Avocados: Mexico's green gold. The U.S. opioid crisis and its impact on Mexico's drug cartel violence*

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Abstract

The global increase in the demand for avocados has attracted the attention of rent-seeking criminal organizations in Mexico. As a result, farmers and packing houses have become the targets of drug trafficking organizations (DTOs). This paper aims to answer whether declining drug revenues have motivated cartels to target licit businesses, such as avocado farms, rather than continue specializing in the production and distribution of illicit drugs. To do this, I exploit exogenous variation in the demand for pure heroin in the U.S. between 2011 and 2019. In particular, I use the introduction of Fentanyl in the U.S. as a proxy for the reduction in the demand for pure heroin in Mexico to answer whether this led to an increase in homicides and cartel presence in avocado- and poppy-growing municipalities. Using municipal level data, I show that the decrease in the demand for heroin increased homicide rates (including those of agricultural workers) in avocado-growing municipalities. I find no evidence of higher cartel presence in these municipalities, suggesting that, while DTOs do not seem to be moving into these municipalities, they have become more violent toward civilians. Furthermore, I find that the fall in the demand for heroin led to a decrease in cartel presence and homicide rates in poppy-growing municipalities. Overall, this paper provides evidence of inter-sector spillovers resulting from drug demand changes.

JEL Classifications: K42, O12, O13, O17, Q17

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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] In particular, cartels target avocado farmers and packinghouses by extracting protection fees from them (Linthicum, 2019). Moreover, between 7 and 10 avocado truckloads are stolen every week in the state of Michoacán (Agren, 2019).

This paper analyzes the impact of declining drug revenues on violent crimes in avocado-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)

The fall in opium revenues has been attributed to a decrease in the demand for pure Mexican heroin caused 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

[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).

et al., 2019; Financial Times, 2020; Centers for Disease Control and Prevention, 2021). As the availability of Fentanyl rose in the U.S. starting in 2014, drug dealers started using Fentanyl to dilute other drugs, such as heroin, to increase these drugs' potency while lowering the dealers' costs (Drug Enforcement Administration, 2020b). Additionally, drug consumers have increasingly turned to Fentanyl because it provides a potent and cheap alternative (Felter, 2022). This is of foremost importance to Mexico, the third major producer of heroin and the leading supplier to the U.S., with over 90% of the heroin available in the U.S. market coming 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-growing municipalities in Mexico. Using detailed information on homicides obtained from the Mexican Department for Health Information (DGIS), and cartel presence data from the Mapping Criminal Organizations in Mexico project, this paper seeks to answer two particular questions: i) Did the introduction of Fentanyl increase the number of murders in poppy- and avocado-suitable municipalities?, and ii) Did the opioid crisis increase cartel presence in avocado-suitable municipalities?

Changes in the prices of commodities have been used to measure the effect on violence of changes in the demand for a good (Sobrino, 2019; Dube et al., 2016). However, using this strategy has several problems in this context; for instance, heroin prices measured through undercover purchases are subject to measurement error, 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 to 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. This paper contributes to the literature on crime by providing a novel alternative to circumvent potential problems of endogeneity in changes in prices.

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. In particular, I use information on the eight leading states in the production of avocados in Mexico. This includes the state of Michoacán, the major exporter of avocados in the country and the only one authorized as of 2021 to export avocados to the

U.S. (Ambrozek et al., 2018), and the state of Guerrero, the country's main producer of opium (Le Cour Grandmaison et al., 2019).

My results show that the decrease in the demand for heroin increased murders in avocado-growing municipalities, particularly among agricultural workers and the general population. Contrary to what would be expected, I observe no effect on the number of cartels present in these municipalities and no impact on potentially inter-cartel-related murders. This suggests that cartels are not more likely to enter these municipalities, and that they mainly target civilians rather than confronting other cartels. Further evidence of this is increasing rates of thefts in which violence is present and truckload thefts in avocado-growing municipalities. Meanwhile, poppy-growing municipalities show significant decreases in homicide rates among agricultural workers and the general population. I find a negative but not statistically significant relationship between Fentanyl and cartel presence in poppy-growing municipalities, suggesting that cartels still have incentives to remain in control of these areas. I also find evidence of lower theft rates in these municipalities.

This paper contributes to the literature on crime by providing further evidence on 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; Miguel et al., 2004). On the other hand, more income increases the returns to appropriation (Angrist and Kugler, 2008; Chimeli and Soares, 2017; Parker and Vadheim, 2017; Dube and Vargas, 2013). In other words, individuals have higher 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 and empirical evidence shows 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 on this relationship, by looking into the effects of a change in the demand for heroin on violence in two labor-intensive sectors.

More importantly, this paper provides a new explanation as to why cartels diversify. So far, the literature has found that diversification is driven by greater cartel competition resulting from the Mexican government's kingpin strategy between 2006 and 2012 (Magaloni et al., 2020; Herrera and Martinez-Alvarez, 2022; Jones, 2013).[5] Although this is a reasonable explanation, it does not fully explain more contemporary events, since the federal government strategy against cartels has changed since 2012.

While this study is not the first to look at the effect of changes in the demand for heroin in the U.S. on violence in Mexico (see Sobrino (2019)), it is the first to look into the effect of the introduction of Fentanyl in the U.S., and more specifically its impact in the avocado sector. My paper differs substantially from Sobrino (2019)'s study in three main ways. First, Sobrino (2019) focuses on the 2010 OxyContin reformulation that led to an increase in the demand for heroin in the U.S., while I look into the period post-2010 when the introduction of Fentanyl decreased the demand for heroin. Second, Sobrino (2019) uses changes in the prices of heroin in the U.S. for identification, while I use Fentanyl overdoses to proxy for the availability of Fentanyl in the U.S. Finally, I use different methodologies to measure poppy suitability in Mexico. While Sobrino (2019) uses a machine learning approach to build an index based on opium yield data and conditions from Afghanistan, I use a well-established model used by agronomists. My model uses data from the UN Food and Agriculture Organization (FAO) on agro-climatic requirements for poppy growing to create a suitability index.

This paper is organized as follows. Section 2 describes the background. This includes information on the U.S. opioid crisis and its effect on violence in Mexico. Section 3 describes the conceptual framework. Sections 4 and 5 include a description of the data used and the empirical strategy. Finally, Section 6 contain the main results on violence and cartel presence.

[5] 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).

2 Background

2.1 Production of Mexican avocados

The *Persea americana*, commonly known as avocado, is a semi-tropical tree native to Mexico, Central America, and South America. The most common variety of avocado used for exportation purposes is the Hass avocado.[6] Hass trees have a long flowering period and can bloom up to three times a year, making it possible for them to be harvested year-round if conditions are optimal.[7] Moreover, avocados ripen off the tree and can be stored in the tree for several weeks. Because of this, avocados are usually sold at the tree for a fixed price (Hass Avocado Board, 2019).

Avocados are labor-intensive goods that take at least five years to be able to bear fruit. Farmers are mainly in charge of cultivating and fertilizing the avocado trees (USDA, 2020). Most of the production in Mexico is carried by small producers that own or rent land. The picking of trees is considered the most labor-intensive part of the production process. This is usually done by contractors hired by exporters. The contractors choose the avocados that fit the size requirements for exportation and leave the rest to mature at the tree (Hass Avocado Board, 2019).

As the nutritional properties of avocados have become more widely known, avocados have gained popularity in many parts of the world, leading to an increase in the global demand for this fruit. This has important implications for Mexico, the world's largest producer and exporter of avocados in the world, with a total production of over 2 million tons in 2018 (SENASICA, 2017). Currently, Mexico produces more than a third of the global production, from which over 75% of the total volume exported of avocados goes into the U.S (Hansen, 2017).

Most of the avocados in Mexico are grown in the state of Michoacán, located in the west-center area of Mexico. By itself, Michoacán produces over 76% of the total national production, followed by its neighboring state, Jalisco, with 9.2%. Michoacán is also the leading exporter of avocados, accounting for over 90% of the country's exports of this fruit (USDA, 2018). Moreover, as of April 2022, Michoacán was the only state in Mexico authorized to export avocados to the U.S., with Jalisco just recently allowed (The Associated Press, 2021).

[6] This variety of avocado was discovered in California in 1926 and is preferred in the global market due to its high resistance to plagues, high quality of its pulp, and high oil content (Hofshi, 2001).

[7] Mexico is the only country that has the optimal conditions for avocados to be harvested year-round, which gives it a comparative advantage compared to other growing countries (Ambrozek et al., 2018).

2.2 Cartel violence in the avocado sector

The increase in the demand for avocados and the resulting increased revenues have attracted the attention of criminal organizations. In recent years, reports have appeared of DTOs demanding protection money from farmers (Linthicum, 2019; de Cordobá, 2014; Padgett, 2013; Rainsford, 2019). While there is no consensus on the amount, reports on the annual fee range between US$150 per hectare in 2014 to $250 in 2019 (de Cordobá, 2014; Linthicum, 2019).[8] Moreover, local authorities in the municipality of Tancítaro– the largest producer of avocados in the country– estimate that, in 2014, Los Caballeros Templarios may have obtained up to US$150 million per year from extortion in the avocado sector (de Cordobá, 2014).

