to enforce extortion payments from civilians.[14] Therefore, as the value for heroin decreases, homicides in an avocado municipality will increase. Conversely, in poppy-suitable municipalities, cartels invest less in capital and require fewer armed personnel, resulting in a decrease in violence.

Cartel presence. The model discussed here focuses on DTO's decision to diversify into an extractive activity. Predictions rely on the free mobility of capital across locations. However, in practice, access to a strategic location is expensive for DTOs. It demands investments in human capital and resources and, potentially, requires them to fight a rival cartel to access a territory. In this section,

[14] Evidence from the palm oil sector in Indonesia by Kenny et al. (2022) shows how commodity boom violence can emerge from resource extraction through extortion and from violent competition among criminal groups.

I delve into the implications of relaxing this assumption on cartel mobility across locations.

Cartels will decide to enter a location if the expected returns net of their entry cost are larger than continuing business as usual in their already occupied locations. Therefore, a decrease in the value of drug trafficking will increase a cartel's incentives to enter an avocado municipality if its expected profits from diversifying outweigh the cost of expanding its operations. If this is the case, a fall in the value of heroin will result in the heightened presence of DTOs in avocado-suitable municipalities.

As for the presence of DTOs in municipalities suitable for illegal crops, whether or not a cartel exists will depend on the expected profitability of the place and the reduction of the market size. I hypothesize that the decrease in the demand for heroin will lower cartels' incentives to fight over a suitable poppy territory, but will not necessarily result in their exit. First, occupied territories can offer other amenities beyond access to poppy, such as access to strategic locations along trafficking routes and ports. Second, DTOs invest not only in capital and armed labor but also allocate funds for bribes to corrupt local officials. There is also evidence that some DTOs make expenditures in public goods and relief to gain the support of the local population (Bustamante, 2020; Calderon et al., 2021). This strategy decreases the costs associated with maintaining a presence in a municipality and lowers their risk of military detection, thereby reducing their incentives to leave an already occupied place. As a result, I hypothesize that a decrease in the value of heroin, will likely not lead to lower cartel presence in poppy-suitable municipalities.

Long run vs short run. Note that previous arguments predict cartel movement by comparing their entry cost to the expected profitability from entering/exiting a territory. In the long run, cartels have the potential to acquire additional capital, enabling them to expand and relocate their operations. In the short run, however, cartels operate with a fixed amount of capital. Consequently, limited capital can hinder their ability to move into a particular location, thus leading to no changes in cartel presence in the short run.

It is important to note that while capital remains fixed in the short run, drug cartels are still able to invest in armed labor. Consequently, even if cartels have limited mobility to other territories due to high entry costs and fixed capital, they can resort to violence as a means to extract profits from their existing territories. Therefore, in the short run, with fixed capital and limited cartel mobility, instances of violence perpetrated by drug cartels are more likely to stem from changes in their behavior along the intensive margin (by increasing their investment in armed labor) rather than from conflicts raising from cartels fighting for entry into a territory (extensive margin).

4 Data

To assess the validity of my hypotheses, I analyze the relationship between the demand for heroin and criminal violence in avocado- and poppy-suitable municipalities. The analysis focuses on major avocado producers in states with over 0.2% of their agricultural land dedicated to avocado production, resulting in a sample of eight states.[15] These states account for more than 94.7% of average avocado production between 2011 and 2019.[16] These states are also contiguous and share similar agro-climatic conditions. The sample includes Michoacán, the main producer of avocados, and Guerrero, the leading producer of poppy, accounting for over 60% of the total national opium production (Le Cour Grandmaison et al., 2019).

I analyze the period between 2011 and 2019 for two reasons. First, to cover the years before and after the start of the third wave of the opioid crisis in 2013. Second, to study the post-war against drugs period (2010-), which saw a significant increase in cartel competition due to the fragmentation of Mexico's major DTOs (Atuesta and Ponce, 2017; Calderón et al., 2015; Jones, 2013).[17] The resulting sample consists of 6,516 observations consisting of 724 municipalities observed over nine years. A detailed summary of the data sources used in this study can be found in Table A1 in the Appendix.

4.1 Data on violence

To estimate the effect on criminal violence, I use homicide data from the National Department of Health Information (Sistema Nacional de Información en Salud; SINAIS). This database provides individual-level information on deaths from 1998 to 2019, with details on the cause of death, location, weapon used (in the case of murder), and characteristics of the deceased such as sex, age,

[15]The states included in the sample are Michoacán, Morelos, México, Jalisco, Nayarit, Puebla, Colima, and Guerrero. Each of them accounts for at least 2% of the national production of avocados, except for Colima (0.33%).
[16]Source: Own estimates based on information from SAGARPA.
[17]See Appendix A.2.1 for more information on the war on drugs.

and occupation. Using municipal-level population data from the National Institute of Statistics and Geography (INEGI), I estimate homicide rates per 100,000 people.

The SINAIS database has two main advantages over other homicide data sources. First, it relies on death certificates, rather than police records, reducing the likelihood of under-reporting for cases not investigated.[18] Second, the SINAIS database includes information on occupation, sex, and type of weapon used, which I exploit to identify homicides of agricultural workers and potential murders linked to inter-cartel violence.

I estimate murders resulting from potential inter-cartel violence using data on homicides of males aged 15-40 killed with a firearm. In the absence of more reliable data on cartel-related homicides, previous studies have used homicide rates for young men to proxy for murders linked to criminal activity in Mexico (Magaloni et al., 2020), as men between the ages of 15 and 40 are the group most vulnerable to criminal violence (Calderón et al., 2015; Herrera and Martinez-Alvarez, 2022). Moreover, firearms ownership is illegal in Mexico, and their use implies their acquisition through unlawful means. In fact, over 70% of all guns recovered in crime scenes in Mexico can be traced to drug trafficking organizations (Mineo, 2022).

Lastly, information on other crimes was obtained from SSP police records, which cover all cases reported between 2011 and 2019 at the municipal level. Despite the availability of information on other crimes, homicides remain the most reliable proxy for violent crime in countries like Mexico, where incidents often go unreported. According to Mexico's National Survey of Victimization and Perceptions of Public Security (ENVIPE), 93.2% of all crimes in the country are not reported or not filed by the police (INEGI, 2019a).[19] Therefore, to mitigate issues arising from under-reporting, I rely on homicides for my main results, with estimates on other crimes available in Section 6.3.

4.2 Drug cartel presence

To evaluate changes in DTOs' territorial expansion and competition, I use municipal-level data from the Mapping Criminal Organizations (MCO) project.[20] This database uses a web-crawling

[18] Homicide data from police records are available from the Ministry of Public Security (SSP). SINAIS records are also contrasted to INEGI's homicide records before their release.

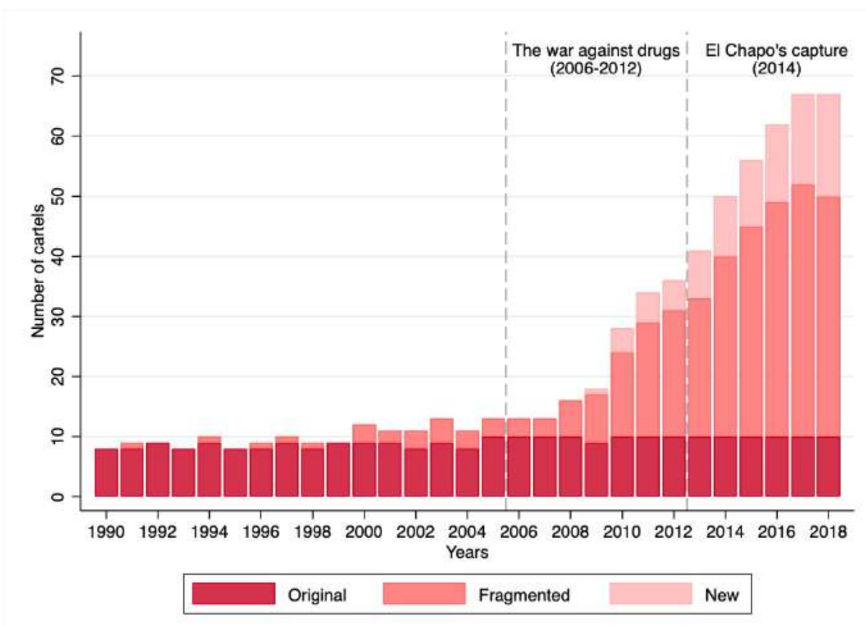
[19] According to the 2018 ENVIPE, 31.7% of the surveyed individuals felt reporting a crime to the police was a waste of time, and 17.4% did not trust the police (INEGI, 2019a).

[20] The MCO project is supported by the Center for U.S.-Mexico Studies at UCSD, the Mamdouha S. Bobst Center for Peace and Justice at Princeton University, and the Empirical Studies of Conflict Project (see Signoret et al. (2022) for details).

technique to identify news related to drug cartels on Google and Google News. It tracks the number of paragraphs mentioning a cartel alongside a municipality in a year. A cartel is considered present in a municipality if it is mentioned at least once. The MCO database covers 75 different DTOs in Mexico (including the top eight cartels identified by the DEA) and traces their presence at the municipal level from 1990 to 2020. While other data sources have attempted to measure cartel presence in Mexico (Coscia and Rios, 2012; Phillips, 2015), to the best of my knowledge, this is the only one with municipality-level data for my period of interest: 2011-2019.

The MCO database also includes information on a DTO's "mother group" (the DTO from which it splintered). [21] Using this information and the date of each cartel's first appearance in the data, I distinguish between cartels existing before the 2006 war against drugs (original), splintered cartels (fragmented), and new cartels with no previous DTO affiliation.[22] Figure 2 shows the evolution in the number of cartels operating at the national level between 1990 and 2018.

Figure 2: Fragmented and new cartels present by year



Source: Data from the MCO project. Fragmented cartels are defined as originating from other cartels. Original DTOs existed before 2006 and did not originate from another cartel. New cartels emerged post-2006 and have no prior affiliation to a cartel.

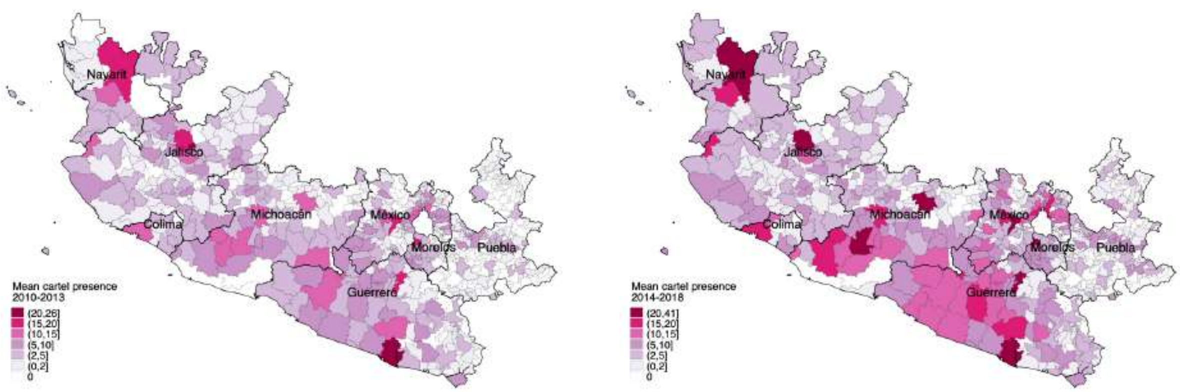
[21] This database does not indicate the history of fragmentation. For example, if Cartel A fragmented into B and C, and then cartel B fragmented again and formed cartel D, I would have cartel A as D's mother group, but no information on it being part of cartel B.

[22] Original cartels were defined as those that preceded the war against drugs (2006) and did not fragment from another cartel. Fragmented cartels are those with a cartel name different than their mother group. New cartels are defined as those that emerged after 2006 and have no prior affiliation to a cartel.

Within the past two decades, the number of cartels in Mexico has risen from around 12 to almost 70. This increase was mainly due to cartels splintering during the war on drugs and following the capture of Mexico's most powerful drug lord, El Chapo, in 2014 (Atuesta and Ponce, 2017; Calderón et al., 2015; Jones, 2013).[23] Additionally, new cartels with no previous links to DTOs arose during this period. Figure 3 shows the average number of cartels present in my sample for 2010-2013 and 2014-2018, highlighting the increase in DTOs present between these periods, particularly in Michoacán, Guerrero, and Jalisco.

Figure 3: Cartel presence before and after the introduction of Fentanyl in the U.S.

(a) Mean cartel presence (2010-2013) (b) Mean cartel presence (2014-2018)



Notes: This figure shows the difference in cartel presence for the sample before and after the introduction of Fentanyl in the U.S. in 2014. Panels (a) and (b) show the mean cartel presence by municipality from 2010-2013 and 2014-2018, respectively.

4.3 Crop suitability measure

Due to the nature of criminal activities, information on illegal crop production is limited in Mexico. The DEA has national estimates on poppy cultivation since 2011, and the United Nations Office on Drugs and Crime (UNODC) has satellite-based data on poppy cultivation for 2014-2018. However, neither source provides data at the municipality level, and the original data is not publicly accessible. Moreover, while FAO has municipal-level information on agro-climatically attainable yields on some crops, it does not cover my two crops of interest: avocados and poppy. To address this, I built a suitability index for each crop based on information on minimum and optimal agro-climatic

[23] For more information on the war against cartels see Section A.2.1 in the Appendix.

characteristics obtained from FAO's Ecological Crop Requirements (Ecocrop) database. For this, I use a well-established model for crop suitability used by agronomists (Møller et al., 2021): the Ecocrop suitability model, proposed by Hijmans et al. (2017). An advantage of this approach is its use of reliable information based on academic research from experts in the field.

The Ecocrop suitability model utilizes temperature, precipitation, and elevation data for a given area and compares them to the crop's climatic requirements throughout the growing season. These requirements are divided between the minimum conditions necessary for growth and the optimal conditions for achieving maximum yield. The model assigns an index between zero and one, where zero indicates areas that do not meet the minimum requirements for growth (unsuitable) and one indicates areas with optimal conditions (Ramirez-Villegas et al., 2013).

To estimate the avocado and poppy suitability indices, I use historical precipitation and temperature data obtained from AgMerra, along with land elevation data from INEGI. A detailed description of how each suitability index was built, including the variables used and the optimal temperature, precipitation, and altitude requirements can be found in Section A.4.1 of the Appendix. Furthermore, I assess the validity of the avocado and poppy suitability indices by regressing each index against production outcomes, such as hectares of avocado cultivated and area of poppy eradicated.[24] The results show a positive and statistically significant correlation between each index and their respective production outcomes for the entire country and within my sample (see Section A.4.1.4 in the Appendix).

Figures 4 (a) and 4 (b) show the mean annual avocado production of avocados and the geographical distribution of poppy-eradicated areas in my sample between 2011 and 2018. Note that, while Michoacán and Guerrero produce both avocados and poppy, Michoacán mostly produces avocados, and Guerrero mostly produces poppy. The proximity between the main producer of avocados and the leading poppy producer contributes to my hypothesis that this proximity played a role in the drug cartels' diversion into the avocado business after a decrease in the demand for heroin. Figures 4 (c) and 4 (d) show the distribution of the avocado-suitability and poppy-suitability indices, respectively.

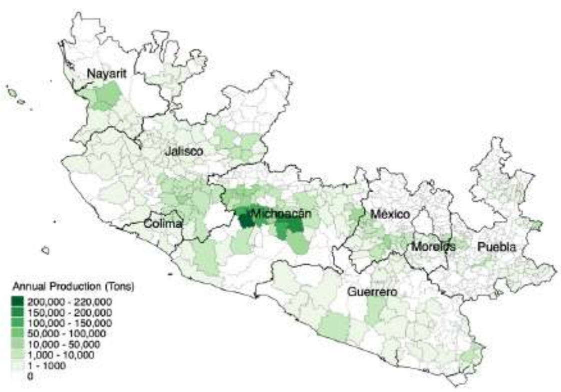
Because avocados and poppies share similar weather requirements (e.g., optimum temperatures

[24] Information on avocado production was obtained from the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA). Data on poppy eradication was obtained from the Ministry of National Defense (SEDENA) and was used as a proxy for production.

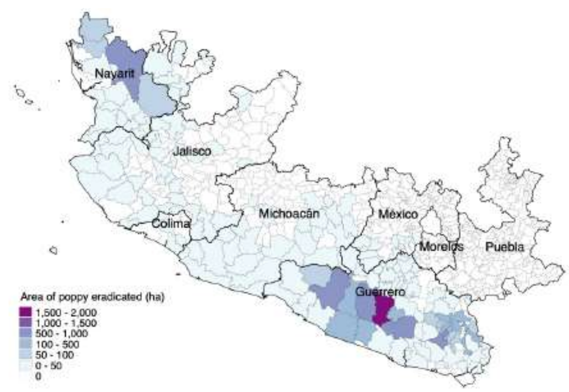
and precipitation), I observe a significant correlation between the suitability indices. Figure 5 shows how municipalities highly unsuitable for avocados are also unsuitable for poppy. Conversely, municipalities highly suitable for avocados have a poppy suitability index of at least 0.4. The correlation between these two indices is 0.82. Because it is not possible to identify exclusively avocado or poppy-suitable municipalities, my empirical strategy relies on municipalities' relative suitability for each crop rather than absolute classifications.

