

# Essays on Economic Development and Crime

By

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*To Chuy and Gloria*

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# Contents

<b>Introduction</b>	<b>xi</b>
<b>1 Avocados: Mexico’s green gold. The U.S. opioid crisis and its impact on Mexico’s drug cartel</b>	<b>1</b>
1.1 Introduction . . . . .	1
1.2 Background . . . . .	6
1.2.1 Production of Mexican avocados . . . . .	6
1.2.2 Cartel violence in the avocado sector . . . . .	7
1.2.3 Heroin production and distribution . . . . .	8
1.2.4 The U.S. opioid crisis . . . . .	9
1.2.5 The effect of the U.S. opioid crisis in Mexico . . . . .	11
1.3 Conceptual Framework . . . . .	14
1.3.1 Cartel presence . . . . .	14
1.3.2 Use of violence . . . . .	16
1.4 Data . . . . .	18
1.4.1 Data on violence . . . . .	19
1.4.2 Drug cartel presence . . . . .	21
1.4.3 Crop suitability measure . . . . .	23
1.4.4 Heroin prices . . . . .	29
1.4.5 Fentanyl overdoses . . . . .	32
1.4.6 Other variables . . . . .	33

1.5	Empirical Strategy . . . . .	34
1.5.1	Main specification . . . . .	34
1.5.1.1	Cartel presence . . . . .	38
1.6	Results . . . . .	39
1.6.1	Results on violence . . . . .	39
1.6.2	Cartel presence . . . . .	42
1.6.2.1	Fragmented and new cartels . . . . .	45
1.6.3	Other criminal behaviour . . . . .	46
1.7	Conclusion . . . . .	48
<b>2</b>	<b>The effect of NAFTA on violence in Mexico's avocado sector</b>	<b>51</b>
2.1	Introduction . . . . .	51
2.2	Background . . . . .	56
2.2.1	NAFTA ease of regulations on Mexican avocados . . . . .	56
2.2.2	Production of avocados in Mexico . . . . .	57
2.2.2.1	Mexican avocados in the global market . . . . .	59
2.2.2.2	Michoacán . . . . .	60
2.3	Model and Conceptual Framework . . . . .	61
2.4	Data . . . . .	65
2.4.1	Data on crime and cartel presence . . . . .	66
2.4.2	Information on the production of avocado and suitability measure . . . . .	68
2.4.2.1	Avocado Suitability Measure . . . . .	68
2.4.3	Other variables . . . . .	70
2.5	Empirical Strategy . . . . .	71
2.5.1	Difference-in-Differences estimation . . . . .	71
2.5.1.1	Parallel trends assumption . . . . .	72
2.5.2	Event Study . . . . .	74
2.6	Results . . . . .	75

2.6.1	Event Study Results . . . . .	76
2.6.2	Mechanisms . . . . .	77
2.6.2.1	Drug cartels presence . . . . .	77
2.6.2.2	Household characteristics . . . . .	79
2.6.3	Threats to Identification . . . . .	81
2.7	Conclusion . . . . .	85
<b>3</b>	<b>Pipelines and Crime in Mexico</b>	<b>87</b>
3.1	Introduction . . . . .	87
3.2	Background . . . . .	90
3.2.1	The war against drugs and cartel diversification . . . . .	90
3.2.2	Illegal fuel theft . . . . .	91
3.3	Data . . . . .	94
3.3.1	Hydrocarbon fuels infrastructure data . . . . .	94
3.3.2	Illegal taps of fuel and LPG pipelines . . . . .	96
3.3.3	Data on violence . . . . .	97
3.3.4	Presence of drug trafficking organizations . . . . .	98
3.4	Empirical Strategy . . . . .	99
3.4.1	Main identification strategy . . . . .	99
3.4.2	Event study . . . . .	100
3.5	Results . . . . .	101
3.5.1	Results on homicides . . . . .	101
3.5.1.1	Event study results . . . . .	102
3.5.2	Results on other crimes . . . . .	104
3.5.3	Cartel presence . . . . .	105
3.5.4	Robustness Checks . . . . .	106
3.5.4.1	Spillover effects . . . . .	106
3.6	Conclusions . . . . .	107