Additionally, avocado theft has increased, with an average of 7 to 10 truckloads stolen every week in Michoacán. Each truck carries about 8 tons of avocados destined for exportation, with an average value of US$10,000 per truck (García Tinoco, 2019; Agren, 2019).[9] Moreover, DTOs have also targeted USDA avocado inspectors. The USDA had to temporarily suspend its avocado inspection program in August of 2019 after its employees in Uruapan received threats (Linthicum, 2019). More recently, the U.S. temporarily banned imports of Mexican avocados for the same reason (The Associated Press, 2022).

2.3 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).[10] 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

[8] DTOs are sophisticated. They can charge differentiated prices to farmers, with specific quotes for every avocado plant bought in a greenhouse and more extensive quotes per hectare of production for farmers that export. They can also differentiate each farmer and charge fees accurately because they have access to information on the number of avocado trees planted and the fields' size (Padgett, 2013).

[9] The estimates are based on an exchange rate of 20 Mexican pesos per U.S. dollar.

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

farmers for a kilogram of raw opium paste was about 15,000 pesos (USD$1,175),[11] 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 pure heroin across the border. These cartels then sell it to U.S. DTOs at a wholesale price (Le Cour et al., 2019).

U.S. drug trafficking organizations buy pure heroin from drug cartels in Mexico. They separate it into small quantities and sell it to consumers at a retail price. This point in the distribution is where heroin is diluted with other substances, like Fentanyl, as a strategy for retailers to increase their markups (Drug Enforcement Administration, 2021). According to the DEA and U.S. Customs and Border Protection (CBP), seizures of heroin mixed with Fentanyl are rare at the southern border, [12] suggesting that diluting pure heroin at the wholesale level is not currently part of the distribution strategy (Drug Enforcement Administration, 2021).

2.4 The U.S. opioid crisis

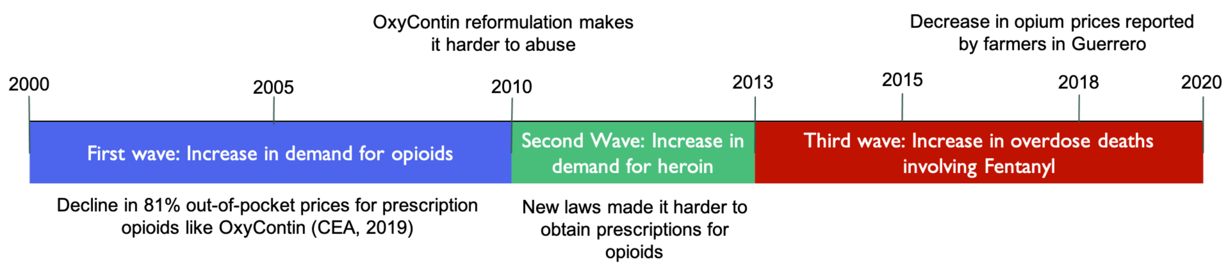
According to the U.S. Centers for Disease Control and Prevention (CDC), the opioid crisis can be characterized by three different waves (see Timeline in Figure 1). The first one has its origin in the

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

[12] According to the DEA, out of all wholesale seizures of powder in the U.S., only 16% of the total weight corresponds to Heroin-Fentanyl mixes. Meanwhile, at the retail level, 32% corresponds to heroin laced with Fentanyl (Drug Enforcement Administration, 2021).

increase of prescribed opioids in the late 1990s, with 1999 often regarded as the first year of this wave (CDC, 2021; UN, 2020). This wave resulted from an increase in overdose deaths involving misuse of prescription opioids. The rise in prescribed opioid addiction has been attributed to the pharmaceutical industry's efforts to promote the use of opioids for pain management by downplaying its risks and encouraging doctors to prescribe them (Van Zee, 2009). Moreover, obtaining opioids was relatively cheap. Between 2001 and 2010, the out-of-pocket price for opioids declined by 81 percent (CEA, 2019). This, along with extensive marketing campaigns promoting their widespread use, made them easy to abuse and contributed to more people becoming addicted. Figure 2 shows the evolution of overdose deaths in the U.S. by the type of opioid after each wave.

Figure 1: Timeline of the U.S. opioid crisis



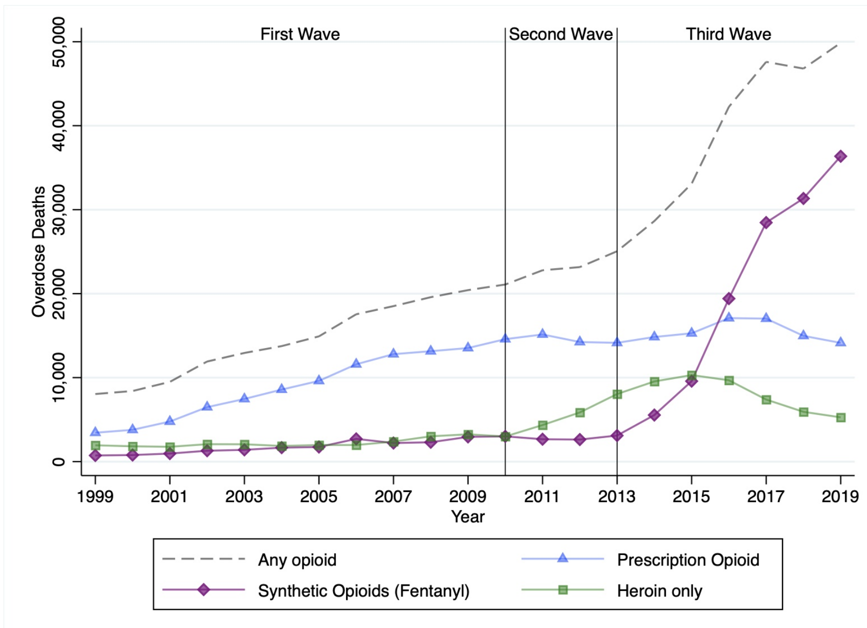
The second wave began in 2010 after the U.S. increased restrictions on opioids (CEA, 2019). As a result, people substituted heroin for prescribed opioids. An increase in heroin overdoses characterizes the second wave (CDC, 2021). To decrease overdose deaths resulting from the first wave, the government increased restrictions on prescriptions for opioids and changed the formulation of extended-release pills such as OxyContin to make them harder to abuse (CEA, 2019).[13] While these measures did decrease the number of overdoses due to prescribed opioids, they also had the unintended consequence of increasing the demand for illicit opioids, such as heroin. Individuals who used to consume pills substituted with readily available and less expensive illegal opioids. Between 2002 and 2011, 79.5 percent of new heroin users had previously taken prescription pain relievers without having them prescribed (Muhuri et al., 2013).

Finally, during the third wave (2013-2021), the U.S. saw an increase in overdoses involving a mix of heroin with Fentanyl (CDC, 2021). Fentanyl is a synthetic opioid analgesic often used to treat

[13] 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).

severe pain, since it is between 50 and 100 times more potent than morphine (Centers for Disease Control and Prevention, 2021). Drug dealers often mix Fentanyl with heroin because it is cheap and provides the same high as pure heroin with higher profit margins. Furthermore, Fentanyl's potency makes it easier for individuals to overdose if they are unaware that they purchased heroin with Fentanyl. Between 2013 and 2019, the total number of overdose deaths from Fentanyl increased by tenfold, from 3,105 overdose deaths in 2013 to over 36,300 in 2019.[14]

Figure 2: Opioid overdose deaths in the U.S. 1990-2017



Notes: Constructed using information from the National Center for Health Statistics (NCHS). Fatalities from synthetic opioids are primarily due to Fentanyl and exclude overdoses from Methadone.

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

Mexico is currently the third-largest producer of opium in the world, following Afghanistan and Myanmar. It is responsible for supplying 6 percent of the total global opium production. Most of the heroin is produced in the northern states of Chihuahua, Sinaloa, and Durango– known as the Golden Triangle– and in Nayarit and Guerrero (see Figure 3). Guerrero alone accounts for around 60 percent of the country's opium production (Le Cour Grandmaison et al., 2019).

Mexico is also the major exporter of heroin to the U.S. It accounts for 90 percent of all heroin

[14]Source: own estimates with information from the National Center for Health Statistics (NCHS).

consumed in the U.S. (Le Cour Grandmaison et al., 2019). Because of this, any fluctuations in the demand for heroin in the U.S. can affect opium production in Mexico, cartel competition, and even violence. Sobrino (2019) finds that the increase in the demand for heroin after the reformulation of OxyContin in 2010 increased cartel entry in suitable poppy municipalities and, consequently, the number of murders.