Figure 4: Spatial distribution of avocados and poppy

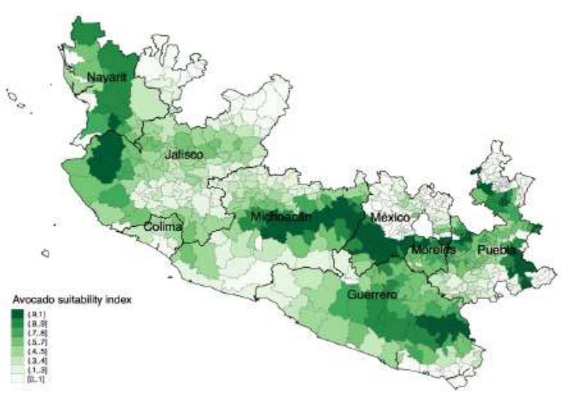
(a) Annual avocado production in sample (mean, 2011-2018)



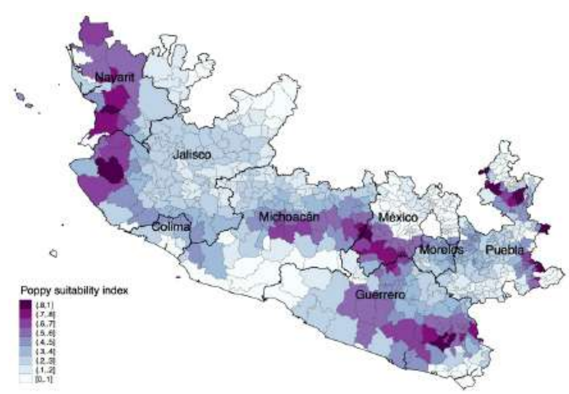
(b) Eradication of poppy in sample (mean, 2011-2018)



(c) Avocado suitability index

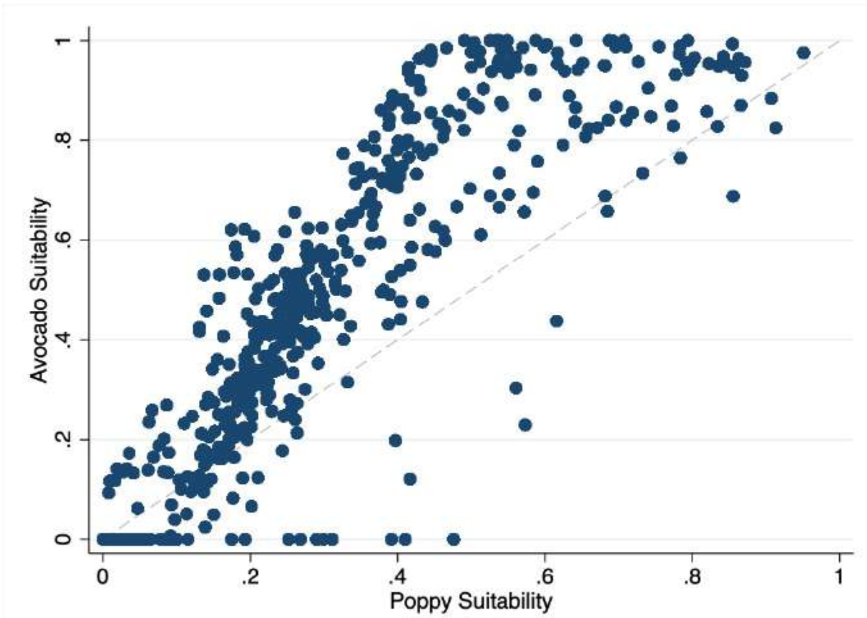


(d) Poppy suitability index



Notes: This figure shows the spatial distribution of the avocado and poppy suitability indices and compares them to production measures for each crop analyzed. Panels (a) and (c) show the mean annual avocado production in 2011-2018 and the avocado suitability index, respectively. Panels (b) and (d) show the mean yearly poppy eradication in 2011-2018 and the poppy suitability index, respectively.

Figure 5: Avocado and poppy suitability distribution



Notes: This figure shows the distribution of the avocado and poppy suitability indices. The dashed line indicates the 45°line.

4.4 Fentanyl overdoses

Data on Fentanyl overdoses in the U.S. was obtained from the National Center for Health Statistics (NCHS), covering national overdoses by type of drug from 1990 to 2018. The database includes information on overdoses linked solely to Fentanyl and overdoses involving heroin mixed with Fentanyl.

Due to the illegality of non-prescribed Fentanyl sales in the U.S. and the limited information on smuggled amounts from China, I use Fentanyl overdose deaths as a proxy for its market presence. I argue this is possible for two main reasons. First, Fentanyl is highly lethal; 2 milligrams are enough to provoke an overdose, and counterfeit pills can contain up to 5.1 milligrams (DEA, 2020b). Second, the presence of Fentanyl in drugs laced with this substance is unobservable for consumers. Dealers often mix Fentanyl with heroin to maintain the same potency while reducing their costs. Because the amount of Fentanyl required is minimal, even the most experienced drug users can't notice its presence by sight, taste, or smell. Moreover, even when consumers knowingly purchase counterfeit fentanyl pills, they cannot know precisely their Fentanyl content. This inability to detect fentanyl prevents consumers from adjusting their demand and increases their risk of overdose. Therefore, an increase in fentanyl-related overdoses would indicate a higher presence of this substance in the market.

To verify the validity of this proxy, I contrast the number of overdoses from Fentanyl with the number of reports in which Fentanyl was found in drugs obtained from DEA's undercover purchases. I find that Fentanyl overdose deaths show a similar trend across time as the DEA's Fentanyl reports (see Figure A3) and both measures exhibit a high and statistically significant correlation (0.98 significant at the 0.1% level). While this measure shows a similar trend as Fentanyl-related overdoses, I do not use this as a proxy. In contrast to overdose data, information from Fentanyl forensic reports can suffer from sample bias and measurement error due to undercover purchases not being representative of the market (see A.4.2 for more information).

4.5 Other variables

Data on population by municipality was obtained from INEGI National Census of 2010. The municipal mayor party affiliation information comes from the National Institute for Federalism and Municipal Development (INAFED). It includes information on all elected mayors between 1993 and 2019. I use this as a proxy for enforcement and use of force against drug cartels. Empirical evidence has shown that parties differ in their treatment of DTOs (Magaloni et al., 2020; Dell, 2015). Dell (2015) finds evidence that municipalities governed by the PAN party experienced higher levels of drug-related violence during the war against cartels (2006-2012) led by President Felipe Calderón. Table A2 in the appendix shows the descriptive statistics.

5 Empirical Strategy

5.1 Main specification

To assess whether a decrease in the demand for heroin in the U.S. led to violence in Mexico, I would ideally like to estimate how changes in the price of heroin as perceived by drug cartels led to an increase in violence in avocado-suitable municipalities. However, identification using this strategy is impossible because the prices perceived by DTOs are not observable to researchers and are likely endogenous. Moreover, heroin prices in the U.S., as reported by the DEA, might not be a good proxy for DTO's wholesale prices. First, dealers charge effective prices by modifying the quality of heroin rather than by adjusting its price. Secondly, prices obtained through undercover purchases may not be representative of prices paid by consumers (Horowitz, 2001), and sampling changes may be overestimating heroin prices (for more detailed information, see Section A.4.2). Furthermore, transportation costs, market competition, the intensity of enforcement in the U.S., as well as the dealers' ability to modify quality to deal with fluctuations in the heroin price can decrease the extent to which the prices charged to consumers react to changes in the prices charged by Mexican DTOs.

Therefore, I use the introduction of Fentanyl as an exogenous shock in the demand for heroin. As Fentanyl made its way into the U.S. market, heroin retail dealers started to mix heroin with Fentanyl to increase profitability by maintaining the same level of high for their users (DEA, 2021; Ordonez and Salzman, 2023). Identification is possible under the following two assumptions: i) the introduction of Fentanyl decreased the demand for heroin in the U.S., which shifted heroin revenues for cartels, and ii) the only effect of the introduction of Fentanyl on violence is through its impact on heroin revenues obtained by cartels. I argue below that these two conditions are met.

First, laboratory evidence suggests an increasing presence of Fentanyl in heroin (DEA, 2020a), with Fentanyl and heroin being the most common mixture among all Fentanyl exhibits in undercover purchases that could be verified in 2019 (around 27.5%).[25] Moreover, there is evidence of a drop in opium paste prices received by farmers in Mexico, along with a decrease in the number of hectares cultivated (ONDCP, 2021; Le Cour Grandmaison et al., 2019; Semple, 2019). This supports the first assumption.

Second, I argue that changes in the demand for heroin resulting from the introduction of Fentanyl are exogenous to violence in Mexico. For one, most of the Fentanyl consumed in the U.S. up to 2019, came from China, which accounted for 90% of the global supply (Dudley et al., 2019). From China, Fentanyl pills arrive in the U.S., either shipped directly through the mail or smuggled through the U.S-Mexico border. While Mexican DTOs are now active players in the smuggling of Fentanyl into the U.S., their participation is recent; up until 2017, there were no seizures of Fentanyl-laced pills at the border (Dudley et al., 2019). Moreover, heroin seizures at the border show that lacing heroin with Fentanyl is not a strategy followed by Mexican DTOs, rather heroin and Fentanyl are smuggled separately and mixing is done at the retail level in the U.S. (DEA,

[25] Source: Own estimates based on information from the 2020 DEA National Drug Threat Assessment (DEA, 2021).

2020a). In 2019, only 16% of all wholesale heroin seizures had Fentanyl, while Fentanyl-laced heroin constituted 32% of retail heroin seizures (DEA, 2021).

Identification is possible if Fentanyl overdoses are a good proxy for the availability of Fentanyl in the U.S. market. I argue this is true since the presence of Fentanyl in heroin, as in other drugs, is unobservable to even the most experienced drug users. Thus, consumers cannot adjust their demand accordingly. This makes Fentanyl overdose exogenous to violence in Mexico. Finally, an advantage of using this identification strategy is that data on overdoses do not suffer from the same measurement problems as the DEA's Fentanyl reports (see Section 4.4).

The main specification is as follows:

$$Y_{it} = \alpha_i + \tau_t + \gamma(S_i^a \times F_{t-1}) + \delta(S_i^p \times F_{t-1}) + X_{it}'\beta + v_{it} \tag{1}$$

where Y_{it} is a measure of violence in municipality i in year t, S_i^a and S_i^p are agro-climatic suitability measures for avocado and poppy, respectively. F_{t-1} is the number of overdoses from Fentanyl in the previous year $t-1$. I use a lag to account for a delay between a decrease in the demand for heroin by domestic dealers in the U.S. and by cartels in Mexico. Meanwhile, X_{it} is a vector of controls that include municipal mayor party affiliation,[26] an indicator equal to one if the municipal mayor party coincides with the president's party,[27] and baseline characteristics interacted with time trends. These baseline characteristics include the number of hectares in municipality i in which poppy was eradicated in 2010, which I use as a proxy for drug cultivation, and the municipality marginalization rate of 2010. The marginalization rate is an index created by Mexico's National Council for the Evaluation of Social Development Policy (CONEVAL) to account for different levels of social deprivation, including access to health care, basic services, dwelling quality, and level of education. Higher positive levels are indicative of severe social deprivation (Aguila et al., 2014). Finally, to account for shocks in time and time-invariant characteristics of each municipality, I include municipality (α_i) and time (τ_t) fixed effects.

[26]Empirical evidence suggests that some parties in Mexico are more prone than others to fight cartels (Magaloni et al., 2020; Dell, 2015).

[27]I use this as a measure for enforcement. Matching parties means that the municipal mayor is more likely to be supported by the president. This could mean a higher military presence than in other municipalities and could result in lower murder rates.

Using the main specification, I test the effect of the introduction of Fentanyl (and the subsequent decrease in the demand for heroin) on violence in avocado and poppy municipalities. As a measure of violence, I use the log transformation on the number of homicides per 100,000 people. Additionally, I test for the effect on homicides of agricultural workers and potentially drug cartel-related deaths. Since homicide data does not necessarily involve a police investigation, there is no information on who perpetrated the murder. However, I use the homicides of men ages 15-40 killed by a firearm who did not work in the agricultural sector as a measure of potential inter-cartel-related homicides.[28]

The coefficients of interest in the specification are γ and δ, where γ measures the impact of Fentanyl on suitable avocado municipalities, and δ measures the effect on suitable poppy municipalities. For all homicides, I expect to see an increase in suitable avocado municipalities because cartels have incentives to fight to get control of these areas and/or need to employ violence to enforce payments ($\gamma > 0$). Moreover, because cartels have fewer incentives to fight over poppy-suitable municipalities, I expect to see $\delta < 0$.

Evidence on whether cartels use violence to enforce extortion payments or to fight other cartels will be given by results on the effect of homicides against agricultural workers and against individuals potentially linked to cartels. If cartels are using violence to fight against each other, I expect to see a positive correlation between Fentanyl overdoses and potentially cartel-related homicide rates. If, instead, violence is being used to enforce extortion, I would expect to see an increase in murders of agricultural workers and other types of civilians but no effect on cartel-related homicides.

5.1.1 Cartel presence

To shed light on whether changes in homicides are associated with cartels moving into or out of a territory, I estimate Equation 1 on three different measures for cartel presence. The first is the total number of cartels present in a municipality in a given year. For this, I use the number of mentions for each cartel in a given municipality and year; I consider a cartel to be present in a location when the number of mentions is non-zero. I estimate results for the overall number of cartels present in a municipality. I also distinguish the presence of nine of the most dominant DTOs in Mexico,[29]

[28] I use homicides of men by firearm to proxy inter-cartel-related homicides as DTOs have disproportionately more men than women in their ranks (Magaloni et al., 2020), and most guns recovered in crime scenes can be linked to DTOs (Mineo, 2022). For additional details, see Section 4.1.

[29] The nine most dominant cartels are Sinaloa, Los Zetas, Gulf, La Familia Michoacana, the Knights Templar, Cartel Jalisco Nueva Generación (CJNG), the Beltrán Leyva Organization, Tijuana and Juárez (Beittel, 2020).

according to the DEA. These are the main cartels specialized in the trafficking of heroin.[30]

The second measure is the overall number of mentions of cartels in a municipality. A particular concern with these measures is that the number of mentions in a municipality is likely correlated with media coverage. For instance, more prominent cities will have more mentions than small rural municipalities. I control for this by including municipality fixed effects in my estimates.

Finally, I estimate a Herfindahl-Hirschman index using the number of times a cartel was mentioned in a municipality. I use this index as a measure of cartel concentration. This index ranges between zero and one, where one would indicate a full concentration of the market (monopoly), and zero would correspond to perfect competition.

6 Results

6.1 Results on violence

In this section, I examine the relationship between a decrease in the demand for heroin in the U.S. and violence in Mexico. The main identification strategy tests for the impact of changes in Fentanyl overdose deaths in the U.S. on the homicide rate of municipalities that are suitable for producing avocados and municipalities that are suitable for poppy.

Table 1 shows the effect on homicide rates. All specifications include municipality and time fixed effects, all controls (the municipal mayor party and an indicator variable equal to one if the mayor's party coincides with the president's party), and baseline trends for municipality marginalization and poppy production. Column (1) shows the effect of Fentanyl overdoses on the overall homicide rate. Results show a heterogeneous impact on homicides for avocado- and poppy-suitable municipalities. In particular, I observe that the introduction of Fentanyl in the U.S. led to increases in the homicide rates of avocado-suitable municipalities, while having the contrary effect on poppy-suitable municipalities.

Columns (2) – (4) show the effect on murders of agricultural workers, homicides that are potentially related to cartel violence, and homicides on the rest of the population (non-agricultural

[30]The main cartels trafficking heroin according to the DEA are Sinaloa Cartel, Cartel Jalisco Nueva Generación (CJNG), Juarez, Gulf, Los Zetas, the Beltrán-Leyva Organization, La Familia Michoacana, Los Rojos and Guerreros Unidos (DEA, 2021).

Table 1: Results on the effect of Fentanyl on violence in avocado and poppy municipalities

	Log(Murders)			
	All	Agricultural workers	Potentially cartel related	Rest of the population
	(1)	(2)	(3)	(4)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.208**	0.243***	0.156	0.174*
	(0.103)	(0.093)	(0.104)	(0.090)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.340**	-0.368***	-0.295*	-0.245*
	(0.165)	(0.139)	(0.164)	(0.142)
Observations	6516	6516	6516	6516
Adj. R-squared	0.395	0.332	0.359	0.368
Mean dep. var.	2.441	1.065	1.198	1.682
Year FE	X	X	X	X
Municipality FE	X	X	X	X

Notes: All outcome variables are the log of the number of murders per 100,000 inhabitants. All regressions control for the municipal mayor party, whether the mayor party was the same as the President's party, and baseline time trends on municipal marginalization and poppy eradication. Potentially cartel-related murders are homicides of men ages 15-40 killed by a firearm that did not work in the agricultural sector. The rest of the population are homicides of individuals that are not potentially related to cartels and do not work in the agricultural sector. Standard errors clustered at the municipal level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

workers and non-cartel-related).[31] The results in Column (2) show an increase in homicides of agricultural workers for avocado-suitable municipalities, suggesting that cartels may be using force to extract revenue from farmers, possibly to enforce extortion payments, or through violent robberies. In Section 6.3, I expand on this by examining changes in violent theft rates and extortion.

For potentially inter-cartel-related murders (Column 3), I observe no effect in avocado-suitable municipalities and a decrease in poppy-suitable municipalities. This suggests that cartels are less likely to fight each other to control poppy-suitable municipalities as the demand for heroin decreases. Finally, Column (4) shows the results on homicides of the rest of the population, that is, those that are not potentially related to cartels or agricultural workers. The results show a similar pattern as that for murders of agricultural workers but at a lower magnitude, suggesting that cartels target both agricultural workers and the general population in avocado-suitable municipalities. Finally, I find that the introduction of Fentanyl led to fewer homicides of the rest of the population in poppy-growing municipalities.