Figure 3: Poppy production in Mexico

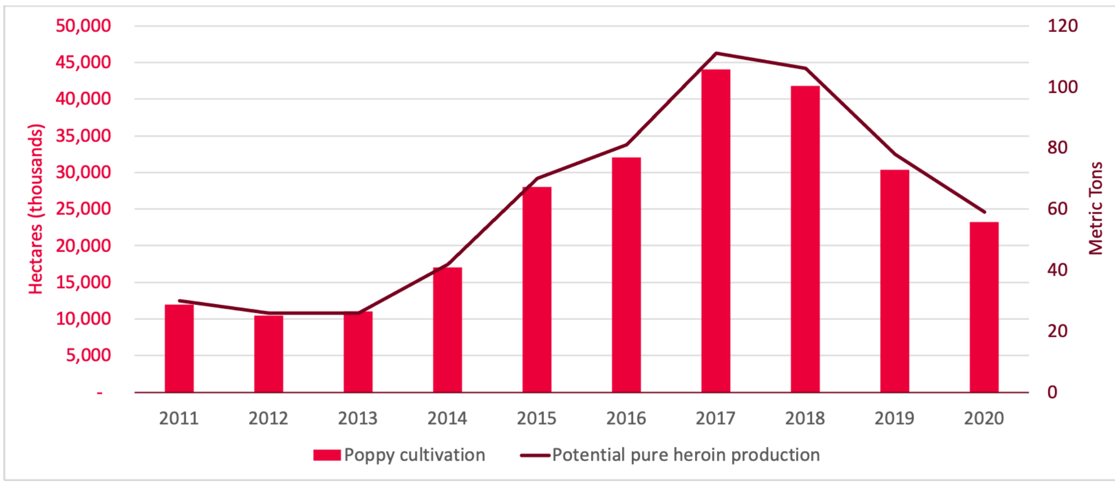
Source: Borrowed from Le Cour Grandmaison et al. (2019).

However, news reports and a recent survey indicate a different effect during the third wave. The introduction of Fentanyl decreased the demand for pure opium paste, and thereby reduced the prices received by opium farmers. In 2017, opium farmers in Guerrero reported selling opium resin at \$590 per pound, but by 2019 this price had fallen by 50% (Semple, 2019). A survey of two villages in the states of Nayarit and Guerrero also found evidence of a decrease in opium prices (Le Cour Grandmaison et al., 2019), with prices falling from \$950-\$1,050 per kg in 2017 to \$420 in 2018 (corresponding to a 50% decrease). Moreover, they estimated a reduction of almost 80 percent in opium prices in Guerrero over these two years.

With the fall of opium prices, poor farmers in rural areas in the state of Guerrero saw their primary means of income disappear, forcing some of them to migrate out of their communities (Semple, 2019). This led to a decrease in the area of poppy grown by farmers in Mexico. UN estimates based on satellite imagery showed that, in 2017-2018, 28,000 hectares of poppy were cultivated, in contrast to 30,600 ha in 2016-2017, corresponding to about a 9 percent decrease

(UNODC, 2020). Similarly, the White House Office of National Drug Control Policy (ONDCP) estimates a 24 percent decrease between 2019 and 2020, with an overall fall of 47 percent compared to 2017 (see Figure 4, ONDCP (2021)). In summary, empirical evidence seems to signal a decline in prices and in the hectares of poppy cultivated since 2007, three years following the start of the third wave of the opioid crisis and, consequently, the introduction of Fentanyl.

Figure 4: Potential poppy cultivation in Mexico (2011-2020)



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

3 Conceptual Framework

To understand cartel behavior, I start by assuming that drug trafficking organizations (DTOs) behave as profit-maximizing firms. These DTOs are multi-production firms that mainly produce and distribute illegal goods but can also engage in other criminal activities such as theft and extortion of licit businesses. In line with multi-product firms, a decrease in the revenue of one of the DTO's products can increase the effort put into another. Therefore, these cartels have incentives to diversify into other sectors to decrease their overall risk when the prices of illegal goods decrease.

This paper relies on some simplifying assumptions. First, I assume an economy with only two goods: illegal crops (poppy) and legal crops (avocados). Municipalities specialize in one of these two goods, and they do so based on their agro-climatic suitability. Moreover, I assume there is a fixed number of cartels that behave as profit-maximizing firms and decide on: i) entry into and exit from municipalities, and ii) whether they employ violence.

3.1 Cartel presence

In this market, cartels aim to control territories that can provide them with a technical advantage over their competition. For instance, territories that are suitable for the production of illegal drugs (e.g., poppy), strategic locations for the introduction of drugs and precursor substances[15] into the country (e.g., ports) and to gain access to consumer markets (e.g., border crossings to the U.S.) (Magaloni et al., 2020). Other territories provide access to profitable markets attractive to criminal organizations, such as mining regions in Colombia (Le Billon, 2001) and Congo (Parker and Vadheim, 2017).

Access to a strategic location is expensive, as it requires human capital, resources, and potentially fighting a rival cartel to access a territory. Therefore, cartels will decide whether to enter a location if the expected returns net of the entry costs are larger than continuing business as usual. This decision can be triggered by changes in the prices of illegal goods, as shown by Sobrino (2019), who finds evidence of cartels competing for poppy municipalities in response to a rise in heroin prices in the U.S.

Whether DTOs exit municipalities suited for growing illegal crops and enter municipalities that specialize in legal crops is not straightforward. Suppose a decrease in the demand for drugs from Mexico affects the revenues perceived by drug cartels and increases their concerns over the future profitability of the production of illegal drugs. Then, as their expected profits decrease, DTOs try to diversify and compensate for their lost profits. Moreover, they can do this by engaging in other violent activities, such as extortion, theft, and kidnapping.

At the same time, there is substantial wealth heterogeneity across municipalities. The richer a municipality is, the more resources are available for cartels to tap into. Therefore, the losses due to staying in the same municipality might be enough incentive for cartels to enter other highly productive markets, such as avocado municipalities. If expected returns are sufficiently high in these communities to make it worth the cost of entry (including the possibility of fighting another cartel for control of the territory), I expect to see an increase in cartel presence in municipalities that

[15] The production of certain drugs, such as methamphetamine, require precursor chemicals that are procured illegally from other countries (Drug Enforcement Administration, 2018).

produce legal crops, as the demand for illegal crops decreases. This leads to my first hypothesis:

Hypothesis 1 *As the demand for illegal drugs decreases, the number of cartels present in a legal crop municipality will increase.*

As for the presence of DTOs in municipalities suitable for illegal crops, whether or not a cartel exits will depend on its expectations over the future profitability of the place and the reduction of the market size. I hypothesize that the decrease in profitability from heroin will lower cartels' incentives to fight over a suitable poppy territory as the market size decreases and the cost of entry outweighs the benefit. However, cartels that already control a poppy municipality may have little incentive to exit a territory. This leads to my second hypothesis:

Hypothesis 2 *As the demand for illegal drugs decreases, the number of cartels present in an illegal crop municipality will remain constant.*

3.2 Use of violence

Cartels can decide whether or not to employ violence against competing cartels and civilians. I assume that DTOs use violence to fight against other cartels to gain control over a territory and/or enforce extortion payments from civilians. The excessive use of violence increases homicide rates in affected municipalities. I argue that DTOs have no incentives to use excessive force against civilians other than to extract revenue from them through theft or extortion.

As heroin profitability decreases relative to avocado profitability, cartels have higher incentives to enter a suitable avocado municipality. Since market share falls with the number of cartels, DTOs have incentives to gain control of a territory. Therefore, the entry of a cartel into a municipality already controlled by another cartel results in fighting, leading to higher murder rates (Sobrino, 2019). If this is the case, I expect to observe an increase in deaths related to cartel conflict. Moreover, even if the cost of entry is high, the decrease in heroin revenues may lead cartels already present in avocado-suitable municipalities to diversify their portfolio by extracting rents from civilians. If force is required to enforce payments, this may lead to higher murder rates in these municipalities, particularly among agricultural workers.

Conversely, in poppy-suitable municipalities, cartels may have fewer incentives to fight over these areas or to extract rent from civilians in the presence of decreasing heroin prices. Since maintaining control over territory is expensive, a decrease in the price of heroin can result in lower incentives for cartels to remain or fight over control of poppy-suited municipalities. This should be reflected in a reduction in the number of homicides related to cartel conflict. Moreover, the decrease in the cash flow in these areas decreases the marginal returns of using extortion against civilians (including agricultural workers) in these municipalities and, therefore, is expected to reduce the use of force. This would mean lower homicide rates for civilians, particularly agricultural workers. Considering all of the above, I expect to see lower murder rates in poppy-suitable municipalities. The previous statements lead to the following hypotheses:

Hypothesis 3 *As the demand for illegal drugs decreases, murders in legal crop municipalities will increase.*

Hypothesis 4 *As the demand for illegal drugs decreases, murders in illegal crop municipalities will decrease.*

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. For this reason, I focus my analysis on the main producers of avocados. In particular, I use data from states with over 0.2% of their agricultural land devoted to the production of avocados. This results in a sample of eight states: Michoacán, Morelos, México, Jalisco, Nayarit, Puebla, Colima, and Guerrero. These states account for over 94.7% of the average production of avocados between 2011 and 2019[16]. These states are contiguous and therefore share similar agro-climatic conditions. Moreover, each of these states accounts for at least 2% of the total production of avocados, except for Colima (0.33%). The sample also includes the state of Michoacán (the major producer of avocados in Mexico and the only state authorized to export Hass avocados to the U.S.) and the state of Guerrero (the main producer of poppy in the country)(Le Cour Grandmaison et al., 2019).[17]

I estimate my results between 2011 and 2019 for two reasons. First, it allows me to account for the years before and after the start of the third wave of the opioid crisis (2013). Second, after

[16]Source: own estimates based on information from SAGARPA.