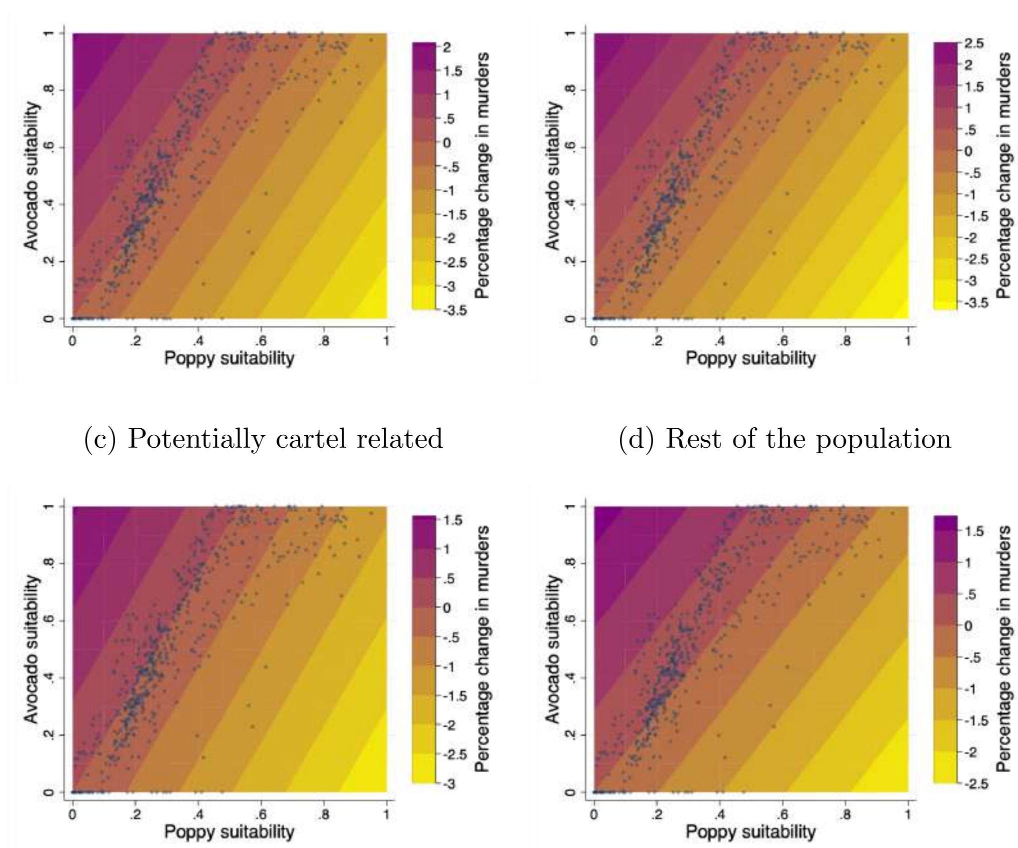
[31] Potentially related murders are murders of men between ages 15-40 killed by a firearm, who are not agricultural workers. More details can be found in Section 4.1.

Since the interpretation of coefficients for interactions between continuous variables is not straightforward, I estimated the marginal effects in terms of Fentanyl overdose deaths.[32] To help visualize the results, I present the marginal effects using heat maps. Figure 6 graphs the marginal effect of a 10% increase in Fentanyl overdose deaths on homicides for different degrees of poppy and avocado suitability. For example, Figure 6 (a) shows that a 10% increase in overdose deaths from Fentanyl results in a 2% rise in the homicide rates for municipalities with an avocado suitability index of 0.8 and a poppy suitability index of 0.3.

Figure 6: Marginal effect of a 10% increase in Fentanyl overdose deaths on murders in avocado and poppy suitable municipalities.

(a) All murders　　(b) Agricultural workers

(c) Potentially cartel related　　(d) Rest of the population



Notes: Figure constructed from the coefficient estimates for Table 1. Panels (a)-(d) show the marginal effect of a 10% increase in Fentanyl overdoses on murder rates for all combinations of poppy and avocado suitability levels. The scatter plot shows the support for the estimations. Potentially cartel-related murders correspond to the homicide rate of men ages 15-40 killed by a firearm who did not work in the agricultural sector. The rest of the population includes all homicides except for potentially cartel-related and agricultural workers.

[32]The corresponding marginal effect equation is as follows: $\frac{\partial log Y_{it}}{\partial log F_{t-1}} = \hat{\gamma} S_i^a + \hat{\delta} S_i^p$. According to this equation, the interpretation of results depends on the relative suitability for poppy and avocado production.

For all outcomes, the observed patterns strongly suggest that municipalities that are more avocado-suitable and less poppy-suitable have experienced an increase in the number of murders as a result of an increase in the presence of Fentanyl in the U.S. market. Meanwhile, municipalities that are more suitable for poppies than for avocados have experienced a decrease in homicide rates. These diagrams also show that highly avocado-suitable municipalities can experience up to a 2% increase in the homicide rate. In contrast, highly poppy-suitable municipalities can observe up to a 3.5% decrease in homicides in response to a 10% increase in Fentanyl overdose deaths. While the previous estimates may appear relatively small, we need to consider that between 2013 and 2019, Fentanyl overdose deaths increased by an average of 55% annually. Consequently, the observed effects of a 10% increase in Fentanyl overdose deaths yield conservative estimates of the actual impact.

6.2 Cartel presence

In this section, I analyze whether the observed changes in the homicide rates in poppy- and avocado-suitable municipalities are linked to changes in cartel presence. Table 2 shows the effect of Fentanyl on the different cartel presence measures. All specifications include municipality and time fixed effects and covariates. Columns (1)-(3) show the results for changes in the number of cartels present in a municipality. All estimates are expressed in logarithmic form. I prefer this specification because of its simplicity and ease of interpretation; however, my estimates are robust to other specifications. Column (1) shows the effect of the number of cartels present in a municipality. Column (2) shows results for the presence of the major DTOs in Mexico, and Column (3) for cartels that work on the distribution of heroin. Finally, Columns (4) and (5) show the results on the total number of mentions of cartels and the HH index.

Overall, the results reveal small and no statistically significant effects on cartel presence and market concentration in municipalities suited for avocados. This suggests that, despite substantial revenue growth in the avocado industry over the past two decades, the potential profits that cartels can extract are not significant enough for them to move into these municipalities.

It is plausible that they are unable to extract sufficient revenue or that the entry costs may be too high (e.g., fighting other cartels is expensive). This observation is consistent with short-run predictions regarding cartel mobility. In the short run, criminal organizations have limited capability to increase capital, such as firearms and artillery needed to confront other criminal

Table 2: Results on the effect of Fentanyl on cartel presence in avocado and poppy suitable municipalities

	Log(Cartels)				
	All cartels (1)	Main cartels (2)	Heroin cartels (3)	Log(Mentions) (4)	HH index (5)
Avocado Suitable × Log(Fentanyl_{t-1})	0.0733	0.0373	0.0223	0.142	-0.0136
	(0.048)	(0.039)	(0.023)	(0.099)	(0.036)
Poppy Suitable × Log(Fentanyl_{t-1})	-0.0911	-0.0611	-0.0269	-0.114	0.0543
	(0.073)	(0.060)	(0.035)	(0.151)	(0.052)
Observations	6516	6516	6516	6516	3390
Adj. R-squared	0.764	0.721	0.543	0.790	0.465
Mean dep. var.	0.781	0.626	0.336	1.336	0.556
Year FE	X	X	X	X	X
Municipality FE	X	X	X	X	X

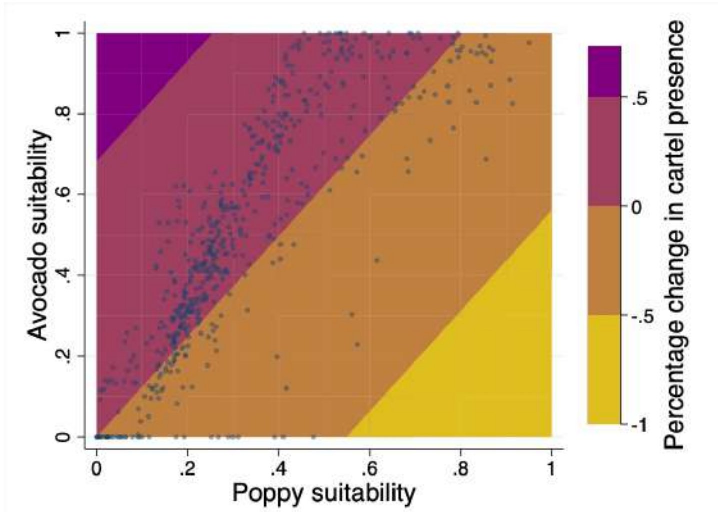
Notes: This table shows the effect of Fentanyl on cartel presence. Fentanyl overdoses are expressed in logarithmic form. The number of cartels and the mentions are also expressed in logarithmic form. The variable mentions correspond to the number of times a cartel was mentioned in the same paragraph as the municipality. The HH index corresponds to a Herfindahl-Hirschman Index calculated using the number of mentions of each cartel in a municipality. All regressions control for the municipal mayor party, a binary variable indicating whether the mayor party is the same as the President's party, and baseline time trends on municipal marginalization and poppy eradication. The number of main cartels corresponds to the nine major DTOs recognized by the DEA. Heroin cartels are DTOs categorized by the DEA as heroin trafficking organizations. Standard errors clustered at the municipal level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

organizations, thereby impeding their relocation to other municipalities. Since results do not show changes in drug cartel presence, the increased violence observed in avocado-suitable municipalities can be attributed to changes in the behavior of already present cartels, who resort to heightened violence against civilians as a means to extract rents.

When examining municipalities suitable for poppy cultivation, results also show no statistically significant changes in cartel presence. However, these results still show a negative correlation between Fentanyl and the number of cartels in poppy-suitable municipalities. Although the result does not reach statistical significance, it suggests that cartels may have reduced incentives to maintain a presence in these areas.

Figure 7 shows the marginal effects for the total number of cartels, corresponding to Column (1) results. While estimates are not statistically different from zero, they follow the same pattern observed for homicides (see Figure 6). This provides further evidence of worsened outcomes for avocado-suitable municipalities and improvements for poppy-suitable municipalities.

Figure 7: Marginal effect of a 10% increase in Fentanyl overdose deaths on the number of cartels in avocado and poppy suitable municipalities



Notes: Figure constructed from coefficient estimates in Table 2. This figure shows the marginal effect of a 10% increase in Fentanyl overdoses on the number of cartels present in a municipality for all combinations of poppy and avocado suitability. The scatter plot shows the support for the estimations.

6.2.1 Fragmented and new cartels

Over the past decade, there has been a notable transformation in cartel behavior due to the emergence of new cartels, some of which arise from existing ones (fragmented), while others have no prior affiliation with any existing drug trafficking organization (new). Even though I observe no changes in the overall cartel presence, I look into whether it is more likely for fragmented or new cartels to be present in avocado or poppy municipalities due to declining heroin revenues.

I use a fixed effects model and estimate Equation 1 using as outcomes the presence of different types of cartels. To test changes in the presence of cartels after the introduction of Fentanyl, I consider cartels to be fragmented or new only if they appeared for the first time in the data after 2013. I consider all cartels that existed before 2013 to be *preceding cartels*, regardless of how they originated.

Columns (1)-(3) in Table 3 show the estimates of the number of cartels present in a municipality. Columns (4)-(6) have as a dependent variable a binary variable equal to one if there is at least one cartel present in a municipality, and zero otherwise. Overall, the results show no changes in cartel presence for any cartel type, except for an increase in the likelihood of the presence of fragmented cartels in avocado-suitable municipalities. A possible explanation is that preceding cartels are established criminal organizations with defined markets, and may not need to expand into avocado-suitable areas. However, newly fragmented and new cartels may need to find new markets. The difference between fragmented and new cartels is that the former have the know-how and the organizational capabilities to enter these municipalities. Not only do they potentially have lower entry costs, but they also have an advantage over new cartels in terms of manpower and infrastructure in fighting over territory. This could explain why any new cartel is less likely to enter an avocado- or a poppy-suitable municipality.

Table 3: Results on the presence of new and fragmented cartels

	Number of cartels present			Cartel presence (1/0)		
	Preceding cartels (1)	Fragmented (2)	New (3)	Preceding cartels (4)	Fragmented (5)	New (6)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.190	0.076	-0.051	0.044	0.065*	-0.021
	(0.153)	(0.103)	(0.036)	(0.033)	(0.034)	(0.021)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.251	-0.013	-0.001	-0.055	-0.053	-0.004
	(0.237)	(0.165)	(0.053)	(0.048)	(0.051)	(0.032)
Observations	6516	6516	6516	6516	6516	6516
Adj. R-squared	0.836	0.486	0.328	0.549	0.418	0.302
Mean dep. var.	2.227	0.233	0.0625	0.515	0.127	0.0474
Year FE	X	X	X	X	X	X
Municipality FE	X	X	X	X	X	X

Notes: This table provides estimates of the presence of fragmented cartels and new cartels. Columns (1) - (3) provide estimates of the number of cartels present in a municipality. Columns (4) - (6) are estimates on a binary variable equal to one if one or more cartels were present in a municipality. Preceding cartels are those that first appeared before 2013. Fragmented cartels indicate those that separated from another cartel after 2013. New cartels are criminal organizations that had no previous affiliation to existing cartels. All specifications control for the municipal mayor party and baseline time trends on municipal marginalization and poppy eradication. Specifications also include municipality and time-fixed effects. Standard errors clustered at the municipality level in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6.3 Other criminal behaviour

So far, my results show that Fentanyl led to changes in homicide rates for avocado- and poppy-suitable municipalities. However, changes in cartel presence have not accompanied these trends. This suggests that, while cartels are not likely to move in or out of these territories, they have changed their use of force against civilians.

In this section, I analyze the effect of Fentanyl on other types of crime. Using data from police reports, I look into changes in violent thefts, truckload thefts, and extortion reports. Violent thefts are those classified as common theft with violence and include reports of thefts of households, businesses, and pedestrians, among others. Truckload thefts are reports of violent thefts of cargo trucks on a highway. Finally, extortion cases are reported by citizens to the police.

Note that, because of a change in the methodology through which crimes are classified, I cannot estimate the effect on violent thefts and truckload thefts after 2017. Therefore, my estimates for these two variables are only for the years for which there is a consistent data series (2011-2017). Extortion cases were not affected by this change in methodology, and therefore, I estimate the impact on extortion for the entire period of interest: 2011-2019. Finally, all measures are expressed as the log number of cases per 100,000 people.

Table 4 shows the coefficient estimates for these three types of crimes. In general, the results show that the introduction of Fentanyl increased violent thefts and truckload thefts in avocado-suitable municipalities. The latter coincides with reports on thefts of trucks transporting avocados in Michoacán (García Tinoco, 2019; Agren, 2019). Moreover, I observe a negative correlation between Fentanyl and thefts in poppy-suitable municipalities, providing further evidence of improving conditions in these areas. Note that these are reports of thefts in a country where most people do not report a crime because they distrust the police or consider it a waste of time (INEGI, 2019a). Therefore, increased thefts in avocado-suitable municipalities are likely to be a conservative estimate of the effect of Fentanyl. Figure 8 shows the marginal effects of a 10% increase in Fentanyl overdose deaths in rates of thefts with violence and truckload thefts.

Column (3) shows estimates of the extortion reports. In general, they show that Fentanyl decreased extortion cases in avocado-suitable municipalities compared to municipalities that cannot grow avocados. This contrasts with the other results that show an increase in homicides and thefts in these municipalities. Meanwhile, there have been numerous news reports that farmers and packinghouses are targets of extortion, as well as the threats to USDA officials, discussed above (Linthicum, 2019; de Cordobá, 2014; Padgett, 2013; Rainsford, 2019). A likely explanation for this coefficient is that people stopped reporting extortion cases because they fear DTOs, believe police cannot do anything, or have normalized this behavior.

Table 4: Results on the effect of Fentanyl on other crimes in avocado and poppy suitable municipalities

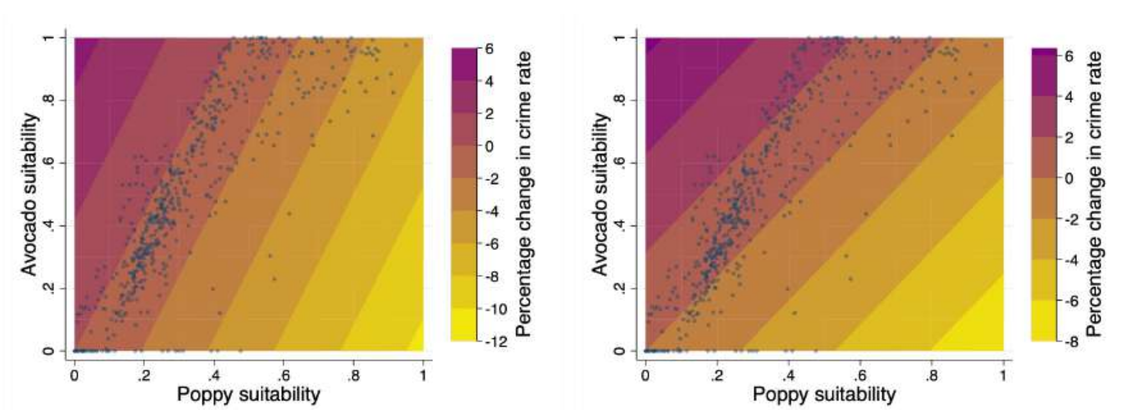
	Violent theft (1)	Truckload theft (2)	Extortion (3)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.477***	0.636***	-0.330***
	(0.181)	(0.131)	(0.091)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-1.050***	-0.757***	0.112
	(0.296)	(0.201)	(0.126)
Observations	4726	4726	6174
Adj. R-squared	0.638	0.430	0.418
Mean dep. var.	2.902	0.284	0.758
Year FE	X	X	X
Municipality FE	X	X	X

Notes: This table shows the effect of Fentanyl on other crimes. Violent thefts include thefts of households, businesses, and pedestrians, among others in which criminals used violence. Truckload thefts are reports of cargo trucks attacked on a highway. All outcome variables are the log of the number of cases per 100,000 inhabitants. All regressions control for the municipal mayor party, a binary variable indicating whether the party coincides with the President party, and baseline time trends on municipal marginalization and poppy eradication. Standard errors clustered at the municipality level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 8: Marginal effect of a 10% increase in Fentanyl overdose deaths on crime rates in avocado and poppy suitable municipalities

(a) Theft with violence

(b) Truckload theft



Notes: Figure constructed from the coefficient estimates for Table 4. Panels (a)-(b) show the marginal effect of a 10% increase in Fentanyl overdoses on theft rates for all combinations of poppy and avocado suitability levels. The scatter plot shows the support for the estimations.

6.3.1 Threats to identification

This section addresses some potential concerns regarding the main identification strategy. First, I address a potential concern on the correlation between the avocado and poppy suitability measures. Second, I look into potential measurement errors in the outcomes. Finally, I address concerns over omitted variable bias.

One genuine concern for this study is the observed correlation between the poppy and avocado suitability measures. As shown in Figure 5, there is a positive and significant correlation of 0.82 between these two suitability measures.[33] A high correlation between dependent variables can lead to a multicollinearity problem, which results in larger standard errors of the estimated coefficients but does not bias the coefficients. In other words, it yields consistent but less precise estimates.

The presence of multicollinearity becomes particularly pertinent when results lack statistical significance, as it is not possible to distinguish whether this insignificance is a consequence of inflated standard errors or an intrinsic property of the variable. It is important to note that, despite the potential for standard error inflation, the majority of estimates for homicides and other crimes are statistically significant at the 0.05 level. For the results on the presence of drug cartels, inflated standard errors may be contributing to non-statistically significant findings. However, even if they were statistically significant, the results' magnitude is small and economically insignificant.

A second potential concern with the main specification is that it considers the effects of avocado suitability and poppy suitability, separately. To deal with this, I estimated a model in which I interact the number of overdoses of fentanyl with the avocado and poppy suitability measures. The coefficients from these regressions can be found in Section A.5 of the Appendix. I find that my main results are robust to this specification. Not only coefficient estimates are similar in magnitude and maintain the same predicted sign for avocado and poppy suitable municipalities, but the estimated marginal effect also shows a similar behavior.

One caveat when incorporating the interaction term into the main specification is that it amplifies the correlation between the explanatory variables, consequently resulting in larger standard errors. Despite the less precision of the estimates, the results for homicides of agricultural workers,

[33] To further the analysis, I estimated the variance-covariance matrix and the variance inflation factor (VIF) for the main specification in Table 1. I find that the correlation between the coefficients γ and δ is -0.86 with a mean VIF of 4.51.

violent theft, and truckload theft remain statistically significant at the 0.10 level. Because adding the interaction term does not provide additional information to the analysis and leads to higher imprecision of the estimates, I prefer the results from the main specification as they can be considered to be more precise and informative of the true effect.

Another potential concern is the measurement error of the outcome variables. As mentioned in Section 4.1, INEGI estimates that over 90% of crimes in Mexico are not reported by individuals or filed by the police. Because of this, I use the estimates of homicides for my main results. While homicides in Mexico can also be underreported, the measurement error is likely to be classical since homicides are unlikely to be reported differently among avocado and poppy-suitable municipalities. Therefore, this would result in less precise estimates but will not bias the estimates.

In the case of violent theft and truckload theft, we could have biased estimates if thefts are less likely to be reported in avocado-suitable or poppy-suitable municipalities. This could be the case if civilians are scared of potential cartel retaliation for reporting the theft or if they consider it to be a waste of time. If this is the case, estimates for avocado-suitable municipalities would be downward biased and, therefore, they should be considered a lower bound of the real effect. In the case of poppy-suitable municipalities, this would mean the estimated results are overestimating the real effect. However, I do not expect this to change the interpretation of the results, as estimates for homicides signal a decrease in violence in these municipalities.

One final concern is potential omitted variable bias. In the main specification, I control for the municipal mayor party and whether this coincides with the President at the time party to account for municipality-specific government strategies. I also include municipality-fixed effects to control for time-invariant characteristics of a municipality such as distance to a military base, port, main road, or a drug route, as well as the availability of police stations. Unfortunately, information on military deployment is not publicly available as it's protected for national security reasons.

Finally, estimates could be confounded if areas suitable for avocado growing are also ideal for other profitable crops that cartels can target, potentially resulting in upward biased estimates for avocado-suitable areas. To address this, I use municipal-level data on FAO's suitability measures aggregated by Dube et al. (2016) for six crops in which Mexico ranks as one of the world's top producers (SIAP, 2016).[34] In Table A9, I control for this by including each suitability measure

[34]The six crops and their corresponding correlation with the avocado suitability are: sorghum (0.08), alfalfa (0.33),

interacted with year dummies. I find the results to be robust to this specification.

7 Conclusion

Crime in Mexico has increased dramatically over the past two decades. Even though drug cartels have been prominent in Mexico since the 1980s, contemporary organized crime remains relatively understudied. Journalists and scholars have pointed to a change in drug cartels' behavior, where DTOs have gone from specializing in the production and distribution of illegal drugs to diversifying into other sectors (Herrera and Martinez-Alvarez, 2022; Jones and Sullivan, 2019; Avilés, 2015; Linthicum, 2019; de Cordobá, 2014; Padgett, 2013; Rainsford, 2019; Agren, 2019). However, evidence on the factors driving this change in behavior has been limited, and it mostly points to an increase in competition as the key factor driving these groups to diversify (Herrera and Martinez-Alvarez, 2022; Jones and Sullivan, 2019).

As cartel violence has soared and DTOs increasingly target civilians, it has become more urgent for policymakers to understand more about the factors that shape cartels' behavior. To fill this gap, I examine the case of the avocado sector, a prominent and lucrative sector that has become the target of criminal organizations in the past decade. In this paper, I provide new evidence on a different path that seems to have shaped cartels' behavior. I argue that the 2014 introduction of Fentanyl in the U.S. market led to a decrease in the demand for heroin from Mexican drug cartels, resulting in declining cartel revenues. To deal with this loss, cartels turned to other activities in an effort to diversify their portfolios. These included extortion and theft in licit industries, such as the avocado sector.

Using municipal-level data on annual homicides and cartel presence between 2011 and 2019, I examine the effect of declining heroin revenues on violence in avocado- and poppy-growing municipalities in Mexico. I find that the introduction of Fentanyl into the U.S. market increased homicide rates among agricultural workers and other civilians in avocado-growing municipalities. However, it did not affect homicide rates for potentially cartel-related individuals. At the same time, I tested whether the increase in the demand for heroin led to a higher cartel presence in these municipalities. I find no evidence that cartels moved into these areas. Based on these results, I conclude that

maize (0.26), tomato (0.17), wheat (0.34), and potato (0.36). Mexico ranks in the top 10 globally for the first four crops and in the top 40 for wheat and potato (SIAP, 2016).

Fentanyl increased violent crimes in avocado-growing communities, mainly by targeting civilians, rather than through conflict between cartels. This is supported by evidence that Fentanyl has led to higher rates of other types of violent crime, such as theft with violence and truckload theft. Finally, since I find no evidence of cartels entering avocado-suitable municipalities, I conclude that the overall profits from targeting civil society in these areas do not overcome the potential entry costs (e.g., fighting against existing criminal organizations over control of the territory).

I also test the impact of the introduction of Fentanyl on homicides in poppy-growing municipalities. I find that Fentanyl led to a decrease in the number of homicides in these areas, and, in particular, of agricultural workers and civilians. The results also show no changes in cartel presence in these municipalities, indicating that cartels may not have incentives to leave these areas. One explanation is that municipalities suitable for poppy production may also be advantageous to cartels for other reasons. For one, poppies are usually grown in remote mountainous areas, which are also excellent hiding spots for criminal organizations. Moreover, these territories provide access to roads and other potential places to exploit. Thus, even in the face of declining revenues from heroin, it may be more costly for a cartel to leave a territory in terms of its opportunity cost.

This paper shows contemporary evidence of the effects of changes in the demand for heroin on violence in Mexico and explores a new cause driving these changes. Moreover, it sheds light on how decreases in drug demand can have heterogeneous effects on legal and illegal sectors. This has important implications for policy design, as policymakers are challenged with developing policies that need to consider possible effects in areas dominated by an illegal sector and the potential spillovers to other industries.

References

Agren, D. (2019). Up to four avocado trucks stolen in Mexican state every day. *The Guardian.*

Aguila, E., Kapteyn, A., Gonzalez, N. J. M., Robles, R., Vargas, O., Weidmer, B. A., et al. (2014). Geographic targeting in urban areas: A social-welfare program for older people in mexico.

Angrist, J. D. and Kugler, A. D. (2008). Rural windfall or a new resource curse? Coca, income, and civil conflict in Colombia. *The Review of Economics and Statistics*, 90(2):191–215.

Anguiano, C., Alcántar, J., Toledo, B., Tapia, L., and Vidales-Fernández, J. (2007). Caracterización edafoclimática del área productora de aguacate de Michoacán, México. In *Proc. VI World Avocado Congress (Viña Del Mar, Chile, 2007).*

Anthony, R. W., Cseko Jr, A., Gaither, C. C., and Schulman, E. (2008). The price and purity of illicit drugs.

Arkes, J., Pacula, R. L., Paddock, S. M., Caulkins, J. P., and Reuter, P. (2008). Why the DEA STRIDE data are still useful for understanding drug markets. Technical report, National Bureau of Economic Research.

Atuesta, L. H. and Ponce, A. F. (2017). Meet the Narco: Increased competition among criminal organisations and the explosion of violence in Mexico. *Global Crime*, 18(4):375–402.

Avilés, D. (2015). Oro y 'narco' alimentan la violencia en Guerrero. *El Financiero.*

Bandiera, A. (2021). Deliberate displacement during conflict: Evidence from Colombia. *World Development*, 146:105547.

Bandiera, O. (2003). Land reform, the market for protection, and the origins of the sicilian mafia: theory and evidence. *Journal of Law, Economics, and Organization*, 19(1):218–244.

Beittel, J. S. (2020). Mexico: Organized crime and drug trafficking organizations (crs report no. r41576). *Retrieved from the Federation of American Scientists website: https://fasorg/sgp/crs/row*, 41576.

Benacchio, S. (1982). Algunas exigencias agroecológicas en 58 especies de cultivo con potencial de producción en el Trópico Americano. *FONAIAP-Centro Nacional de Investigaciones Agropecuarias. Ministerio de Agricultura y Cría.*

Berman, N. and Couttenier, M. (2015). External shocks, internal shots: the geography of civil conflicts. *Review of Economics and Statistics*, 97(4):758–776.

Berman, N., Couttenier, M., Rohner, D., and Thoenig, M. (2017). This mine is mine! how minerals fuel conflicts in africa. *American Economic Review*, 107(6):1564–1610.

Bernard, A. B., Redding, S. J., and Schott, P. K. (2010). Multiple-product firms and product switching. *American economic review*, 100(1):70–97.

Brückner, M. and Ciccone, A. (2010). International commodity prices, growth and the outbreak of civil war in Sub-Saharan Africa. *The Economic Journal*, 120(544):519–534.

Buonanno, P., Durante, R., Prarolo, G., and Vanin, P. (2012). On the historical and geographic origins of the sicilian mafia. *Available at SSRN 2009808.*

Bustamante, J. (2020). Children of Mexican former drug lord El Chapo build makeshift school for the poor. *Reuters.*

Calderón, G., Robles, G., Díaz-Cayeros, A., and Magaloni, B. (2015). The beheading of criminal organizations and the dynamics of violence in Mexico. *Journal of Conflict Resolution*, 59(8):1455–1485.

Calderon, L. Y., Heinle, K., Kuckertz, R. E., Rodriguez Ferreira, O., and Shirk, D. A. (2021). Organized crime and violence in Mexico: 2020 special report. *Justice in Mexico, University of San Diego.*

Caulkins, J. P. (2007). Price and purity analysis for illicit drug: Data and conceptual issues. *Drug and Alcohol Dependence*, 90:S61–S68.

CDC (2021a). Fentanyl. Available at https://www.cdc.gov/opioids/basics/fentanyl.html.

CDC (2021b). Understanding the epidemic. Available at https://www.cdc.gov/opioids/basics/epidemic.html.

CEA (2019). The role of opioid prices in the evolving opioid crisis. Available at https://trumpwhitehouse.archives.gov/wp-content/uploads/2019/04/The-Role-of-Opioid-Prices-in-the-Evolving-Opioid-Crisis.pdf.

Chabat, J. (2010). La respuesta del gobierno de Calderón al desafío del narcotráfico: Entre lo malo y lo peor.

Chassang, S. and Padró i Miquel, G. (2009). Economic shocks and civil war. *Quarterly Journal of Political Science*, 4(3):211–28.

Chimeli, A. B. and Soares, R. R. (2017). The use of violence in illegal markets: Evidence from mahogany trade in the Brazilian Amazon. *American Economic Journal: Applied Economics*, 9(4):30–57.

Coplan, P. M., Chilcoat, H. D., Butler, S. F., Sellers, E. M., Kadakia, A., Harikrishnan, V., Haddox, J. D., and Dart, R. C. (2016). The effect of an abuse-deterrent opioid formulation (oxycontin) on opioid abuse-related outcomes in the postmarketing setting. *Clinical Pharmacology & Therapeutics*, 100(3):275–286.

Coscia, M. and Rios, V. (2012). Knowing where and how criminal organizations operate using web content. In *Proceedings of the 21st ACM international conference on Information and knowledge management*, pages 1412–1421.

Dal Bó, E. and Dal Bó, P. (2011). Workers, warriors, and criminals: Social conflict in general equilibrium. *Journal of the European Economic Association*, 9(4):646–677.

de Cordobá, J. (2014). La guerra de los aguacates que se consumen en EE.UU. se libra en México. *The Wall Street Journal*.

DEA (2020a). 2019 National Drug Threat Assessment. Available at https://www.dea.gov/documents/2020/01/30/2019-national-drug-threat-assessment.

DEA (2020b). Facts about Fentanyl. Available at https://www.dea.gov/resources/facts-about-fentanyl.

DEA (2021). 2020 National Drug Threat Assessment. Available at https://www.dea.gov/sites/default/files/2021-02/DIR-008-21%202020%20National%20Drug%20Threat%20Assessment_WEB.pdf.

Dell, M. (2015). Trafficking networks and the Mexican drug war. *American Economic Review*, 105(6):1738–79.

Dimico, A., Isopi, A., and Olsson, O. (2017). Origins of the sicilian mafia: The market for lemons. *The Journal of Economic History*, 77(4):1083–1115.

Dube, O., García-Ponce, O., and Thom, K. (2016). From maize to haze: Agricultural shocks and the growth of the Mexican drug sector. *Journal of the European Economic Association*, 14(5):1181–1224.

Dube, O. and Vargas, J. F. (2013). Commodity price shocks and civil conflict: Evidence from Colombia. *The Review of Economic Studies*, 80(4):1384–1421.

Dubrovina, I. and Bautista, F. (2014). Analysis of the suitability of various soil groups and types of climate for avocado growing in the state of Michoacán, Mexico. *Eurasian Soil Science*, 47(5):491–503.

Dudley, S., Bonello, D., Lopez-Aranda, J., Moreno, M., Clavel, T., Kjelstad, B., and Restrepo, J. J. (2019). Mexico's role in the deadly rise of Fentanyl. *Wilson Centeer*.

Felbab-Brown, V. (2016). The rise of militias in Mexico: Citizens' security or further conflict escalation? *Prism*, 5(4):172–187.

Felter, C. (2022). The U.S. opioid epidemic. Available at https://www.cfr.org/backgrounder/us-opioid-epidemic.

Financial Times (2020). Avocado crime soars as Mexican gangs turn focus from opium to 'green gold'. Available at https://financialpost.com/financial-times/avocado-crime-soars-ahead-of-super-bowl-as-mexican-gangs-hijack-truckloads-of-green-gold-heading-north.

Flannery, N. P. (2013). Calderón's war. *Journal of International Affairs*, pages 181–196.

GAO (2002). Report to the co-chairman, Caucus on International Narcotics Control, U.S. Senate. Available at https://www.govinfo.gov/content/pkg/GAOREPORTS-GAO-02-416/html/GAOREPORTS-GAO-02-416.htm.

García Tinoco, M. (2019). Robo de aguacate no para en Michoacán. *Excelsior*.

Hansen, O. (2017). Deforestation caused by illegal avocado farming. *The University of Miami Inter-American Law Review*, 49(1):89–128.

Hartman, Travis (2019). Garden and gun: In southern Mexico, illicit poppy gardens lie in the middle of economics, violence, addiction and potentially, regulation and legitimacy. Available at https://graphics.reuters.com/MEXICO-DRUGS/0100903B05G/index.html.

Herrera, J. S. and Martinez-Alvarez, C. B. (2022). Diversifying violence: Mining, export-agriculture, and criminal governance in Mexico. *World Development*, 151:105769.

Hijmans, R. J., Phillips, S., Leathwick, J., Elith, J., and Hijmans, M. R. J. (2017). Package 'dismo'. *Circles*, 9(1):1–68.

Hoffer, L. and Alam, S. J. (2013). "Copping" in heroin markets: The hidden information costs of indirect sales and why they matter. In *International Conference on Social Computing, Behavioral-Cultural Modeling, and Prediction*, pages 83–92. Springer.

Horowitz, J. L. (2001). Should the DEA's STRIDE data be used for economic analyses of markets for illegal drugs? *Journal of the American Statistical Association*, 96(456):1254–1271.

Hughes, C., Hulme, S., and Ritter, A. (2020). The relationship between drug price and purity and population level harm. *Trends and Issues in Crime and Criminal Justice*, (598):1–26.

Humphrey, C. (2003). Narcotics, economics and poverty in the southern states. *Policy Note*, 17.

Idrobo, N., Mejía, D., and Tribin, A. M. (2014). Illegal gold mining and violence in colombia. *Peace Economics, Peace Science and Public Policy*, 20(1):83–111.

INEGI (2019a). Encuesta Nacional de Victimización y Percepción sobre Seguridad Pública (ENVIPE) 2019: Principales resultados. Available at https://www.inegi.org.mx/contenidos/programas/envipe/2019/doc/envipe2019_presentacion_nacional.pdf.

INEGI (2019b). Estadisticas de mortalidad (1990-2019).

Jones, N. (2013). The unintended consequences of kingpin strategies: Kidnap rates and the Arellano-Felix Organization. *Trends in Organized Crime*, 16(2):156–176.

Jones, N. P. and Sullivan, J. P. (2019). Huachicoleros. *Journal of Strategic Security*, 12(4):1–24.

Jones, T. and Awokoya, A. (2019). Are your tinned tomatoes picked by slave labour? How the Italian mafia makes millions by exploiting migrants. Available at https://www.theguardian.com/world/2019/jun/20/tomatoes-italy-mafia-migrant-labour-modern-slavery.

Kenny, P., Aspinall, E., and Shrestha, R. (2022). Commodity booms, conflict, and organized crime: Logics of violence in Indonesia's oil palm plantation economy.

Le Billon, P. (2001). The political ecology of war: natural resources and armed conflicts. *Political geography*, 20(5):561–584.

Le Cour, R., Morris, N., and Smith, B. (2019). The US fentanyl boom and the Mexican opium crisis: Finding opportunities amidst violence. *Woodrow Wilson Center*.

Le Cour Grandmaison, R., Morris, N., and Smith, B. (2019). The last harvest? From the US fentanyl boom to the Mexican opium crisis. *Journal of Illicit Economies and Development*, 1(3):312–329.

Linthicum, K. (2019). Inside the bloody cartel war for Mexico's multibillion-dollar avocado industry. *Los Angeles Times*.

López Cruz, I. and Torrens, G. (2023). Hidden drivers of violence diffusion: Evidence from illegal oil siphoning in Mexico. *Journal of Economic Behavior & Organization*, 206:26–70.