[17]Guerrrero accounts for over 60% of the total national opium production (Le Cour Grandmaison et al., 2019)

2010, the behavior of cartels changed considerably. The government's "kingpin" strategy during the war against drugs (2006-2012) led to the fragmentation of Mexico's major DTOs.[18] This resulted in increased competition among DTOs (Atuesta and Ponce, 2017; Calderón et al., 2015; Jones, 2013) and changed their incentives to diversify (Herrera and Martinez-Alvarez, 2022). My resulting sample consists of 6,516 observations with information for 724 municipalities over nine years. Table 1 includes a detailed summary of the data sources used for this study.

Table 1: 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
News reports on murders, thefts and extortion	GDELT Global Knowledge	2015-2020	Municipality	Daily
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

4.1 Data on violence

To estimate the effect on criminal violence, I use information on homicides from the National Department of Health Information (Sistema Nacional de Información en Salud; SINAIS). This database consists of individual-level information on deaths from 1998 to 2019. It includes detailed information on the cause of death (including homicide), the location where the death occurred, the weapon used (in the case of homicides), and details of the deceased (sex, age, marital status, and occupation, among others). Along with municipal-level population data obtained from the National

[18] The appendix A.2.1 provides more information on the war against drugs.

Institute of Statistics and Geography (INEGI), I calculate homicide rates per 100,000 people.

I prefer to use the SINAIS database instead of other homicide data sources for two reasons. First, since information on deaths comes from death certificates, the SINAIS database does not suffer from under-reported homicides. While the Ministry of Public Security (SSP) has rich data on homicides, their information comes from police reports. Because of this, the SSP murder accounts can be under-reported if not every homicide is investigated. Second, the SINAIS database includes information on the occupation, sex, and type of weapon used. I exploit to identify homicides of agricultural workers and possible murders linked to inter-cartel violence.

As an estimate for murders resulting from potential inter-cartel violence, I use the information on homicides of males ages 15-40 who were killed with a firearm. In the absence of more reliable data that can attribute homicides directly to cartel activity, other authors have used homicides rates for men to proxy for murders linked to criminal activity in Mexico (Magaloni et al., 2020). This is because men between the ages of 15 and 40 are the population group most vulnerable to criminal violence (Calderón et al., 2015; Herrera and Martinez-Alvarez, 2022). In contrast to other studies, I argue that homicides of men by a firearm can provide a better estimate. First, firearms ownership is illegal in Mexico, and their use implies their acquisition through unlawful means. Secondly, cartels often employ firearms in engagements against other DTOs and the military (Mineo, 2022).[19]

Finally, information on extortion reports is available from the Ministry of Public Security. This contains information on police records for all cases registered in the country from 2011-2019. These are reported every month and are available at the municipal level. While detailed information on extortion reports is available for the period of my analysis, it is essential to note that homicides continue to be the best proxy for violent crime in countries like Mexico, where crimes are often not reported. Mexico's National Survey of Victimization and Perceptions of Public Security (ENVIPE) has been used by Mexican authorities to look into unreported crimes. Based on the survey, INEGI estimates that in 2018, 93.2% of total crimes in the country were not reported by individuals or were not filed by the police. In the survey, 31.7% said that reporting a crime to the police was a waste of time and 17.4% mentioned that they did not trust the police (INEGI, 2019a). For this reason, I use homicide data for my main results. However, estimates on the effect on extortion

[19] Over 70% of all guns recovered in crime scenes in Mexico can be traced to drug trafficking organizations (Mineo, 2022).

reports is available in Section 6.3.

4.2 Drug cartel presence

To evaluate changes in territorial expansion and competition of DTOs, I use municipal-level data from the Mapping Criminal Organizations project (MCO).[20] This database uses a web-crawling technique to identify news related to drug cartels on Google and Google News. In particular, it identifies the number of paragraphs in which a cartel was mentioned in the news alongside a municipality in a given year. I consider a cartel to be present in a municipality if the number of mentions is non-zero. The MCO database includes information on 75 different DTOs in Mexico (including the top eight cartels identified by the DEA) and their presence at the municipal level from 1990 to 2020. While other data sources have tried to measure cartel presence in Mexico (Coscia and Rios, 2012; Phillips, 2015; Sobrino, 2019), to the best of my knowledge, this is the only one that has information at the municipal level for my period of interest: 2011-2019.

Aside from the number of mentions of a cartel in a municipality, the database includes information on its "mother group" (the cartel from which it splintered).[21] Using the information on the mother group, along with the date on which cartels appeared for the first time in the data, I can distinguish between the cartels that preceded the war against drugs in 2006 (*originals*), cartels that fragmented from other cartels, and new cartels that had no previous affiliation to other cartels.[22]

Figure 5 shows the evolution in the number of cartels operating at the national level between 1990 and 2018. Within the past two decades, the number of cartels in Mexico has increased from around 12 to almost 70. This has occurred mainly as a result of cartels splintering during the war against drugs and after the capture of El Chapo (Mexico's most powerful drug lord at that time) during that period, in 2014. Moreover, the increase in cartel presence seems to have also resulted from the formation of new criminal organizations that had no previous link to DTOs.

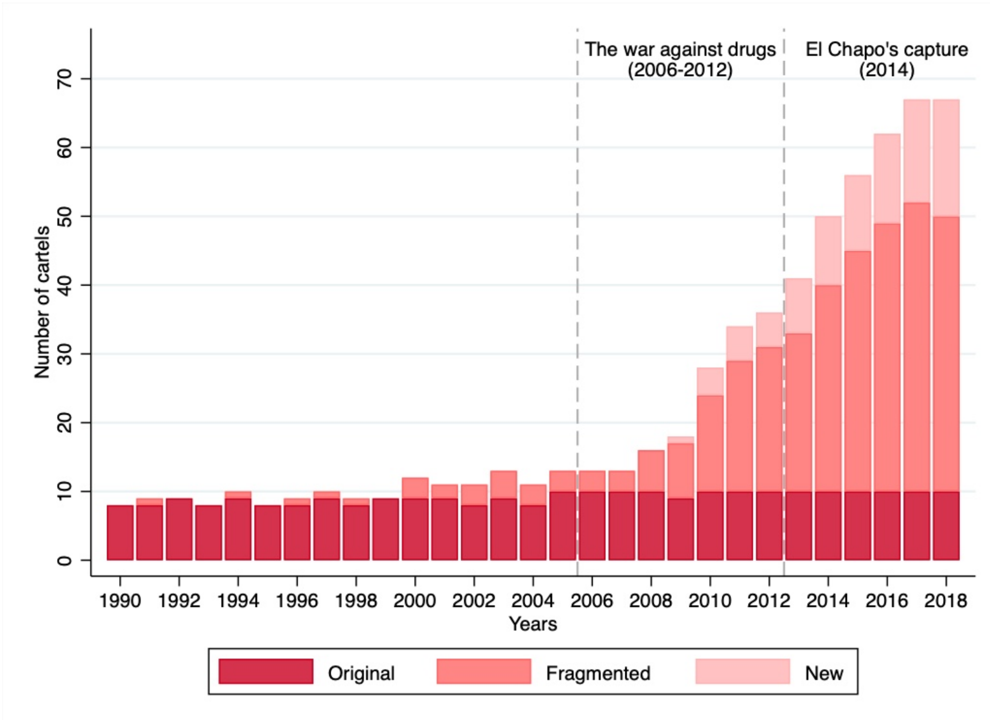
[20] The Mapping Criminal Organization project is supported by the Center for U.S.-Mexico Studies at the University of California San Diego (UCSD), the Mamdouha S. Bobst Center for Peace and Justice at Princeton University, and the Empirical Studies of Conflict Project Signoret et al. (2022).

[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 its being part of cartel B. Therefore, I can't obtain the information on the entire fragmentation history for each cartel from the database.

[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 for which I can identify the mother group, which is different from their cartel name. New cartels are those that appeared after 2006 with an unknown mother group in the data that appeared after 2006.

Finally, Figure 6 shows the average number of cartels present in my sample for 2010-2013 and 2014-2018. This shows a significant increase in the number of cartels between the two different periods, particularly in Michoacán, Guerrero, and Jalisco.

Figure 5: Fragmented and new cartels present by year



Source: Constructed using data from the Mapping Criminal Organizations project. Fragmented cartels correspond to cartels that originated from another cartel. Original cartels are criminal organizations that existed before 2006 and did not originate from another cartel. New cartels correspond to those with no previous affiliation to other DTOs, which appeared for the first time after 2006.