Magaloni, B., Robles, G., Matanock, A. M., Diaz-Cayeros, A., and Romero, V. (2020). Living in fear: the dynamics of extortion in Mexico's drug war. *Comparative Political Studies*, 53(7):1124–1174.

Marciano, M. A., Panicker, S. X., Liddil, G. D., Lindgren, D., and Sweder, K. S. (2018). Development of a method to extract opium poppy (papaver somniferum l.) dna from heroin. *Scientific reports*, 8(1):1–15.

Miguel, E., Satyanath, S., and Sergenti, E. (2004). Economic shocks and civil conflict: An instrumental variables approach. *Journal of Political Economy*, 112(4):725–753.

Millán-Quijano, J. and Pulgarín, S. (2023). Oiling up the field. forced internal displacement and the expansion of palm oil in Colombia. *World Development*, 162:106130.

Mineo, L. (2022). Stopping toxic flow of gun traffic from U.S. to Mexico. Available at https://news.harvard.edu/gazette/story/2022/02/stopping-toxic-flow-of-gun-traffic-from-u-s-to-mexico/.

Møller, A. B., Mulder, V. L., Heuvelink, G., Jacobsen, N. M., and Greve, M. H. (2021). Can we use machine learning for agricultural land suitability assessment? *Agronomy*, 11(4):703.

Muhuri, P. K., Gfroerer, J. C., and Davies, M. C. (2013). CBHSQ data review. *Center for Behavioral Health Statistics and Quality, SAMHSA*, 1:17.

NIDA (2021). Fentanyl DrugFacts. Available at https://nida.nih.gov/publications/drugfacts/fentanyl.

Office of National Drug Control Policy (2001). The price of illicit drugs: 1981 through the second quarter of 2000. Available at https://obamawhitehouse.archives.gov/sites/default/files/ondcp/policy-and-research/bullet_5.pdf.

ONDCP (2021). The Office of National Drug Control Policy announces the third consecutive year of reduction in poppy cultivation and potential heroin production in Mexico. *The White House*.

O'Neil, S. (2009). The real war in Mexico: How democracy can defeat the drug cartels. *Foreign Affairs*, 88:63.

Ordonez, V. and Salzman, S. (2023). Fentanyl: The deadly drug dealers use to lace illicit drugs.

Ornelas, R. and Gutiérrez, S. R. (2017). Los grupos de autodefensa en Michoacán. *De Raíz Diversa. Revista Especializada en Estudios Latinoamericanos*, 4(7):249–282.

Padgett, H. (2013). Aguacate: "oro verde" de Los Templarios. *Sin Embargo*.

Palmer, B. (2009). Is it easier to grow poppy than wheat? Available at https://slate.com/news-and-politics/2009/06/the-cost-of-poppy-production.html.

Parker, D. P. and Vadheim, B. (2017). Resource cursed or policy cursed? US regulation of conflict minerals and violence in the Congo. *Journal of the Association of Environmental and Resource Economists*, 4(1):1–49.

Phillips, B. J. (2015). How does leadership decapitation affect violence? The case of drug trafficking organizations in Mexico. *The Journal of Politics*, 77(2):324–336.

Rainsford, C. (2019). Carteles en México extorsionan a los productores de aguacate. *InSight Crime*.

Ramirez-Villegas, J., Jarvis, A., and Läderach, P. (2013). Empirical approaches for assessing impacts of climate change on agriculture: The EcoCrop model and a case study with grain sorghum. *Agricultural and Forest Meteorology*, 170:67–78.

Ruiz Corral, J. A., Medina-García, G., González-Acuña, I., Flores-López, H., Ramírez-Ojeda, G., Ortiz-Trejo, C., Byerly-Murphy, K., and Martínez-Parra, R. A. (1999). Requerimientos agroecológicos de cultivos. *Libro Técnico*, (3).

Semple, K. (2019). Mexican opium prices plummet, driving poppy farmers to migrate. *New York Times*.

SIAP (2016). México lider productor agroalimentario. Available at http://infosiap.siap.gob.mx/opt/publicaciones/mexico_web.pdf.

Signoret, P., Alcocer, M., Farfan-Mendez, C., and Sobrino, F. (2022). Mapping criminal organizations in mexico.

Sobrino, F. (2019). Mexican cartel wars: Fighting for the US opioid market.

Srivastava, P. (2019). Avocados: The Superfood with a Golden Future. Available at https://medium.com/@srivastava.p_36605/avocados-the-superfood-with-a-golden-future-88a9796f03f7.

The Associated Press (2021). Jalisco se unirá a Michoacán para exportar aguacate a EEUU. Available at https://www.chicagotribune.com/espanol/sns-es-jalisco-se-unira-a-michoacan-para-exportar-aguacate-a-eeuu-20211208-fiokd7rhbjcwtdnmv6e5ckvf6a-story.html.

The Associated Press (2022). U.S. suspends Mexican avocado imports after threat to inspector. Available at https://www.nbcnews.com/news/mexico/us-suspends-mexican-avocado-imports-threat-inspector-rcna1605.

The Guardian (2019). Are Mexican avocados the world's new conflict commodity? Available at https://www.theguardian.com/global-development/2019/dec/30/are-mexican-avocados-the-worlds-new-conflict-commodity.

UN (2020). World Drug Report 2019. Available at https://wdr.unodc.org/wdr2019/.

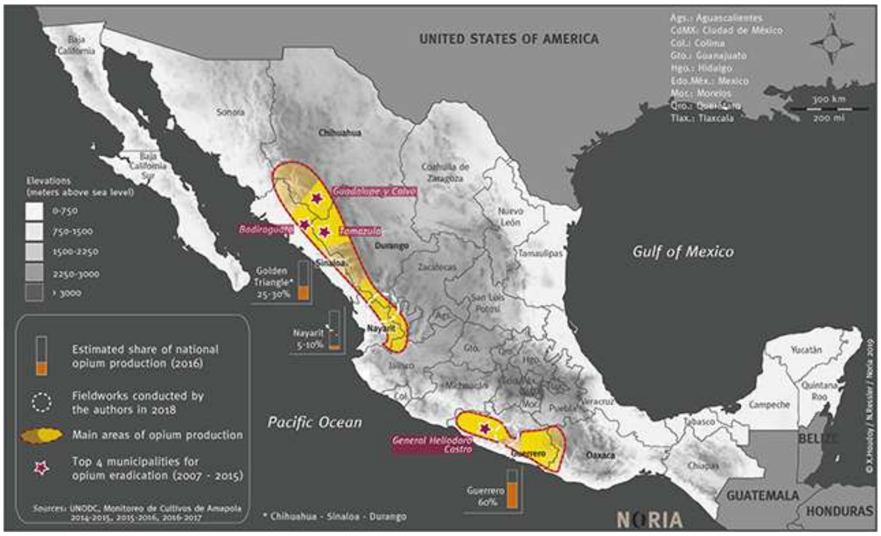
UNODC (2020). Monitoreo de cultivos de amapola 2017-2018. Available at https://www.unodc.org/documents/crop-monitoring/Mexico/Mexico-Monitoreo-Cultivos-Amapola-2017-2018-Alta.pdf.

Van Zee, A. (2009). The promotion and marketing of oxycontin: Commercial triumph, public health tragedy. *American journal of public health*, 99(2):221–227.

A Appendix

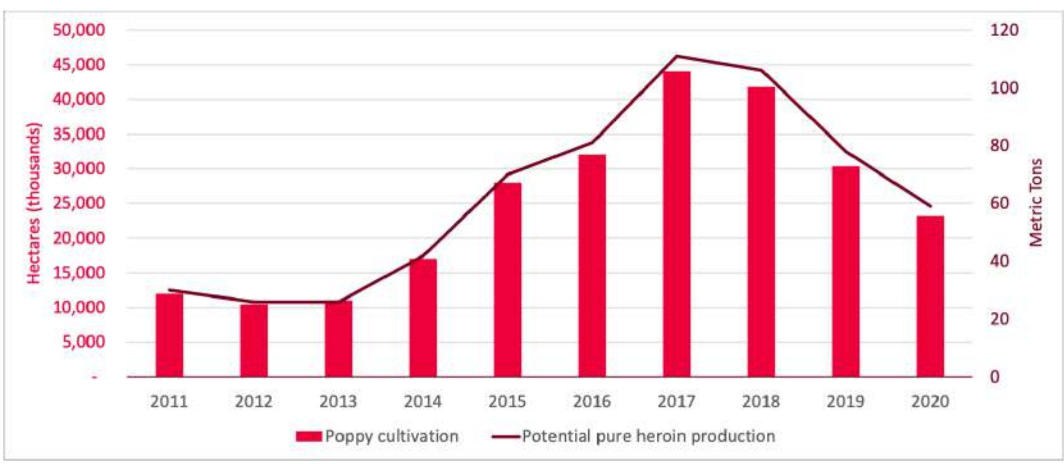
A.1 Tables and figures

Figure A1: Poppy production in Mexico



Source: Borrowed from Le Cour Grandmaison et al. (2019).

Figure A2: Potential poppy cultivation in Mexico (2011-2020)

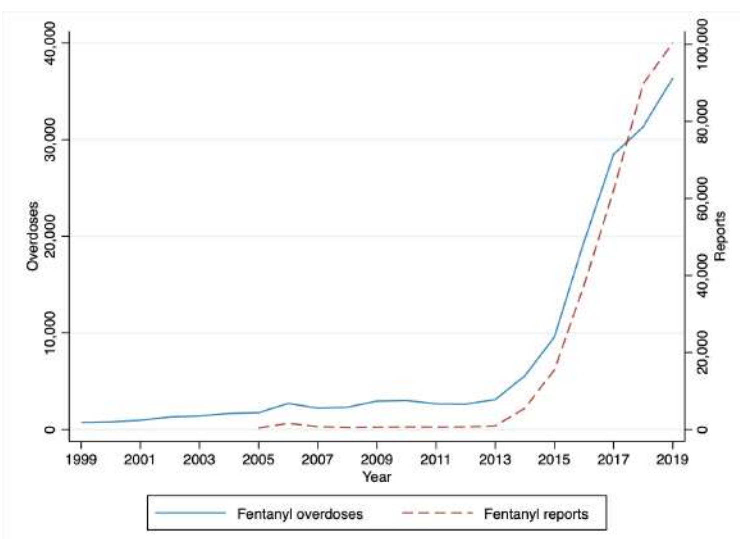


Notes: This graph shows annual estimates on potential poppy cultivation (left axis) and heroin production (right axis) from The White House Office of National Drug Control Policy (ONDCP, 2021).

Table A1: Available data by source, frequency, and aggregation level

Data	Database	Years	Aggregation level	Frequency
Violence & Drug Data				
Deaths	Department of Health Information (DGIS)	1990-2018	Individual	Daily
Extortion cases, kidnaps, and thefts	Ministry of Public Security (SSP)	2011-2019	Municipality	Monthly
Eradicated crops of poppy (# of fields & ha.)	SEDENA	1990-2018	Municipality	Annual
Cartel presence	Mapping Criminal Organizations	1990-2020	Municipality	Annual
Heroin and Overdose Data				
US. heroin retail prices per gram (adj. per purity)	UN	1990-2018	National	Annual
Overdose deaths by drug type	National Center for Health Statistics (NCHS)	1999-2019	National	Annual
Avocado Production				
Production and prices per ton	SAGARPA	2003-2018	Municipality	Annual
Value of avocado exports	BANXICO	1993-2018	National	Monthly
Weather Data				
Precipitation and temperature data	AgMerra	1990-2010	Municipality	Daily
Other Data				
Party affiliation of municipal mayors	INAFED	1993-2018	Municipality	Annual
Population	INEGI	2010	Municipality	Annual

Figure A3: Fentanyl overdose deaths and forensic laboratory reports (1999-2019)



Source: Data from NCHS and the DEA's National Drug Threat Assessment of 2019 and 2020.

Table A2: Descriptive Statistics

	Mean	SD
Violence data		
Murders per 100,000 people	23.49	30.16
Murders ag. workers per 100,000 people	6.06	13.52
Murders non-ag. workers per 100,000 people	17.42	23.10
Murders of potential cartel member	7.00	13.23
Murders of non-potential cartel member	16.48	21.68
Extortion cases per 100,000 people	3.38	6.89
Drug data		
Fields of poppy eradicated	80.21	894.77
Hectares of poppy eradicated	9.85	104.29
Avocado production		
Avocado production (tons)	1,988.51	14,302.39
Price of avocado (MX per ton)	11,752.69	5,548.84
Suitability measures		
Avocado suitability	0.46	0.30
Hass avocado suitability	0.33	0.34
Poppy suitability	0.27	0.21
Annual level data		
U.S. Fentanyl Overdoses	15,455.11	12,856.85
Observations	6,516	
Num. of municipalities	724	

A.2 Background

A.2.1 The war against drugs

Despite the existence of Drug Trafficking Organizations in Mexico, the combat against cartels was not a top priority for the Mexican government until the mid-1980s (Chabat, 2010). To limit violence, government officials had established ties with drug traffickers. This implicit pact between cartels and the Mexican government became disrupted when the hegemonic party PRI started losing elections in the late 1980s (O'Neil, 2009).[35] In 2000, the PRI lost for the first time the presidential election against the National Action Party (PAN) candidate, Vicente Fox.

As a result of the breakage in the ties between drug cartels and government officials, violence from DTOs increased throughout the country. Fighting the DTOs became President Felipe Calderón's top priority after his election in December 2006. Just 11 days after his election, he declared the war against drug cartels (Chabat, 2010). His strategy resulted in a sharp increase in violence in states like Michoacán.[36] Between 2007 and 2012, a total of over 120,000 people were killed, compared to 60,000 in the previous six years (2001-2006). During Felipe Calderon's presidency, the lowest number of homicides reported was in 2007, with 8,000 murders. In 2011, however, homicides had reached over (INEGI, 2019b).

Additionally, the government's "kingpin" strategy may have led to an increase in violence. The capture of prominent cartel leaders led to the fragmentation of DTOs, leading to higher levels of violence due to an increase in the competition among cartels (Atuesta and Ponce, 2017; Calderón et al., 2015; Jones, 2013).[37] According to the U.S. Drug Enforcement Administration (DEA), before 2006, Mexico had only four dominant DTOs: the Tijuana (Arellano Felix) Cartel, the Sinaloa Cartel, the Juárez (Vicente Carrillo) Cartel, and the Gulf Cartel. However, as of 2020, the DEA recognizes the existence of at least nine major DTOs (Beittel, 2020).[38] Fragmentation of the four major DTOs started between 2009 and 2010, with the split of the Gulf Cartel. Los Zetas, a group of highly trained military that defected and joined the Gulf Cartel, separated from the

[35] In 1989, the PRI lost its first election for the governor of the state of Baja California (O'Neil, 2009).

[36] On December 12th, 2006, President Felipe Calderón launched the Operation Michoacán and sent over 4,000 troops to combat drug cartels in his home state. In that year, more than 400 people had been killed by drug cartels in Michoacán (Flannery, 2013).

[37] Jones (2013) finds evidence of an increase in homicide and kidnapping rates in Tijuana after cartel leaders are arrested or killed.

[38] The nine cartels identified by the DEA are: Sinaloa, Los Zetas, Gulf, La Familia Michoacana, the Knights Templar, the Cartel Jalisco Nueva Generacion (CJNG), Beltrán Leyva, Tijuana and Juárez (Beittel, 2020).

former in 2010. Meanwhile, a new armed group originated to eliminate Los Zetas, the Cartel Jalisco Nueva Generation (CJNG), and it is, as of now, one of the most violent DTOs operating in the country. Similarly, in 2011, the Familia Michoacana cartel that controlled the states of Michoacán and Guerrero split and gave origin to the Knights Templar (Beittel, 2020).

A.2.2 Heroin production and distribution

The production of heroin starts with farmers extracting the liquid sap of the *Papaver Somniferum* (commonly known as opium poppy). The opium poppy is a flower used to produce pharmaceutical opiates and heroin. Farmers extract the sap of these flowers by cutting the outer surface of poppy pods (Marciano et al., 2018). The resulting product is known as opium paste or opium gum.

The poppy flower is a low-cost crop that can be grown in small plots (Palmer, 2009).[39] Usually, two hectares of poppy flowers will produce around 22 kilograms of opium paste, which can yield about a kilogram of heroin (Hartman, Travis, 2019). As a reference, in 2013, the price offered to farmers for a kilogram of raw opium paste was about 15,000 pesos (USD$1,175),[40] according to Le Cour et al. (2019).

Poppy farmers are self-employed; in addition to growing poppies, they grow subsistence crops. Because growing poppy in Mexico is illegal, poppy plots are usually located in remote areas, up in the mountains and far from the center of communities. Poppy farmers in these communities rely on gravity-fed irrigation systems, and thus plots usually are strategically located near streams (Le Cour et al., 2019).

After extracting the opium gum, farmers sell it to local drug cartels that assume the role of the *acaparador* (literally, the "gatherer"), responsible for bulk-buying opium. These local groups offer "protection" to local growers and assure them they will buy their opium crop (Le Cour et al., 2019). Since these criminal groups are the sole buyers of the opium paste extracted by farmers, the opium market behaves as a monopsony, where criminal groups mainly determine prices, and farmers have little to no power of negotiation. The local *acaparadores* refine the opium paste to obtain morphine, which they combine with other chemicals to produce heroin. They sell the final product to larger DTOs in charge of the transportation and distribution of heroin across the border. These cartels

[39] Poppy seeds are cheap and durable. Cultivation of this flower requires smaller amounts of fertilizer than other crops and minimal soil preparation (Palmer, 2009).

[40] This dollar estimate is based on a 2013 exchange rate.

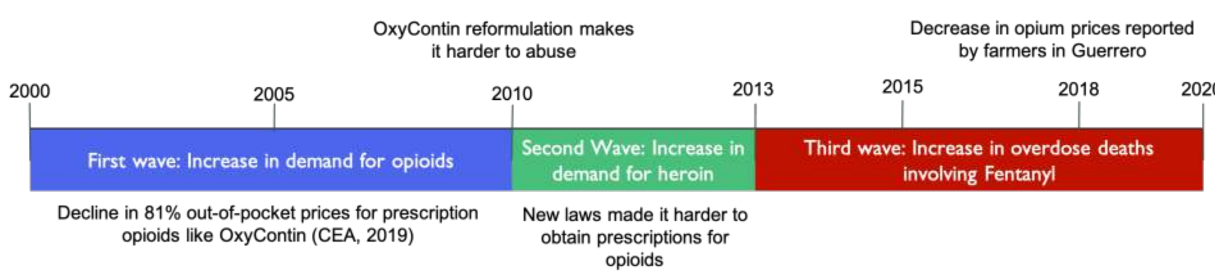
then sell it to U.S. DTOs at a wholesale price (Le Cour et al., 2019).

U.S. drug trafficking organizations buy heroin from drug cartels in Mexico, divide it into small quantities, and then sell it to consumers at a retail price. At this point in the distribution chain, heroin is often mixed with other substances, such as Fentanyl, as a strategy for retailers to increase their markups. Border seizures and lab analyses on wholesale heroin show that lacing heroin with Fentanyl is uncommon at the wholesale level (DEA, 2021). In 2019, only 16% of all wholesale heroin seizures had Fentanyl, while Fentanyl-laced heroin constituted 32% of retail heroin seizures. This indicates that U.S. retailers are primarily responsible for lacing heroin rather than Mexican drug cartels (DEA, 2020a).

A.2.3 The U.S. opioid crisis

The opioid crisis, as defined by the U.S. Centers for Disease Control and Prevention, unfolded in three distinct waves. The first wave can be traced back to a surge in prescribed opioids starting in the late 1990s, with many pointing to 1999 as the starting point (CDC, 2021b; UN, 2020). This initial wave led to an increase in overdose deaths involving misuse of prescription opioids. The spike in prescribed opioid addiction has been attributed to the pharmaceutical industry's efforts to promote opioid use for pain management while downplaying associated risks and encouraging widespread prescription by doctors (Van Zee, 2009). Additionally, opioids became more affordable; between 2001 and 2010, out-of-pocket prices dropped by 81% (CEA, 2019). These factors—combined with extensive marketing campaigns promoting their broad usage—made opioids easy to abuse and contributed to people becoming addicted (see Timeline in Figure A4).

Figure A4: Timeline of the U.S. opioid crisis



The second wave began in 2010 after the U.S. tightened restrictions on opioids to reduce overdose deaths from the first wave. The government imposed stricter regulations on opioid prescriptions and modified the formulation of extended-release pills such as OxyContin to make them harder to abuse (CEA, 2019).[41] As a result, individuals, who used to consume pills, substituted them with readily available and less expensive illegal opioids such as heroin. Between 2002 and 2011, 79.5% of new heroin users had previously taken prescription pain relievers without a prescription (Muhuri et al., 2013). While these measures did succeed in decreasing the misuse of prescribed opioids, they also led to a surge in heroin overdoses (CDC, 2021b). Figure 1 illustrates the evolution of overdose deaths in the U.S. by the type of opioid after each wave.

During the third wave (2013-2021), the U.S. experienced a surge in overdoses involving heroin laced with Fentanyl (CDC, 2021b). Drug dealers often mix Fentanyl with heroin as it provides a similar high to unlaced heroin but at a lower cost. Since traces of Fentanyl can only be detected through a lab test, heroin consumers are unaware of its presence. Due to its potency, small doses of Fentanyl pose a significant risk of overdose, with 2 mg considered a lethal dose according to the CDC (DEA, 2020b). Between 2013 and 2019, overdose deaths related to Fentanyl increased dramatically more than tenfold.[42]

A.3 Theoretical Framework

To understand cartel behavior, I borrow from López Cruz and Torrens (2023)'s model on crime diversification and spatial diffusion of violence. In this model, drug trafficking organizations (DTOs) behave as profit-maximizing firms. DTOs can be thought of as multi-production firms that mainly produce and distribute illegal drugs but can also engage in an extractive criminal activity (i.e. extortion of avocado farmers, theft of natural resources, illegal mining (Le Billon, 2001; Parker and Vadheim, 2017; López Cruz and Torrens, 2023)).

Consider an economy with $N = \{1, ..., N\}$ criminal organizations that operate in $L = \{1, ..., L\}$ locations. Criminal organizations engage in two illegal activities $A = \{d, e\}$, where d corresponds to drug trafficking and e is an extractive activity.[43] These two activities can be disputed by criminal

[41] The U.S. government changed the formulation of OxyContin pills to make them harder to crush. The crushing of extended-release pills releases the active component at once, which allows the body to absorb it faster than by taking a pill (Coplan et al., 2016).

[42] Source: Own estimates using data from the National Center for Health Statistics (NCHS).

[43] In López Cruz and Torrens (2023)'s original model, criminal organizations engage in three activities. Two are

organizations. Each DTO i is endowed with capital k_i, and decides how much to invest in each location l for drug trafficking ($d_{i,l}$) and for extractive activities ($e_{i,l}$). In this paper, I assume that DTOs always invest in drug trafficking ($d_i > 0$) and decide whether to engage in an extractive activity ($e_i \geq 0$). The capital constraint for a DTO i is given by:

$$\sum_{l \in L} (d_{i,l} + e_{i,l}) \leq k_i, \; d_{i,l} \geq 0, e_{i,l} \geq 0 \text{ for } l \in L$$

Let $v^a_{i,l} \geq 0$ represent the value generated by the activity a in location l for DTO i, and let $v^a_{i,l}(a_{i,l})^\beta$ with $\beta \in (0,1)$ denote the total revenue generated by criminal organization i for activity a in location l. Intuitively, the total revenue is determined by the suitability of location l for activity a, the efficiency of a criminal organization in realizing the activity, and the level of capital invested. DTOs also allocate $w^a_{i,l} \geq 0$ towards armed labor to safeguard their revenue in each location l and for each activity a. Let $p^a_{i,l} \in [0,1]$ be the proportion of the total revenue that cannot be disputed by other organizations. The total profit from activity $a \in \{d, e\}$ for DTO i in location l is given by:

$$\pi^a_{i,l} = p^a_{i,l} v^a_{i,l}(a_{i,l})^\beta + \gamma^a_{i,l} \sum_{j \in N} (1 - p^a_{j,l}) v^a_{j,l}(a_{j,l})^\beta - w^a_{i,l}$$

where $\gamma^a_{i,l}$ is the fraction of the total output captured by DTO i in location a. The contest function will depend on how the relative expenditure of each crime organization on armed labor, expressed as follows:

$$\gamma^a_{i,l} = \begin{cases} \dfrac{(w^a_{i,l})^{m^a}}{\sum_{j \in N} \left(w^a_{i,l}\right)^{m^a}} & \text{if } \sum_{j \in N} (w^a_{i,l})^{m^a} > 0 \quad \text{with } m^a \in (0,1] \\ \dfrac{1}{N} & \text{if } \sum_{j \in N} (w^a_{i,l})^{m^a} = 0 \end{cases}$$

The overall profits for each activity across all locations are given by:

$$\Pi^d_i = \sum_{l \in L} \left(1 - q^d_l\right) \pi^d_{i,l}, \quad \Pi^e_i = \sum_{l \in L} \left(1 - q^e_l\right) \pi^e_{i,l} - f\chi^e_i$$

contestable and one (n) is not, which means DTOs do not need to exert territorial control over this activity (e.g., fraud). In this paper, I focus on the case in which DTOs do not invest in the non-disputable good ($n = 0$).

where $q_l^a \in (0,1)$ corresponds to the probability of getting caught in activity a,f is a fixed cost for entering into an extractive activity e and χ_i^e is a binary variable equal to one if DTO i invests in this activity ($e_i = \sum_{l \in L} e_{i,l} > 0$), and equal to one if $e_i = 0$.

The aggregate profit for organization i is given by $\Pi_i = \Pi_i^d + \Pi_i^e$.[44] Each DTO i determines the optimal allocation of capital and armed labor for each activity and location to maximize Π_i. DTOs solve this problem simultaneously and independently. First, each criminal organization chooses the level of capital to invest in each activity and location $((d_{i,l})_{l \in L}, (e_{i,l})_{l \in L})$. Subsequently, DTOs observe $((d_{i,l})_{l \in L}, (e_{i,l})_{l \in L})$ for $i \in N$, and decide $\left((w_{i,l}^d)_{l \in L}, (w_{i,l}^e)_{l \in L}\right)$. Solving the subgame perfect Nash equilibrium through backward induction yields the following conditions.

Choice of armed labor

Given DTOs' capital decisions $(a_{i,l})_{i \in N}$, the Nash equilibrium choice of armed labor for activity $a = \{d, e\}$ is given by:

$$w_{i,l}^a = w_l^a = \frac{m^a (N-1)}{N^2} \left[\sum_{j \in N} \left(1 - p_{j.l}^a\right) v_{j,l}^a \left(a_{j,l}\right)^\beta \right] \text{ for } i \in N \text{ and } l \in L \tag{2}$$

Intuitively, cartels don't have incentives to invest more or less in weapons relative to their counterparts, thus $w_{i,l}^a = w_l^a$. Moreover, w_l^a is increasing in $a_{i,l}$, decreasing in $p_{i,l}^a$ and do not depend on q_l^a. In other words, when capital investment in activity a increases, DTOs tend to allocate more resources to armed labor. Additionally, increased spending on armed labor becomes necessary when their capacity to safeguard a location declines ($p_{i,l}^a$ decreases). Moreover, DTOs do not alter their investment decisions regarding armed labor based on the probability of getting caught (q_l^a).

Capital diversification across locations

Based on the chosen level of armed labor $w_{i,l}^a$, the equilibrium payoff is given by:

$$\Pi_i^a = \sum_{l \in L} \bar{v}_{i,l}^a \left(a_{i,l}\right)^\beta + W_{-i}^a + f^a \chi_i^a \tag{3}$$

[44]In López Cruz and Torrens (2023) original model, the payoff is giving by $\Pi_i = \Pi_i^d + \Pi_i^e + \Pi_i^n$, where $\Pi_i^n = v_i^n n_i$, and v^n is the value of the non-disputable activity. In this paper, I assume $n_i = 0$.

where,

$$\bar{v}^a_{i,l} = (1 - q^a_l)\left[p^a_{i,l} + \frac{N - m^a(N-1)}{N^2}\left(1 - p^a_{i,l}\right)\right] v^a_{i,l} \text{ for } i \in N \text{ and } l \in L \tag{4}$$

and,

$$W^a_{-i} = \frac{N - m^a(N-1)}{N^2}\left[\sum_{l \in L}\sum_{j \in N, j \neq i}(1 - q^a_l)\left(1 - p^a_{j,l}\right) v^a_{j,l}\left(a_{j,l}\right)^{\beta}\right] \text{ for } i \in N$$

Suppose DTO i chooses to invest a_i in activity a={d,e}. Following this decision, they allocate capital across the different locations. By solving Π^a_l subject to $a_{i,l} \geq 0$ for all $l \in L$ and $\sum_{l \in L} a_{i,l} = a_i$, the optimal capital allocation for criminal organization i in location l is given by:

$$a_{i,l} = \left[\frac{\left(\bar{v}^a_{i,l}\right)^{\frac{1}{1-\beta}}}{\bar{v}^a_i}\right] a_i \text{ for } l \in L \tag{5}$$

where, $\bar{v}^a_i = \sum_{l \in L}\left(\bar{v}^a_{i,l}\right)^{\frac{1}{1-\beta}}$ for $i \in N$ represents the value of activity a for DTO i. Hence, DTOs' decision on capital investment in a location will depend on the activity's profitability in location l relative to their overall profitability from activity a. This leads to two significant implications. First, criminal organizations will allocate a greater proportion of their capital $\frac{a_{i,l}}{a_i}$ in locations that have a larger return to capital ($\bar{v}^a_{i,l}$), are easier to protect ($p^a_{i,l}$ is higher), and where the risk of detention is lower (decreasing in q^a_l). Second, this also implies that capital allocation in one location will decrease if the expected profitability of another location increases. In other words, $\frac{a_{i,k}}{a_i}$ decreases with $v^a_{i,l}$ and $p^a_{i,l}$, and increases with q^a_l for $k \neq l$.

Note that based on the optimal allocation of armed labor and capital (Equations 2 and 5), cartels will invest more in capital and armed labor in places with a higher return on their investment.

Capital diversification across activities:

Substituting $a_{i,l}$ (Equation 5) in $w^a_{i,l}$ and Π^a_i (Equations 2 and 3, respectively), it yields: $\Pi^a_i = (\bar{v}^a_i)^{1-\beta}(a_i)^{\beta} + W^a_{-i} - f^a\chi^a_i$. Based on this, DTOs choose the allocation of capital to each activity (d_i, e_i) that maximizes their overall profits, following this maximization problem:

$$\max_{d_i,e_i} \quad \left\{\Pi_i = \left(\bar{v}_i^d\right)^{1-\beta}(d_i)^\beta + \left(\bar{v}_i^e\right)^{1-\beta}(e_i)^\beta + W_{-i}^d + W_{-i}^e - f\chi_i^e\right\}$$
$$\text{s.t.:} \quad d_i + e_i = k_i, d_i \geq 0, e_i \geq 0$$

Suppose that $\bar{v}_i^d \geq \left(\frac{v_i^n}{\beta}\right)^{\frac{1}{1-\beta}} k_i$.[45] The optimal capital allocation among each activity for DTO i is as follows:

$$(d_i, e_i) = \begin{cases} (k_i, 0) & \text{if } \bar{v}_i^e \leq h_1(\bar{v}_i^d) \\ \left(\dfrac{\bar{v}_i^d}{\bar{v}_i^d + \bar{v}_i^e}k_i, \dfrac{\bar{v}_i^e}{\bar{v}_i^d + \bar{v}_i^e}k_i\right) & \text{if } \bar{v}_i^e > h_1(\bar{v}_i^d) \end{cases} \tag{6}$$

where,

$$h_1(\bar{v}_i^d) = \left[\left(\bar{v}_i^d\right)^{1-\beta} + \frac{f}{\left(k_i\right)^\beta}\right]^{\frac{1}{1-\beta}} - \bar{v}_i^d$$

Based on the above equation, criminal organizations will decide to engage in an extractive activity if its potential revenue ($\bar{v}_i^e$) exceeds a certain threshold ($h_1(\bar{v}_i^d)$), ensuring that $\bar{v}_i^e$ covers a portion of the fixed entry cost and of the value of drug trafficking $\bar{v}_i^d$. Below this threshold, criminal organizations invest all their capital k_i in drug trafficking. Moreover, the allocation of capital by DTOs between these two activities will be proportionate to the relative value they can attain from each activity. Therefore, from the above, we can conclude that, as the relative value of an extractive activity to drug trafficking increases, criminal organizations will allocate more capital to the extractive activity.

A.3.1 Violence

In this paper's context, criminal organizations engage in the production and distribution of heroin. They can also decide to generate revenue from the avocado sector by stealing avocados and extorting farmers (the extractive activity). Drug cartels will decide whether to engage in the extortion of avocado farmers if their expected returns from diversification exceed those from specializing only

[45]This serves as a necessary condition for $n = 0$ and $d_i \geq 0$. In the model proposed by López Cruz and Torrens (2023), the complete payoff function is expressed as $\Pi_i = \Pi_i^d + \Pi_i^e + \Pi_i^n$, where $\Pi_i^n = v_i^n n_i$. However, in this model, I make the assumption that $n_i = 0$. Intuitively, for this assumption to hold true, the revenue generated from drug trafficking by criminal organization i must surpass a certain threshold, such that it lacks the incentive to invest in the non-disputable good.

in the production of heroin (as represented by Equation 6). Therefore, a decline in the demand for heroin reduces the value of drug trafficking ($\bar{v}_i^d$) [46] for all DTOs and raises their incentives to engage in the extractive activity. Additionally, locations vary in their suitability for poppy and avocado growing. For instance, certain areas may be inadequate for avocado growth, resulting in $v_{i,l}^e = 0$ for location l across all DTOs $i \in N$. Similarly, regions unsuitable for poppy cultivation will have $v_{i,j}^d = 0$.

Competition among criminal organizations over disputed profits leads to violence in profitable locations. DTOs invest in armed labor to safeguard their revenues from other criminal organizations. Consequently, violence in location l can be defined as $H_l = H_l^d + H_l^e$, where H_l^d and H_l^e represent the total armed labor invested by DTOs in drug trafficking and extractive activities, respectively. Homicides in location l corresponding to activity a is given by:

$$H_l^a = \sum_{j \in N} w_{j,l}^a = \frac{m^a(N-1)}{N} \left[\sum_{j \in N} (1 - p_{j,l}^a) \frac{(v_{j,l}^a)^{\frac{1}{1-\beta}}}{\left[\sum_{l \in L} (v_{j,l}^a)^{\frac{1}{1-\beta}} \right]^{\beta}} (a_j)^{\beta} \right]$$

This equation implies a positive correlation between homicides and $v_{i,l}^a$, and a negative correlation with the proportion of revenue obtainable without conflict $p_{i,l}$. Moreover, when drug cartels abstain from extractive activities ($e_i = 0$ for all j), homicides in a location will be exclusively attributed to violence related to drug trafficking.

As the profitability of heroin decreases relative to avocados, cartels have higher incentives to invest in extractive activities in avocado-suitable municipalities. This results in intensified conflict among cartels for revenue, leading to higher homicide rates in these municipalities. Conversely, in poppy-suitable municipalities, cartels invest less in capital and require fewer armed personnel, resulting in a decrease in homicides.

[46] The decline in the demand for heroin can be thought of more properly as a decline on $v_{i,l}^d$ for all $i \in N$ and $l \in L$.