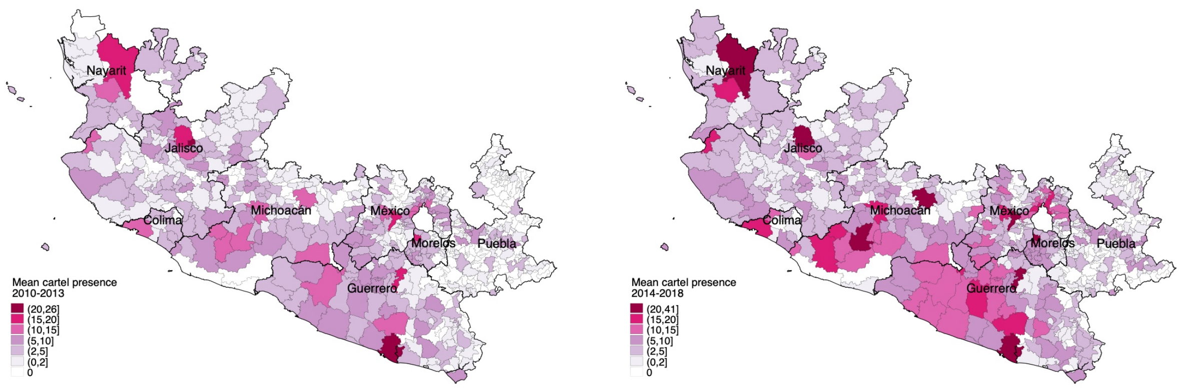
4.3 Crop suitability measure

Due to the nature of criminal activities, information on illegal crop production is limited in Mexico. The U.S. Drug Enforcement Administration (DEA) has provided estimates on poppy cultivation at the national level since 2011, and the United Nations Office on Drugs and Crime (UNODC) has estimated poppy cultivation using satellite images for 2014-2018. However, neither source includes data at the state or municipal level, and the original databases are not open to the public.

Moreover, while the Food and Agricultural Organization (FAO) of the United Nations has municipal-level information on agro-climatically attainable yields on some crops, this data does not exist for my two crops of interest: avocados and poppy. Therefore, this section describes how I

Figure 6: Cartel presence

(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.

built a suitability index for each crop based on information on minimum and optimal agro-climatic characteristics obtained from FAO's Ecological Crop Requirements (Ecocrop) database.

To build the suitability indices for avocado and poppy, I use a well-established model for crop suitability used by agronomists (Møller et al., 2021): the Ecocrop suitability model, named after the data it uses for its estimation and proposed by Hijmans et al. (2017). While other studies have tried estimating suitability indices for crops (particularly illegal drugs) based on machine learning techniques, evidence suggests that machine learning techniques used for crop suitability are not good predictors of ecological suitability (Møller et al., 2021). The main advantage of this approach is that it uses reliable information based on academic research from experts in the area rather than a machine learning approach to identify the relevant climatic characteristics required for crop growing.

The Ecocrop suitability model uses temperature and precipitation data and compares them to the crop's climatic requirements throughout the growing season to estimate a suitability index for a given area. These requirements are divided between the minimum conditions at which a specific crop can grow (absolute measures) and optimal conditions at which crops deliver the highest yield. The model assigns an index between zero and one, where zero is assigned to areas that do not meet the minimum requirements for growth (unsuitable) and a value of one for areas with optimal conditions (Ramirez-Villegas et al., 2013).

To estimate each of the suitability indices (poppy and avocado), I use the information corresponding to the growing requirements of each crop from the FAO Ecocrop database, in addition to temperature and precipitation data obtained from AgMerra. To construct the suitability index, the Ecocrop model requires information on monthly mean and minimum temperatures and total monthly rainfall (Ramirez-Villegas et al., 2013).[23] Using daily data at the municipality level, I calculated the monthly mean and minimum temperature and the total monthly precipitation for each year between 1990 and 2010. Then, I estimated the average monthly values of the mean temperature ($T_{MEAN_{mi}}$), minimum temperature ($T_{MIN_{mi}}$), and precipitation across the period of 1990-2010 for each month m for municipality i. Finally, using this information, I constructed a temperature index and a precipitation index (denoted as T_i^* and R_i^*, respectively) for each crop. These indicate the degree to which a municipality meets the temperature or precipitation requirements for that crop. Section A.3 in the appendix explains in further detail how I built each index.

The final Ecocrop suitability index for each crop is defined as the the product of both indices: $T_i^* \times R_i^*$. However, since avocados and poppies have additional altitude requirements, I create an altitude suitable indicator H_i^* equal to one if the municipality has any localities within the range at the required altitude for growing the crop, and zero otherwise. The final suitability measure is as follows:

$$S_i = T_i^* \times R_i^* \times H_i^*$$

This index takes a value between zero and one, where one indicates that a municipality meets optimal growing requirements and zero if it's unsuitable. Table A2 in the appendix includes information on the optimal and minimum temperature, precipitation, and altitude requirements for avocados and poppy.

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.

[23] A detailed explanation of this suitability measure can be found in Ramirez-Villegas et al. (2013).

Table 2 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 2: Test results for the avocado suitability index

	Whole country		Sample	
	Avocado production (tons)	Hectares harvested	Avocado production (tons)	Hectares harvested
	(1)	(2)	(3)	(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
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 parenthesis. 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 3 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 3: 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

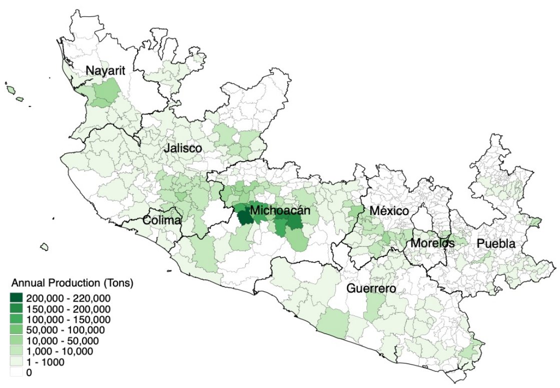
Notes: This table tests the relationship between the poppy suitability index and two proxies for poppy production: annual number of eradicated fields and total hectares of poppy eradicated. This table includes estimates for the whole country and the sample used in this paper. Standard errors clustered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

Figures 7 (a) and (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.

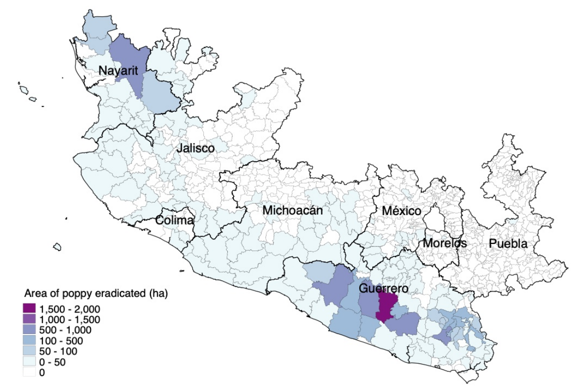
Finally, Figures 7 (c) and (d) show the distribution of the avocado-suitability and poppy-suitability indices, respectively. Measuring an agro-climatic suitability index has the advantage of being completely exogenous to my outcomes (violence). While the suitability index indicates an area's suitability to grow a particular crop, it cannot pick up on why some municipalities decide to produce the crop. For instance, it does not capture whether some municipalities are more likely to produce poppy if they have mountainous areas where poppy farmers can hide the illegal crop.

Figure 7: Spatial distribution of avocados and poppy

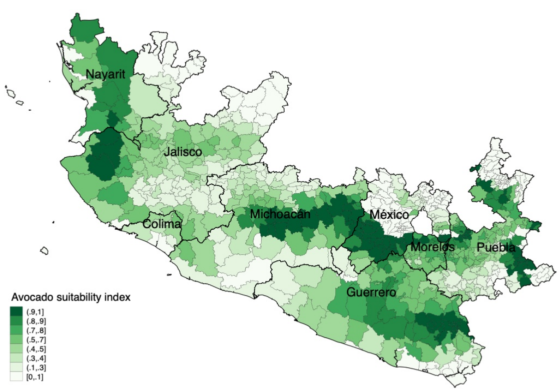
(a) Annual avocado production in sample (mean, 2011-2018)



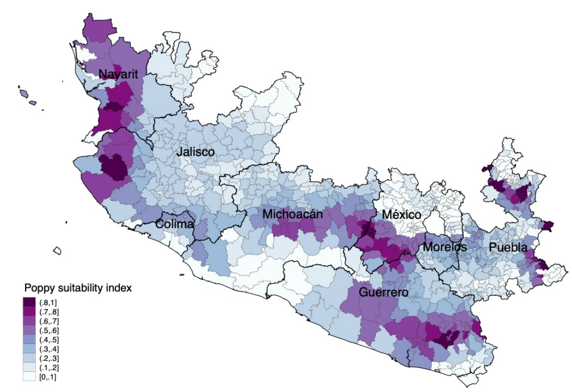
(b) Eradication of poppy in sample (mean, 2011-2018)