A.4 Data

A.4.1 Suitability index

A.4.1.1 Temperature suitability index

For the temperature suitability index (T^*_C) corresponding to crop C, let T_{MIN_C} and T_{MIN_C} be the minimum and maximum absolute temperatures, respectively, within which crop C can be grown as described by the FAO-Ecocrop database. Also, let T_{OPMIN_C} and T_{OPMAX_C} be the minimum and maximum optimum temperatures within which crop C can achieve the highest yield. Finally, let the T_{KILL_C} be the temperature at which, if reached, the plant will die plus 4°C.[47] Given data on the mean temperature ($T_{MEAN_{mi}}$) and the minimum temperature ($T_{MIN_{mi}}$) registered in a month m at the municipality i, I estimate a monthly temperature suitability index for each municipality and crop such that:

$$T^*_{Cmi} = \begin{cases} 0 & T_{MIN_{mi}} < T_{KILL_C} \\ 0 & T_{MEAN_{mi}} < T_{MIN_C} \\ \frac{T_{MEAN_{mi}} - T_{MIN_C}}{T_{OPTMIN_C} - T_{MIN_C}} & T_{MIN_C} \leq T_{MEAN_{mi}} < T_{OPTMIN_C} \\ 1 & T_{OPTMIN_C} \leq T_{MEAN_{mi}} < T_{OPTMAX_C} \\ \frac{T_{MAX_C} - T_{MEAN_{mi}}}{T_{MAX_C} - T_{OPTMAX_C}} & T_{OPTMAX_C} \leq T_{MEAN_{mi}} < T_{MAX_C} \\ 0 & T_{MEAN_{mi}} \geq T_{MAX_C} \end{cases} \tag{7}$$

The Ecocrop suitability measure is estimated considering the length of the growing season. This methodology considers each month of the year as being equally likely to be the starting month of the growing season. Therefore, each year is assumed to have 12 potential growing seasons of a given length (Ramirez-Villegas et al., 2013). A mean suitability index (T^*_{Cgi}) is then calculated for each potential growing season g (Møller et al., 2021). Finally, T^*_C is the minimum of all the temperature indices T^*_{Cgi} estimated for each potential growing period g.

[47] Consistent with (Ramirez-Villegas et al., 2013)'s study, I use the killing temperature plus 4°C since I'm taking the historical average of the minimum temperature, and this accounts for the possibility that the minimum temperature will reach the killing temperature at least one day of the month.

A.4.1.2 Precipitation suitability index

For the precipitation suitability index (R_{Cgi}), I define R_{MIN_C} and R_{MAX_C} as the minimum and maximum precipitation (in mm) at which the crop can grow during the growing season g. Let R_{OPMIN_C} and R_{OPMAX_C} be the minimum and maximum optimum rainfall. For the precipitation index, data is estimated for each growing season rather than monthly. Taking into account the length of the growing season g, I estimate the total precipitation present in a municipality i during that period ($R_{TOTAL-gi}$). Moreover, using the absolute minimum (R_{MIN_C}) and maximum precipitation (R_{MAX_C}) parameters defined by the FAO-Ecocrop database and the minimum (R_{OPTMIN_C}) and maximum optimal (R_{OPTMAX_C}) precipitation, I estimate a precipitation suitability index for each of the potential growing seasons as follows:

$$R^*_{Cgi} = \begin{cases} 0 & R_{TOTAL_{gi}} < R_{MIN_C} \\ \frac{R_{TOTAL_{gi}} - R_{MIN_C}}{R_{OPTMIN_C} - R_{MIN_C}} & R_{MIN_C} \leq R_{TOTAL_{gi}} < R_{OPTMIN_C} \\ 1 & R_{OPTMIN_C} \leq R_{TOTAL_{gi}} < R_{OPTMAX_C} \\ \frac{R_{MAX_C} - R_{TOTAL_{gi}}}{R_{MAX_C} - R_{OPTMAX_C}} & R_{OPTMAX_C} \leq R_{TOTAL_{gi}} < R_{MAX_C} \\ 0 & R_{TOTAL_{gi}} \geq R_{MAX_C} \end{cases} \tag{8}$$

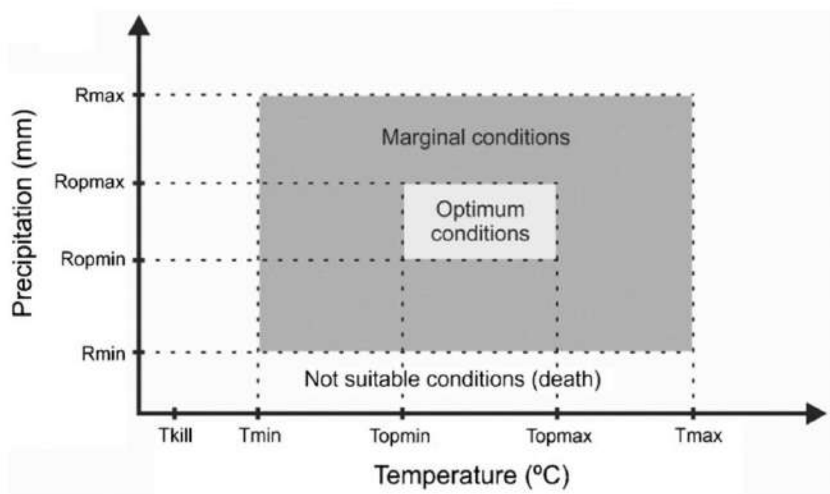
Finally, R^*_{Ci} is defined as the minimum of the precipitation indices R^*_{Cgi}, I estimated for each potential growing period g.

A.4.1.3 Final suitability index

The Ecocrop final suitability measure for crop C in each municipality is estimated by taking the product of the temperature T^*_C and precipitation indices R^*_C (Møller et al., 2021). Figure A5 shows that a municipality is considered to be suitable whenever both its precipitation and temperature parameters fall within the dark grey area and will be considered optimal if they are within the area marked in the light gray area. Therefore, the resulting parameter takes a value of zero for areas that do not meet the minimum requirements for growth, a value of one for areas with conditions within the optimal requirements, and a value between zero and one for places that are suitable but do not fall within the range of optimal suitability (the dark gray area).

I estimate each of the poppy and suitability indices taking into account the agro-climatic requirements for each crop according to the FAO's Ecocrop database (see Table A3). While precipitation and temperature requirements are precise, growing seasons are defined as a range (i.e. the avocado growing cycle is between 270 to 365 days). Therefore, for the avocado suitability, I take into account a 12-month growing period since trees require suitable conditions throughout the year. Meanwhile, poppy flowers can die during winter and then grow again in the spring. Therefore, unsuitable conditions during winter do not affect potential growth for the next year. To account for this, I eliminate growing periods that start with the autumn and winter months.[48]

Figure A5: Diagram of the Ecocrop suitability measure



Source: borrowed from Ramirez-Villegas et al. (2013).

Since avocado and poppy have additional altitude requirements, I create an altitude suitable indicator H^*_{iC} equal to one if the municipality has any localities within the range of required altitude for growing crop C. The final suitability measure used in this study is given by: $S_C = T^*_C \times R^*_C \times H^*_C$. The temperature, precipitation, and altitude minimum and optimal requirements used for constructing the poppy and avocado suitability measures are provided in Table A3.

[48]I restricted my analysis to the months of March-August.

Table A3: Poppy and avocado agro-climatic suitability requirements

	Avocado	Poppy
Temperature (°C):		
Absolute min. temperature	10	3
Absolute max. temperature	28	28
Min. optimum temperature	14	15
Max. optimum temperature	22	24
Killing temperature	-6	-5
Precipitation (mm):		
Min. absolute precipitation	660	300
Max. absolute precipitation	1,800	1,700
Min. optimum precipitation	1,000	800
Max. optimum precipitation	1,400	1,200
Altitude (m.a.s.l.):		
Min. altitude:	800	600
Max. altitude:	3,000	2,400
Hass min. altitute:	1,600	-
Hass max. altitute:	2,200	-
Growing season (months):	12	7

Note: information on crop growing season, and temperature and precipitation requirements are from the FAO-Ecocrop database. Minimum altitude requirements for avocado were obtained from Anguiano et al. (2007); Benacchio (1982); Ruiz Corral et al. (1999) and optimal altitude requirements for Hass avocados from Dubrovina and Bautista (2014).

A.4.1.4 Validation of the suitability index

To assess the reliability and accuracy of my suitability indices, I use information on avocado production and eradication of poppy. For the avocado suitability index, I use data from the Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food of Mexico (SAGARPA). The database includes the number of hectares cultivated and harvested, prices per ton, annual production, and yields for each municipality in Mexico from 2003 to 2018.

Table A4 shows the relationship between the avocado suitability index and two measures of avocado production: annual tons of avocado produced and the number of hectares harvested. To do this, I regressed the suitability index on these two avocado production measures between 2010 and 2018 for the whole country and for my particular sample. The specification is estimated at the municipality-year level and includes year-fixed effects and clustered standard errors at the municipality level. The coefficients show a positive and significant relationship between the avocado suitability index and avocado production for my sample and the whole country.

Table A4: Test results for the avocado suitability index

	Whole country		Sample	
	Avocado production (1)	Hectares harvested (2)	Avocado production (3)	Hectares harvested (4)
Avocado Suitability	4496.5**	422.2**	12603.5**	1182.4**
	(1933.9)	(176.9)	(5330.9)	(486.9)
Observations	4,801	4,801	2,271	2,271
Adj. R-squared	0.176	0.178	0.163	0.163
Mean	3004.2	295.9	6179.1	602.0
Year FE	X	X	X	X
State FE	X	X	X	X

Notes: This table tests the relationship between the avocado suitability index and two production measures: annual estimates for tons of avocado produced and hectares harvested. This table includes estimates for the whole country and the sample used in this paper. Standard errors clustered at the municipality level are shown in parentheses. All specifications include year and state fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

To test the validity of the poppy suitability measure, I use information on drug crop eradication from the Ministry of National Defense (SEDENA) since no official records exist on drug production. This information was obtained through a Freedom of Information Act request and has municipality-level data on the number of fields and hectares of poppy eradicated each year between 1990 and 2018. While eradication is not a production measure, evidence suggests that the military targets the most productive areas, and, therefore, data on eradication can be used as a proxy for production. For instance, between 2014 and 2018, the annual estimated poppy-eradicated area reported by SEDENA corresponded to over 84% of the total cultivated area estimated for the same period by the UNODC using satellite data. Moreover, according to U.S. and Mexican government officials, over 75% of the total drug crop production is eradicated each year (Humphrey, 2003; Dube et al., 2016).

Table A5 shows the relationship between the poppy suitability measure and poppy eradication. The estimates were measured using a fixed effects regression with year and state fixed effects to control for time-invariant characteristics at the state level and for time shocks. The regression also controls for the municipal mayor's party and a binary variable equal to one if the mayor's party coincides with the president's party, to proxy for differences in enforcement among different political parties. The coefficients show a positive and significant relationship between the poppy suitability index and eradication.

Table A5: Test results for the poppy suitability index

	Whole country		Sample	
	Eradicated fields (1)	Eradicated area (ha) (2)	Eradicated fields (3)	Eradicated area (ha) (4)
Poppy Suitability	270.9***	37.6***	382.7**	45.9***
	(85.8)	(12.5)	(151.2)	(17.2)
Observations	22,095	22,095	6,516	6,516
Adj. R-squared	0.051	0.055	0.077	0.083
Mean	50.3	5.8	50.3	5.8
Year FE	X	X	X	X
State FE	X	X	X	X

Notes: This table tests the relationship between the poppy suitability index and two proxies for poppy production: the annual number of eradicated fields and the total hectares of poppy eradicated. This table includes estimates for the whole country and the sample used in this paper. Standard errors clustered at the municipality level are shown in parentheses. All specifications include state and year-fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A.4.2 Heroin prices

Information on heroin retail prices (adjusted per purity) for the U.S. was obtained from the United Nations Office on Drugs and Crime (UNODC) for each year between 1990 and 2018.[49] Figure A6 shows heroin retail prices in the U.S., adjusted by purity, and the price of Afghanistan dry opium paste as a reference.[50] It shows that, without being adjusted for purity, U.S. heroin prices have remained relatively stable over the last two decades, at around USD$300 per gram, with an increase between 2016 and 2018, reaching USD$400 per gram. Meanwhile, prices per gram adjusted for purity show significant fluctuations.[51]

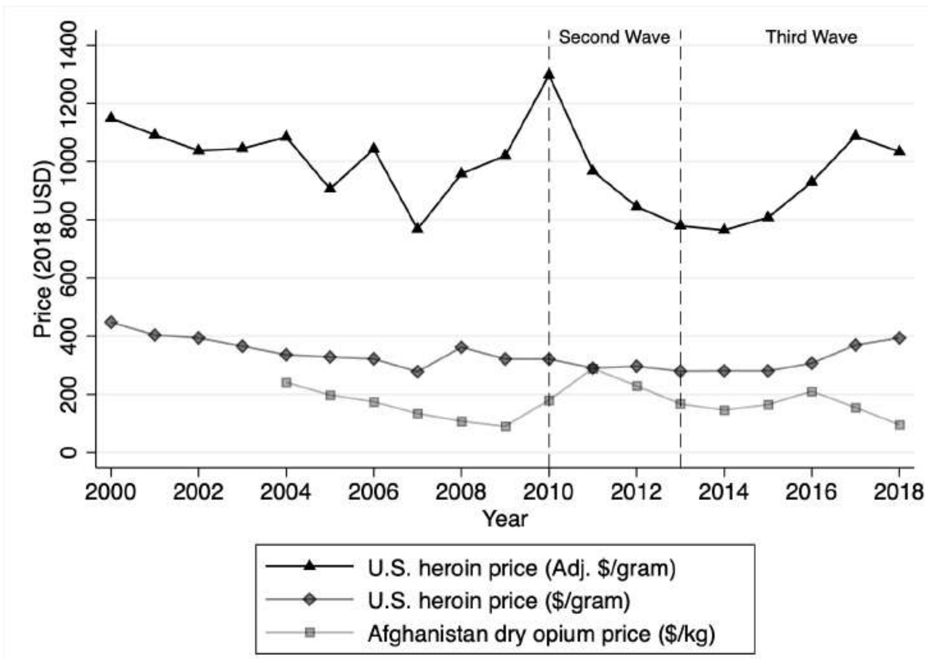
[49] Because heroin is often laced with other substances, such as Fentanyl, it is analyzed in labs to determine its purity, and prices are adjusted to hold quality constant (Hughes et al., 2020; Anthony et al., 2008).

[50] Information on Afghanistan's average farm-gate prices of opium was obtained from the UNODC for 1994-2018.

[51] This rare behavior is part of a pricing strategy by dealers. Since the quality of heroin is hardly observable even to the most experienced consumers, dealers sell at a fixed price to consumers but earn higher profits by decreasing the quality of heroin sold (Office of National Drug Control Policy, 2001; Hoffer and Alam, 2013). For instance, between 1990-2000, a one-milligram bag of heroin would be sold for USD$20 (Office of National Drug Control Policy, 2001). This explains why retail prices (not adjusted for purity) remain stable over time. This pricing strategy allows drug

In contrast to non-adjusted retail prices, prices adjusted per purity experienced a decrease after the second wave, when the demand for heroin increased. After 2013, prices of heroin, as reported by the DEA, showed an increase. While this contradicts the prices observed by farmers in Mexico (Semple, 2019; Le Cour Grandmaison et al., 2019),[52] the disparity in prices of opium perceived by farmers and heroin prices in the U.S. can be explained by how these prices are obtained.

Figure A6: U.S. retail heroin prices, adjusted per purity, and Afghanistan dry opium paste price



Source: Data from the UN Office on Drugs and Crime. This graph shows prices of heroin per gram of heroin in the U.S. (retail and adjusted per purity) and Afghanistan dry opium prices per kilogram.

While heroin prices in the U.S. are usually used in the literature (e.g., Sobrino (2019)), in this paper, I argue that they may not be representative of prices perceived by DTOs and farmers in Mexico. Prices of heroin in the U.S. are estimated based on purchases by undercover agents and informants of the DEA and state and local agencies (Arkes et al., 2008). However, not all acquisitions are part of this database – only the ones sent to a laboratory. Additionally, these purchases are part of criminal investigations, and, therefore, they do not constitute a random sample of the price paid by consumers (Horowitz, 2001). The price in these purchases also varies

dealers to sell heroin mixed with other diluents to lower their costs while maintaining the same price. In contrast to other diluents, Fentanyl allows dealers to continue to provide the same high to consumers while increasing their profits (DEA, 2020a).

[52] As mentioned in Section 2.2, between 2017 and 2018, poppy farmers in the states of Nayarit and Guerrero perceived a decrease in opium prices of around 50% (Le Cour Grandmaison et al., 2019); such a decrease is not observed in Figure A6.

significantly between agencies, as local law enforcement may be more acquainted than the DEA with local drug dealers and can obtain heroin at lower prices, which raises questions about the internal validity of this data (Horowitz, 2001).

Moreover, heroin prices reported in undercover deals may be biased, because agents pay higher prices than the average consumer (Caulkins, 2007), since i) they have lower bargaining power and ii) they make larger purchases than the average consumer. For instance, DEA undercover purchases must be of at least one gram to ensure a sufficient amount of heroin to identify its origin (GAO, 2002); in practice, purchases by the DEA are more likely to be over 5 grams (Arkes et al., 2008). Prices adjusted by purity obtained through these large purchases are likely to be non-representative of market prices because quality is positively correlated with quantity sold (Office of National Drug Control Policy, 2001).[53]

Finally, the increase in prices observed after 2014 may be partially attributed to changes in sampling. According to the DEA's 2019 National Drug Threat Assessment, new undercover purchases in rural areas, where transportation costs are high, and there is limited availability of drugs, could be the reason behind the increase in the reported price of heroin (DEA, 2020a). Unfortunately, detailed information on each purchase is no longer available, and I cannot correct for the change in sampling. Therefore, I argue that data on heroin prices in the U.S. is not a good proxy for prices perceived by cartels. It is not only subject to measurement error but also fails to capture changes in the opioid market in Mexico. Because of this, I do not use heroin prices for this analysis.

Despite the above, there is increasing evidence of the escalating presence of Fentanyl and a corresponding decline in the demand for heroin. According to the DEA (2021), laboratory reports involving heroin decreased by 13% between 2018-2019. Meanwhile, heroin prices in New Jersey decreased by 18% between 2017 and 2018, in contrast to a 50% increase in the price of Fentanyl (DEA, 2020a).

[53] The Office of National Drug Control Policy (ONDCP) estimates that purity for a wholesale distributor would be about 60%, for a mid-level distributor 40%, and 13% for a small distributor (Office of National Drug Control Policy, 2001).

A.5 Robustness Checks

A.5.1 Violence outcomes

In this section, I present evidence demonstrating the robustness of the results to different specifications. First, I provide robustness checks to mitigate potential concerns regarding the correlation between the avocado and poppy suitability index. Second, I show that my results are robust to using heroin mixed with Fentanyl overdoses, rather than Fentanyl-related overdoses. Finally, I show my results remain robust after controlling for places suitable for other legal crops.