(c) Avocado suitability index



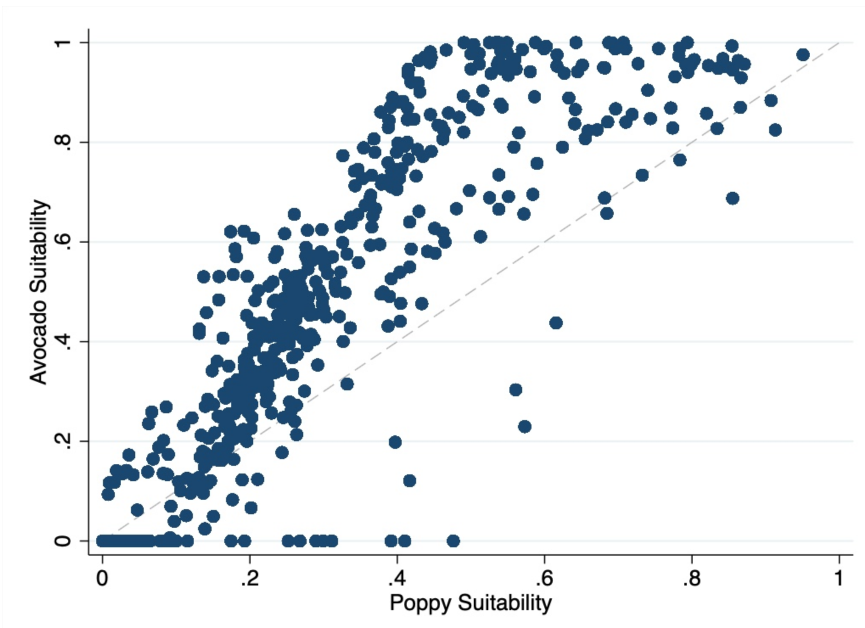
(d) Poppy suitability index



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.

Because these two crops share similar weather requirements (i.e., similar optimum temperatures and precipitation), I observe a significant correlation between avocado- and poppy-suitable municipalities. Figure 8 shows how municipalities that are highly unsuitable for avocados are also unsuitable for poppy. Conversely, municipalities that are highly suitable for avocados have a poppy suitability index of at least 0.4. The correlation between these two indices is 0.82. As a result, it is not possible to distinguish between municipalities that are only suitable for poppy and those that are only suitable for avocados. This fact will become relevant later when interpreting the results.

Figure 8: 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 Heroin prices

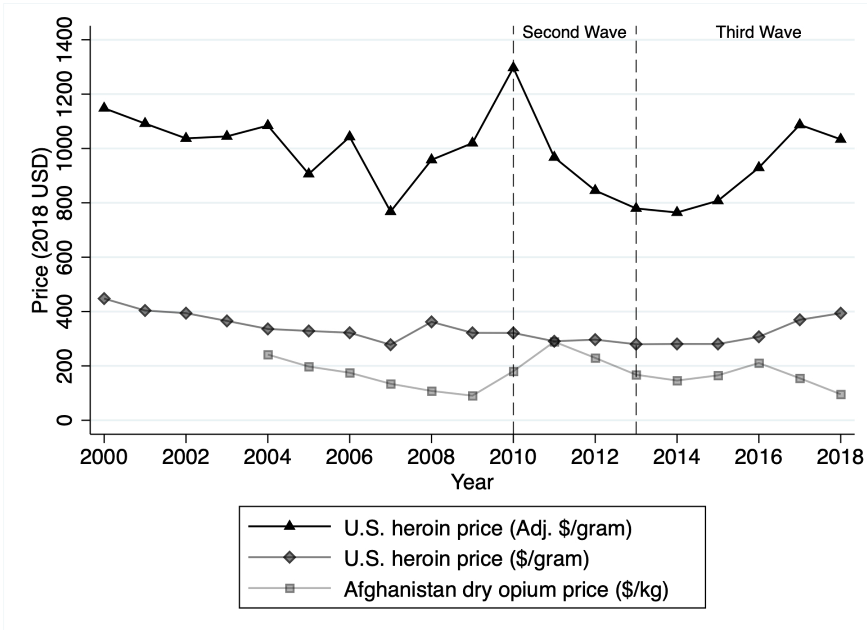
Information on heroin retail prices (adjusted per purity) for the U.S. were obtained from the United Nations Office on Drugs and Crime (UNODC) for each year between 1990 and 2018.[24] Figure 9 shows heroin retail prices in the U.S., adjusted by purity, and the price of Afghanistan dry opium paste as a reference.[25] Figure 9 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

[24]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 reflect the cost of pure heroin (Hughes et al., 2020; Anthony et al., 2008).

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

increase between 2016 and 2018, reaching USD$400 per gram. Meanwhile, prices per gram adjusted for purity show significant fluctuations.[26]

Figure 9: 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.

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[27] (Semple, 2019; Le Cour Grandmaison et al., 2019), 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.

While heroin prices in the U.S. are usually used in the literature (Sobrino, 2019), in this paper, I argue that they may not be representative of prices perceived by DTOs and farmers in Mexico.

[26] 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 across time. This pricing strategy allows drug 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 (Drug Enforcement Administration, 2020a).

[27] As mentioned in Section 2.4.1, 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 9.

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 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 purchases must be at least one gram to ensure a sufficient amount of pure 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).[28]

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 (Drug Enforcement Administration, 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.

Still, there exists evidence of a higher presence of Fentanyl and a subsequent decrease in the demand for heroin. According to the Drug Enforcement Administration (2021), between 2018-2019, the number of laboratory reports involving heroin decreased by 13 percent. Moreover, heroin prices

[28] 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).

in the state of New Jersey decreased by 18 percent in 2018, while the price of Fentanyl increased by 50 percent (Drug Enforcement Administration, 2020a).

4.5 Fentanyl overdoses

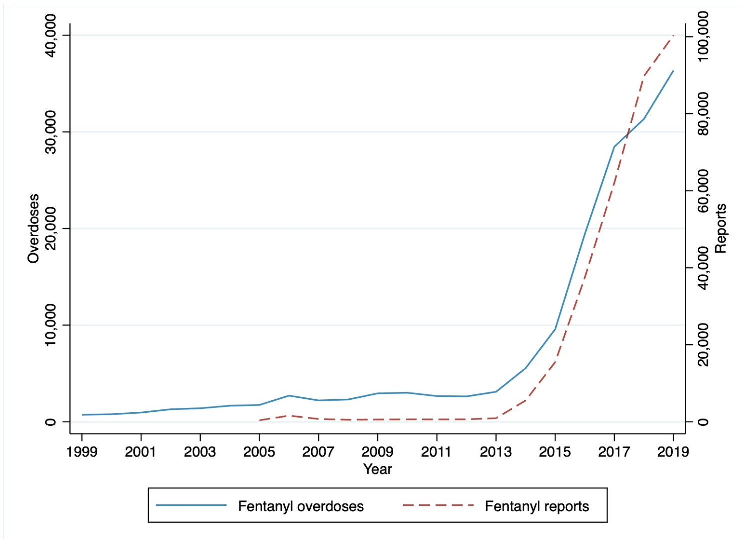
Information on Fentanyl overdoses in the U.S. was obtained from the National Center for Health Statistics (NCHS). It contains information on the national number of overdoses by type of drug for each year between 1990 and 2018. This database allows me to identify the number of overdoses linked to Fentanyl only and those linked to heroin mixed with Fentanyl.

Fentanyl overdose deaths are my proxy for the introduction of Fentanyl in the U.S. market. The sale of non-prescribed Fentanyl is illegal in the U.S., and there is no information on how much Fentanyl has been smuggled from China and Mexico into the U.S. However, it is possible to use overdoses as a proxy for its presence in the market. First, Fentanyl is highly lethal; according to the DEA, 2 milligrams would be enough to cause an overdose, and the market is flooded with counterfeit pills that can go up to 5.1 milligrams (twice as much as the lethal dose) (Drug Enforcement Administration, 2020b). Second, the presence of Fentanyl is unobservable to consumers. For one, dealers can sell heroin mixed with Fentanyl to maintain the same potency while lowering their costs without consumers finding out about it. Because the amounts of Fentanyl needed to maintain the same high are minimal, it is impossible for even the most experienced drug user to notice its presence by sight or taste. Moreover, even when consumers knowingly buy counterfeit Fentanyl pills, they cannot know precisely how much Fentanyl is in each tablet. While Fentanyl does not kill everyone who consumes it, a higher proportion of illegal drugs and counterfeit pills mixed with Fentanyl would increase overdoses, because consumers are unable to identify its presence and adapt their demand accordingly.

Alternatively, information on the number of Fentanyl reports identified by forensic laboratories in the U.S. can measure the availability of Fentanyl in the market. This information is reported by the National Forensic Laboratory Information System (NFLIS) and is available through the DEA's National Drug Threat Assessment of 2019 and 2020. This data has information on the number of forensic reports in which Fentanyl was found for the whole country between 2005 and 2019.