Table A6 shows the results of the effect of Fentanyl on homicides when adding an interaction term between the two suitability measures ($S_i^a \times S_i^p$). I find that the estimates closely align in magnitude and show a similar behavior consistent with the main results (elevated homicides in avocado-rich municipalities and reduced homicide rates in poppy-suitable municipalities). Moreover, in all specifications, the interaction coefficient is relatively small and not statistically significant. Thus, there is no evidence of a joint effect.

Table A6: Results on the effect of Fentanyl on violence

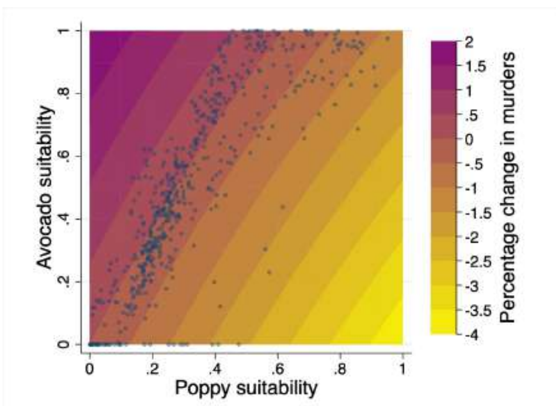
	Log(Murders)			
	All	Agricultural workers	Potentially cartel related	Rest of population
	(1)	(2)	(3)	(4)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.194	0.231**	0.156	0.169
	(0.121)	(0.098)	(0.121)	(0.107)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.392*	-0.414*	-0.294	-0.263
	(0.221)	(0.226)	(0.231)	(0.193)
Avocado Suitable × Poppy Suitable × Log(Fentanyl$_{t-1}$)	0.0771	0.0684	-0.00166	0.0258
	(0.268)	(0.243)	(0.285)	(0.246)
Observations	6516	6516	6516	6516
Adj. R-squared	0.395	0.331	0.358	0.368
Mean dep. var.	2.441	1.065	1.198	1.682
Controls	X	X	X	X
Year FE	X	X	X	X
Municipality FE	X	X	X	X

Notes: Clustered standard errors at the municipality level in parentheses. All outcome variables are the log of the number of cases. All regressions control for municipal mayor party, a binary variable indicating whether the party coincides with the President party, a marginalization index, and poppy eradication. Potentially cartel-related murders are homicides of men ages 16-40 killed by a firearm that do not work in the agricultural sector. The rest of the population are homicides of individuals that are not potentially related to cartels and do not work in the agricultural sector. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

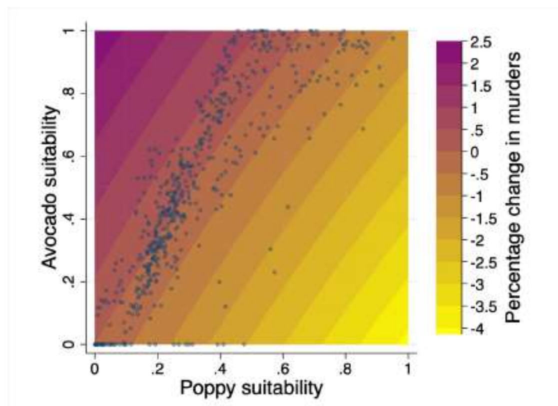
Figure A7 shows the marginal effect of a 10% increase in Fentanyl overdose deaths corresponding to the new specification. Consistent with the previous results, the marginal effect results show a similar pattern as the main results. Finally, Figure A8 and A7 show the estimates from this specification on the effect of Fentanyl on other crimes. In all cases, I find the main results to be robust to this specification.

Figure A7: Robustness check: Marginal effect of a 10% increase in Fentanyl overdose deaths on murders in avocado and poppy suitable municipalities

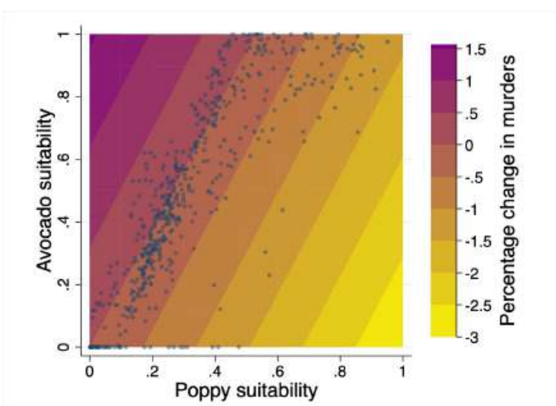
(a) All murders



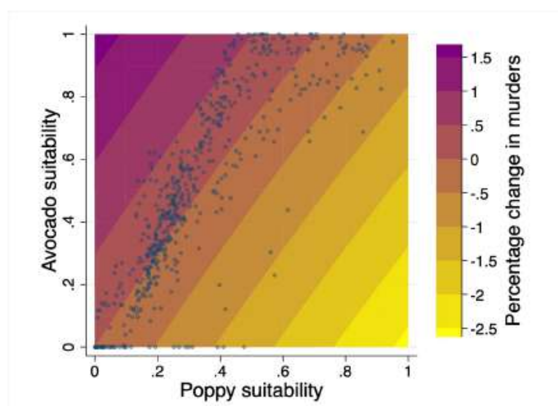
(b) Agricultural workers



(c) Potentially cartel related



(d) Rest of the population



Notes: Figure constructed from the coefficient estimates for Table A6. Panels (a)-(d) show the marginal effect of a 10% increase in Fentanyl overdoses on murder rates for all combinations of poppy and avocado suitability levels. The scatter plot shows the support for the estimations. Potentially cartel-related murders correspond to the homicide rate of men ages 15-40 killed by a firearm who did not work in the agricultural sector. The rest of the population includes all homicides except for potentially cartel-related and agricultural workers.

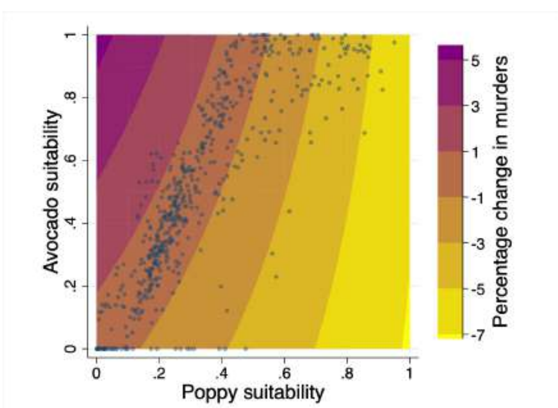
Table A7: Results on the effect of Fentanyl on other crimes

	Violent theft (1)	Truckload theft (2)	Extortion (3)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.565***	0.690***	-0.546***
	(0.198)	(0.149)	(0.097)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.718*	-0.553**	-0.710***
	(0.422)	(0.254)	(0.184)
Avocado Suitable × Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.489	-0.300	1.210***
	(0.454)	(0.315)	(0.218)
Observations	4726	4726	6174
Adj. R-squared	0.638	0.431	0.423
Mean dep. var.	2.902	0.284	0.758
Year FE	X	X	X
Municipality FE	X	X	X

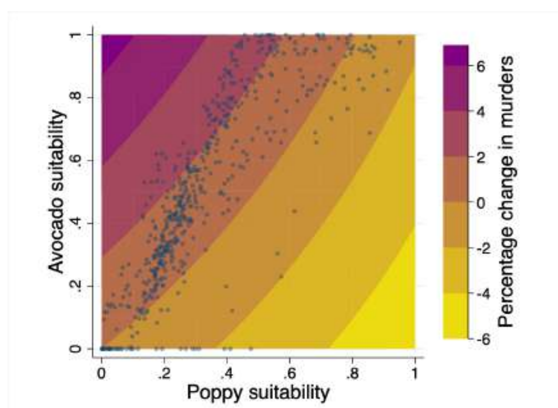
Notes: Clustered standard errors at the municipality level in parentheses. All outcome variables are the log of the number of cases per 100,000 inhabitants. All regressions control for the municipal mayor party, a binary variable indicating whether the party coincides with the President party, a marginalization index, and poppy eradication. Violent thefts include thefts of households, businesses, and pedestrians, among others in which criminals used violence. Truckload thefts are reports of cargo trucks attacked on a highway. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure A8: Marginal effect of a 10% increase in Fentanyl overdose deaths on crime rates in avocado and poppy suitable municipalities

(a) Theft with violence



(b) Truckload theft



Notes: Figure constructed from the coefficient estimates for Table A7. Panels (a)-(b) show the marginal effect of a 10% increase in Fentanyl overdoses on theft rates for all combinations of poppy and avocado suitability levels. The scatter plot shows the support for the estimations.

As mentioned before, the introduction of Fentanyl in the U.S. market can decrease the demand for heroin in two ways: i) dealers mix heroin with Fentanyl and, thus, directly reduce their demand for heroin, and ii) consumers can substitute heroin for the cheaper alternative, Fentanyl. So far, my empirical strategy has only used information on Fentanyl overdoses and does not provide further evidence on whether dealers mixing heroin with Fentanyl is a mechanism for the changes observed in violence in Mexico. To test this, I estimate Equation 1 using overdoses of heroin mixed with Fentanyl. Table A8 shows the estimations for this specification.

Table A8: Results on violence with mixed heroin overdoses

	Log(Murders)			
	All	Agricultural workers	Potentially cartel related	Rest of population
	(1)	(2)	(3)	(4)
Avocado Suitable × Log(Mixed heroin$_{t-1}$)	0.0835*	0.110**	0.0843*	0.0630
	(0.050)	(0.044)	(0.048)	(0.042)
Poppy Suitable × Log(Mixed Heroin$_{t-1}$)	-0.131*	-0.156**	-0.147*	-0.0976
	(0.076)	(0.066)	(0.076)	(0.066)
Observations	6516	6516	6516	6516
Adj. R-squared	0.395	0.332	0.359	0.368
Mean dep. var.	2.441	1.065	1.198	1.682
Controls	X	X	X	X
Year FE	X	X	X	X
Municipality FE	X	X	X	X

Notes: Clustered standard errors at the municipality level in parentheses. All outcome variables are the log of the number of murders per 100,000 inhabitants. All regressions control for municipal mayor party, a binary variable indicating whether the party coincides with the President party, and baseline time trends on municipal marginalization and poppy eradication. Potentially cartel-related murders are homicides of men ages 15-40 killed by a firearm that do not work in the agricultural sector. The rest of the population are homicides of individuals who are not potentially related to cartels and who do not work in the agricultural sector. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Consistent with my previous findings, these results show a positive correlation between heroin mixed with Fentanyl overdoses and homicides in avocado-suitable municipalities and a negative relationship for poppy municipalities. In particular, I find that mixing heroin with Fentanyl led to a rise in homicides of agricultural workers in avocado municipalities and a decrease in poppy municipalities. The main difference with the previous specification is that I find a statistically significant increase in potentially cartel-related murders in avocado municipalities and no effect on homicides in the rest of the population for both types of municipalities. However, the signs remain the same. While these results show evidence consistent with my hypotheses, it is not my preferred specification since heroin is not entirely exogenous to violence in Mexico.

Finally, I look into whether my estimates could be driven if municipalities suitable for avocados are also suitable for other crops that might be profitable for drug cartels. To control for this, I added suitability measures for six other crops, each index interacted with year dummies. Information on crop suitability was obtained from municipality-level estimations from (Dube et al., 2016) based on raster data from FAO's Global Agro-Ecological Zones (GAEZ v3.0). Dube et al. (2016)'s measure is the average of FAO's indices obtained through simulations using different assumptions.[54] Table A9 shows estimates for all main outcomes using the different suitability measures as controls. I find my results to be robust to this specification.

Table A9: Results accounting for suitability to other legal crops

	Murders		No. of Cartels		Other Crimes	
	All Murders (1)	Ag. Workers (2)	All Cartels (3)	Heroin Cartels (4)	Violent Theft (5)	Truckload Theft (6)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.296***	0.351***	0.0676	0.0390	0.807***	0.763***
	(0.114)	(0.102)	(0.054)	(0.025)	(0.189)	(0.142)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.428**	-0.442***	-0.0646	-0.0351	-1.385***	-1.073***
	(0.180)	(0.146)	(0.081)	(0.037)	(0.309)	(0.224)
Observations	6120	6120	6120	6120	4421	4421
Adj. R-squared	0.391	0.328	0.737	0.534	0.615	0.460
Mean dep. var.	2.402	1.089	0.723	0.325	2.797	0.296
Year FE	X	X	X	X	X	X
Municipality FE	X	X	X	X	X	X

Notes: This table presents the results of controlling suitability of other legal crops. Clustered standard errors at the municipality level in parenthesis. Fentanyl overdoses are expressed in logarithmic form. Homicide rates, number of cartels and theft rates are also expressed in logarithmic form. All regressions control for municipal mayor party, a binary variable indicating whether the party coincides with the President party, a marginalization index, and poppy production. Additionally, all regressions include a set of six crop suitabilities, each interacted with year dummies. Heroin cartels are DTOs mentioned by the DEA as specializing in heroin trafficking. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.5.2 Entry and exit of cartels

To look more precisely into changes in cartel presence, I estimate Equation 1 on different measures for cartel entry and exit. Table A10 shows the results for a fixed effects model with year and municipality fixed effects. All specifications include covariates. Columns (1) and (2) show the results on cartel entry, and Columns (3) and (4) on exit. Columns (1) and (3) show the results using as a dependent variable the number of cartels that entered/exited a municipality at time t. Columns (2) and (4) show the coefficients when using as a dependent variable a binary variable equal to one

[54] Crop suitability for 15 different crops are available from Dube et al. (2016); however, I focus on crops more likely to be targeted by cartels. Estimates are also robust to controlling for all 15 crops and are available upon request.

if the municipality had an entry/exit. For all these, the reference group are municipalities that do not experience a change between time t and $t+1$. That is, for entry, I omit municipalities that experienced an exit, and for exit, I omit those that had an entry. Table A10 shows no statistically significant effect of Fentanyl for any of these specifications, consistent with my previous findings of no changes in cartel presence.

Table A10: Results on cartel entry and exit

	Entry		Exit	
	One or multiple (1)	Any cartel (1/0) (2)	One or multiple (3)	Any cartel (1/0) (4)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.0157	0.0389	-0.00881	0.0173
	(0.118)	(0.037)	(0.099)	(0.024)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.0863	-0.0674	0.0511	0.0342
	(0.186)	(0.056)	(0.145)	(0.036)
Observations	5038	5038	4567	6516
Adj. R-squared	0.385	0.390	0.366	0.0652
Mean dep. var.	0.945	0.387	0.681	0.227
Year FE	X	X	X	X
Municipality FE	X	X	X	X

Notes: This table provides estimates on entry and exit of cartels. Columns (1)-(2) provides estimates on entry and Columns (3)-(4) on exit. One or multiple are continuous variables indicating the number of cartels entering/exiting a municipality. Any cartel is an indicator variable equal to one whenever a cartel entered/exited in that year and zero, otherwise. Fentanyl overdoses are expressed in logarithmic form. Avocado and poppy suitability are indices between one and zero, where one indicates that a municipality has optimal conditions. All specifications include covariates. Clustered standard errors at the municipality level are in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

A potential concern with this specification is that data may be noisy and that, by only looking at changes between t and $t-1$, I am not capturing the effect on municipalities that did not have a cartel presence. To verify my results, I estimated the equation considering only municipalities with no cartel presence during k years before time t, with k going from 1 through 4. Estimates were robust to any of these specifications.

A.5.3 Estimates on heroin cartels

In this section, I look into the effect of the introduction of Fentanyl on cartel presence of the cartels identified by the DEA as distributors of heroin (DEA, 2021). In particular, I look into the movement of nine cartels: the Sinaloa Cartel, Cartel Jalisco Nueva Generación (CJNG), the Juarez Cartel, Gulf, Los Zetas, Beltrán-Leyva Organization, La Familia Michoacana, Los Rojos and Guerreros Unidos.

Table A11 shows the results on the presence of these cartels. Cartels in Columns (1)-(7) correspond to cartels that are part of the most dominant criminal organizations (*main cartels*) according to the DEA. The results show no statistically significant effects for most of them, except for Los Zetas and Los Rojos. For these two cartels, I observe that Los Zetas and Los Rojos are more likely to be present in avocado-suitable municipalities and less in those suitable for poppy. An interesting characteristic of these two cartels is that both of them have as their mother group the Gulf Cartel. Even though Los Zetas splintered from the Gulf Cartel and Los Rojos is a known faction of the Gulf Cartel, both are considered fragmented in my data since they operate independently and are recognized as different criminal organizations. These results are consistent with the results from Table 3, where I find that fragmented cartels are more likely to enter an avocado municipality.

Table A11: Results on cartel presence by DTO

	Sinaloa	CJNG	Juarez	Gulf	Los Zetas	Beltrán-Leyva	Fam. Michoacana	Los Rojos	Guerreros Unidos
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.0224	0.00749	0.00367	0.00463	0.0573**	-0.0409	0.0268	0.0548***	-0.0110
	(0.025)	(0.032)	(0.015)	(0.021)	(0.027)	(0.028)	(0.026)	(0.015)	(0.019)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.0360	-0.0196	-0.0176	-0.00273	-0.0777*	0.0271	-0.0142	-0.0666***	0.0122
	(0.036)	(0.050)	(0.021)	(0.035)	(0.043)	(0.044)	(0.038)	(0.018)	(0.032)
Observations	6516	6516	6516	6516	6516	6516	6516	6516	6516
Adj. R-squared	0.451	0.544	0.418	0.424	0.479	0.562	0.551	0.524	0.547
Mean dep. var.	0.183	0.337	0.0463	0.106	0.200	0.170	0.221	0.0522	0.134
Year FE	X	X	X	X	X	X	X	X	X
Municipality FE	X	X	X	X	X	X	X	X	X

Notes: This table provides estimates on cartel presence for the main DTOs in Mexico linked to the trafficking and cultivation of heroin. All outcomes are binary variables equal to one of a cartel was present in a municipality, and zero otherwise. The cartels in Columns (1)-(7) correspond to the main Mexican DTOs recognized by the DEA. Fentanyl overdoses are expressed in logarithmic form. Avocado and poppy suitability are indices between one and zero, where one indicates that a municipality has optimal conditions and zero is unsuitable. All specifications include covariates. Clustered standard errors at the municipality level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$