One disadvantage of using Fentanyl report data as a proxy for presence in the market is that forensic reports are also obtained through undercover purchases and suffer from the same sample bias as heroin prices (see 4.4 for more information).[29] Fentanyl overdose deaths do not suffer from this bias and can be more representative of the presence of Fentanyl in the market. Figure 10 shows the number of Fentanyl overdose deaths and Fentanyl reports between 1999 and 2018. Both overdose deaths and reports follow a similar trend across time and are highly correlated.[30]

Figure 10: Fentanyl overdose deaths and forensic laboratory reports



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

4.6 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 during 1993-2019. 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 A1 in the appendix shows the descriptive statistics.

[29] Despite this, report data can still provide helpful information on trends, the relative availability of some drugs compared to others, and the presence of drug mixes such as Fentanyl-heroin.

[30] The correlation between the number of Fentanyl overdose deaths and DEA reports is 0.98 at a 0.1% significance level.

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 4.4). 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 pure heroin with Fentanyl to increase profitability by maintaining the same level of high for their users. 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 (Drug Enforcement Administration, 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%).[31] 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;

[31] Source: own estimates based on information from the 2020 DEA National Drug Threat Assessment (Drug Enforcement Administration, 2021).

Semple, 2019). This verifies 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. comes from China, which accounts for around 90% of the world's Fentanyl. 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; instead, pure heroin and Fentanyl are smuggled separately, and mixing is done at the retail level inside the U.S. (Dudley et al., 2019). Furthermore, my strategy of regarding Fentanyl overdoses as a proxy for the availability of Fentanyl in the U.S. market strengthens my second assumption, because Fentanyl overdoses in the U.S. would result in more violence in Mexico only through their effect on the demand for pure heroin.

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 4.5).

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,[32] an indicator equal to one if the municipal

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

mayor party coincides with the president's party,[33] 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.

Using the main specification, I test the effect of the introduction of Fentanyl (and the subsequent decrease in the demand for pure 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.[34]

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 ($\gamma > 0$), according to Hypothesis 3. Moreover, because cartels have fewer incentives to fight over poppy-suitable municipalities, I expect to see $\delta \sim 0$, in line with Hypothesis 4.

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

[33] 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.

[34] I argue that I can proxy murders linked to cartel violence using this measure, as DTOs have disproportionately more men than women in their ranks, and most executions involve a firearm (Magaloni et al., 2020). For additional details see Section 4.1.

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 type 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,[35] according to the DEA. These are the main cartels specialized in the trafficking of heroin.[36]

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.

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

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

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 4 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. This suggests that, while poppy-suitable municipalities have benefited from lower homicide rates, the decrease in the demand for heroin has led to more violence in avocado-suitable municipalities.

Table 4: 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, a binary variable indicating whether the mayor party was the same as the President's party, a municipal marginalization index, and hectares of poppy eradicated. Potentially cartel-related murders are homicides of men ages 16-40 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 parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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 workers and non-cartel-related).[37] 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.

Since the interpretation of coefficients for interactions between continuous variables is not straightforward, I estimated the marginal effects in terms of Fentanyl overdose deaths. To help visualize the results, I present the marginal effects using heat maps. Figure 11 graphs the marginal effect of a one percent increase in Fentanyl overdose deaths on homicides for different degrees of poppy and avocado suitability. For example, Figure 11 (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.

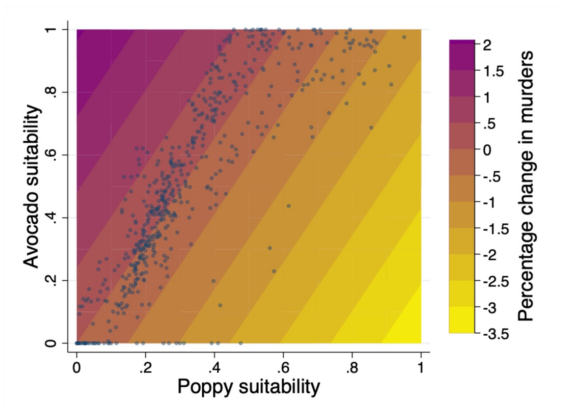
For all outcomes, the observed patterns strongly suggest that municipalities that are more avocado suitable and less poppy suitable have experienced an increase in the number of murders as a result of an increase in the presence of Fentanyl in the U.S. market. Meanwhile, municipalities that are more 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

[37] 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.

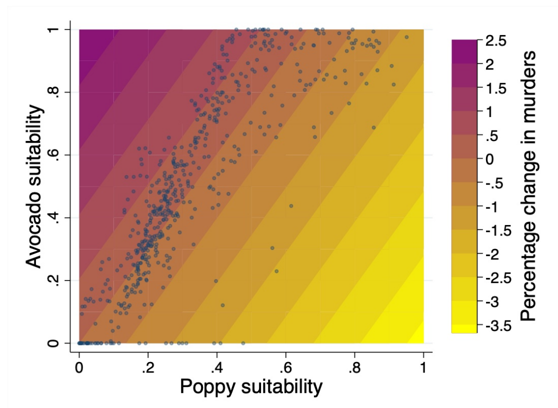
a 3.5% decrease in homicides in response to a 10% increase in Fentanyl overdose deaths.

Figure 11: Marginal effect of a 10% increase in Fentanyl overdose deaths on murders in avocado and poppy suitable municipalities

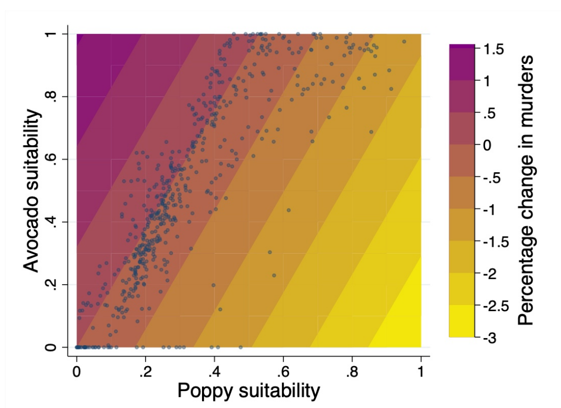
(a) All murders



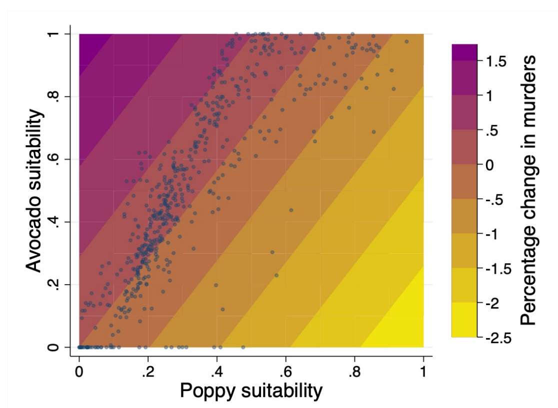
(b) Agricultural workers



(c) Potentially cartel related



(d) Rest of the population



Notes: Figure constructed from the coefficient estimates for Table 4. 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 16-40 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.

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 5 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 on 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.

Table 5: Results on the effect of Fentanyl on cartel presence in avocado and poppy suitable municipalities

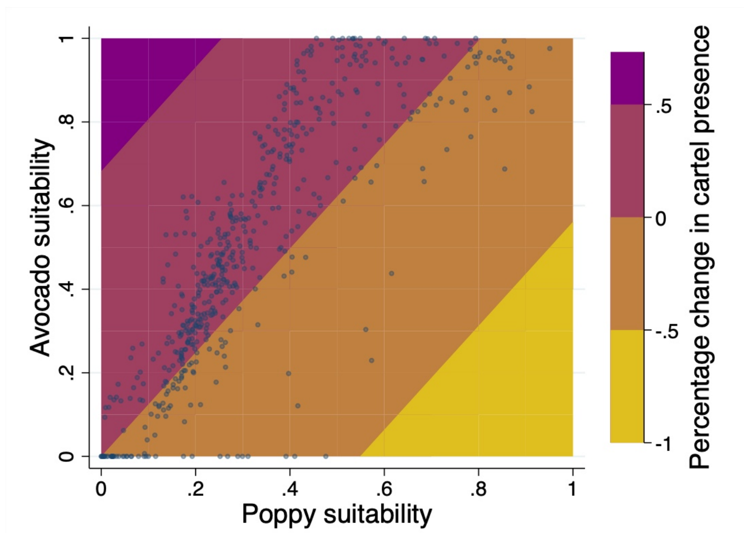
	Log(Cartels)				
	All cartels	Main cartels	Heroin cartels	Log(Mentions)	HH index
	(1)	(2)	(3)	(4)	(5)
Avocado Suitable × Log(Fentanyl$_{t-1}$)	0.0733	0.0373	0.0223	0.142	-0.0136
	(0.048)	(0.039)	(0.023)	(0.099)	(0.036)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.0911	-0.0611	-0.0269	-0.114	0.0543
	(0.073)	(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, a municipality marginalization index, and hectares of poppy eradicated. The number of main cartels corresponds to the nine major DTOs recognized by the DEA. Heroin cartels are DTOs mentioned by the DEA as specializing in heroin trafficking. Standard errors clustered at the municipal level in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Overall, the results show no changes in cartel presence and market concentration in municipalities suited for avocados. This suggests that, even though revenues of avocados have increased substantially in the last two decades, the potential profits that cartels extract are not high enough for them to move into these municipalities. It may be that either they cannot extract enough revenue, or that the entry cost may be too high (e.g., fighting other cartels is expensive). Thus, the increased violence observed in these municipalities seems to be due to the present cartels becoming more violent. Meanwhile, for poppy-suitable municipalities, I also observe no statistically significant changes in cartel presence. However, I do observe the existence of a negative correlation between Fentanyl and the number of cartels in poppy-suitable municipalities. While the result is not significant, this indicates that cartels may have lower incentives to remain in these municipalities.

Figure 12 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 11). This provides further evidence on worsened outcomes for avocado-suitable municipalities and improvements for poppy-suitable municipalities.

Figure 12: 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 5. 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

In the past decade, cartel behavior has changed significantly with the surge of new cartels, some originating from existing cartels (fragmented), and others with no previous link to any existing DTO (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 6 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 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 6: 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	0.0767	-0.0507	0.0444	0.0645*	-0.0219
	(0.153)	(0.103)	(0.036)	(0.033)	(0.034)	(0.021)
Poppy Suitable × Log(Fentanyl$_{t-1}$)	-0.251	-0.0135	-0.00115	-0.0555	-0.0535	-0.00431
	(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) provides estimates on the number of cartels present at a municipality. Columns (4) - (6) are estimates on a binary variable equal to one if one or more cartels were present 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 production. Specifications also include municipality and time-fixed effects. Standard errors clustered at the municipality level in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6.3 Other criminal behaviour

So far, 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 7 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 13 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

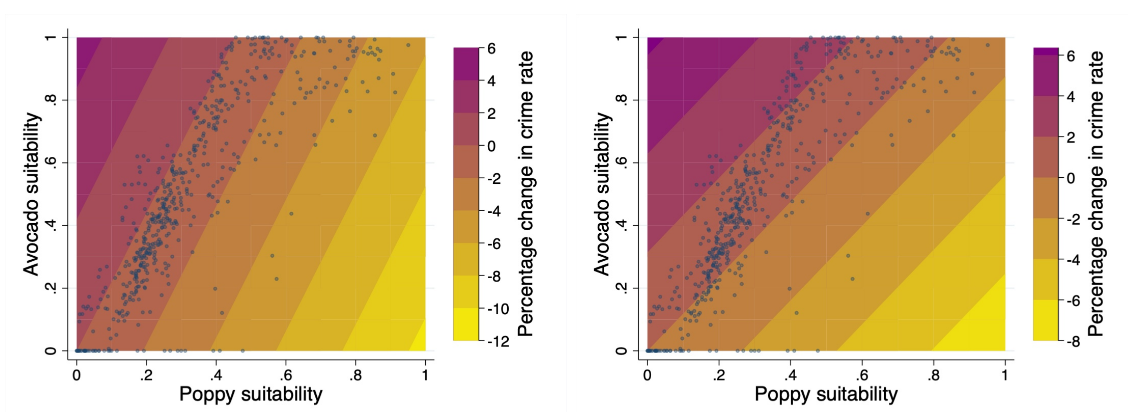
Table 7: Results on the effect of Fentanyl on other crimes in avocado and poppy suitable municipalities

	Violent theft	Truckload theft	Extortion
	(1)	(2)	(3)
Avocado Suitable $\times$ Log(Fentanyl$_{t-1}$)	0.477***	0.636***	-0.330***
	(0.181)	(0.131)	(0.091)
Poppy Suitable $\times$ 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, a marginalization index, and poppy eradication. Standard errors clustered at the municipality level in parenthesis.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 13: 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 7. 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.

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.

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 in 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 pure 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 Fentanyl increased violent crimes in avodado-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-making 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.

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A Appendix

A.1 Tables and figures

Table A1: 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.[38]. (O'Neil, 2009) 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.[39] 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 and picked in 2011 with over 27,000 homicides (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[40] that resulted in an increase in the competition among cartels (Atuesta and Ponce, 2017; Calderón et al., 2015; Jones, 2013). 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).[41] 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

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

[39] 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).

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

[41] 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)

the 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.3 Suitability index

A.3.1 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.[42] 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:

$$T^*_{Cmi} = \begin{cases} 0 & T_{MIN_{mi}} < T_{KILL_C} \\ 0 & T_{MEAN_{mi}} < T_{MIN_C} \\ \frac{T_{MEAN_{mi}} - T_{MIN_C}}{T_{OPTMIN_C} - T_{MIN_C}} & T_{MIN_C} \leq T_{MEAN_{mi}} < T_{OPTMIN_C} \\ 1 & T_{OPTMIN_C} \leq T_{MEAN_{mi}} < T_{OPTMAX_C} \\ \frac{T_{MAX_C} - T_{MEAN_{mi}}}{T_{MAX_C} - T_{OPTMAX_C}} & T_{OPTMAX_C} \leq T_{MEAN_{mi}} < T_{MAX_C} \\ 0 & T_{MEAN_{mi}} \geq T_{MAX_C} \end{cases} \tag{2}$$

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

[42] 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.

potential growing season g (Møller et al., 2021). Finally, T_C^* is defined as the minimum of all the temperature indices T_{Cgi}^* estimated for each potential growing period g.

A.3.2 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:

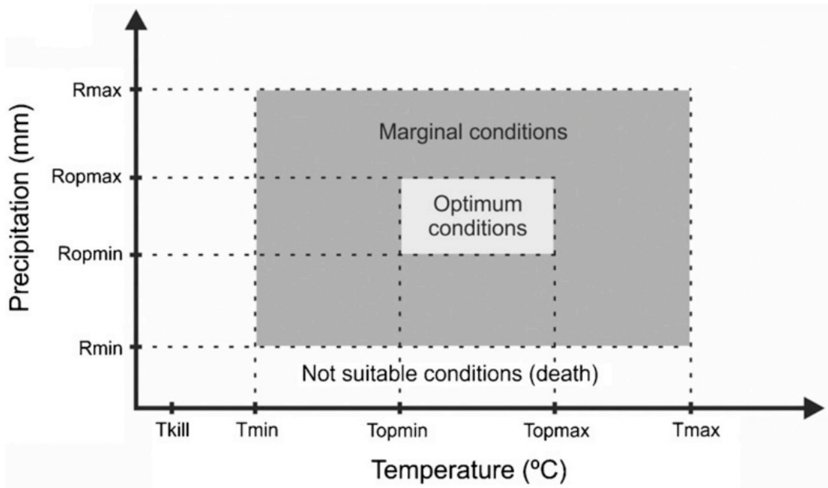
$$R_{Cgi}^* = \begin{cases} 0 & R_{TOTAL_{gi}} < R_{MIN_C} \\ \frac{R_{TOTAL_{gi}} - R_{MIN_C}}{R_{OPTMIN_C} - R_{MIN_C}} & R_{MIN_C} \leq R_{TOTAL_{gi}} < R_{OPTMIN_C} \\ 1 & R_{OPTMIN_C} \leq R_{TOTAL_{gi}} < R_{OPTMAX_C} \\ \frac{R_{MAX_C} - R_{TOTAL_{gi}}}{R_{MAX_C} - R_{OPTMAX_C}} & R_{OPTMAX_C} \leq R_{TOTAL_{gi}} < R_{MAX_C} \\ 0 & R_{TOTAL_{gi}} \geq R_{MAX_C} \end{cases} \tag{3}$$

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

A.3.3 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 A1 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).

Figure A1: Diagram of the Ecocrop suitability measure



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

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 A2). While precipitation and temperature requirements are very punctual, 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 suitability conditions thorough out 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 autumn and winter months.[43]

Since avocado and poppy have additional altitude requirements, I create a altitude suitable indicator $H^*_{i\,C}$ 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 given by:

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

Table A2: 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 Robustness Checks

A.4.1 Violence outcomes

As mentioned before, the introduction of Fentanyl in the U.S. market can decrease the demand for pure heroin in two ways: i) dealers mix heroin with Fentanyl and thus, directly reduce their demand for pure 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 A3 shows the estimations for this specification. Consistent with my previous findings, 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.

Table A3: 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 parenthesis. 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, 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.4.2 Cartel presence

A.4.3 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 A4 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 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 A4 shows no significant effect of Fentanyl for any of these specifications. Consistent with my previous findings of no changes in cartel presence.

Table A4: 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 in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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.4.4 Estimates on heroin cartels

In this section, I look into the effect of the introduction of Fentanyl in cartel presence of the cartels identified by the DEA as distributors of heroin (Drug Enforcement Administration, 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 A5 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 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 municipalities that are avocado suitable and less in municipalities that are suitable for poppy. The 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 6 where I find that fragmented cartels are more likely to enter an avocado municipality.

Table A5: Results on cartel presence by DTO

	Sinaloa (1)	CJNG (2)	Juarez (3)	Gulf (4)	Los Zetas (5)	Beltrán-Leyva (6)	Fam. Michoacana (7)	Los Rojos (8)	Guerreros Unidos (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. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$