<b>Appendix A Avocados: Mexico’s green gold. The U.S. opioid crisis and its impact on Mexico’s drug cartel</b>	<b>109</b>
A1 Tables and figures . . . . .	110
A2 Background . . . . .	111
A2.1 The war against drugs . . . . .	111
A3 Suitability index . . . . .	112
A3.1 Temperature suitability index . . . . .	112
A3.2 Precipitation suitability index . . . . .	113
A3.3 Final suitability index . . . . .	114
A4 Robustness Checks . . . . .	116
A4.1 Violence outcomes . . . . .	116
A4.2 Cartel presence . . . . .	118
A4.3 Entry and exit of cartels . . . . .	118
A4.4 Estimates on heroin cartels . . . . .	119
<b>Appendix B The effect of NAFTA on violence in Mexico’s avocado sector</b>	<b>121</b>
B1 Figures and Tables . . . . .	122
B2 Robustness Checks . . . . .	127
B2.1 Results on violence . . . . .	127
B2.2 Cartel presence . . . . .	129
<b>Appendix C Pipelines and Crime in Mexico</b>	<b>131</b>
C1 Robustness checks for restricted states . . . . .	132
C2 Robustness checks on spillovers . . . . .	133
<b>References</b>	<b>135</b>

## List of Figures

1.1	Timeline of the U.S. opioid crisis. . . . .	10
1.2	Opioid overdose deaths in the U.S. (1990-2017) . . . . .	11
1.3	Production of poppy in Mexico. . . . .	12
1.4	Potential poppy cultivation in Mexico (2011-2020) . . . . .	13
1.5	Fragmented and new cartels present by year . . . . .	22
1.6	Cartel presence before and after the introduction of Fentanyl in the U.S. . . . .	23
1.7	Spatial distribution of avocados and poppy . . . . .	28
1.8	Avocado and poppy suitability distribution. . . . .	29
1.9	U.S. retail heroin prices, adjusted per purity, and Afghanistan dry opium paste price. . . . .	30
1.10	Fentanyl overdose deaths and forensic laboratory reports. . . . .	34
1.11	Marginal effect of a 10% increase in Fentanyl overdose deaths on murders in avocado and poppy suitable municipalities. . . . .	41
1.12	Marginal effect of a 10% increase in Fentanyl overdose deaths on the number of cartels in avocado and poppy suitable municipalities. . . . .	44
1.13	Marginal effect of a 10% increase in Fentanyl overdose deaths on crime rates in avocado and poppy suitable municipalities . . . . .	48
2.1	Timeline on NAFTA openings to U.S. avocado market . . . . .	57
2.2	Annual average production of avocado (2011-2018) . . . . .	58
2.3	Annual average production in Michoacán municipalities (2011-2018) . . . . .	59
2.4	Avocado suitability . . . . .	70

2.5	Murders by suitability (1990-2010) . . . . .	73
2.6	Parallel trend test with avocado suitable municipalities . . . . .	74
2.7	Event study avocado suitable coefficient estimates on log murders (Baseline year: 1997) . . . . .	77
2.8	Annual hectares of avocado cultivated and production in tons (National estimate, 1990-2018) . . . . .	83
3.1	Reports of illegal taps of refined oil products . . . . .	92
3.2	Event study results on LPG and refined oil taps . . . . .	94
3.3	LPG distribution infrastructure . . . . .	95
3.4	Hydrocarbon fuel production and distribution infrastructure . . . . .	95
3.5	Geographical distribution of illegal taps in 2018 . . . . .	96
3.6	Event study results on murders in municipalities with fuel and LPG pipelines . . . . .	103
A1	Diagram of the Ecocrop suitability measure. . . . .	115
B1	Total value of exports (Million USD) . . . . .	122
B2	Avocado Hectares Cultivated and Harvested in Michoacán (1990-2018) . . . . .	122
B3	Avocado prices in Mexico (1990-2018) . . . . .	123

## List of Tables

1.1	Available data by source, frequency, and aggregation level . . . . .	19
1.2	Test results for the avocado suitability index . . . . .	26
1.3	Test results for the poppy suitability index . . . . .	27
1.4	Results on the effect of Fentanyl on violence in avocado and poppy municipalities	40
1.5	Results on the effect of Fentanyl on cartel presence in avocado and poppy suitable municipalities . . . . .	43
1.6	Results on the presence of new and fragmented cartels . . . . .	46
1.7	Results on the effect of Fentanyl on other crimes in avocado and poppy suitable municipalities . . . . .	47
2.1	DID results on violence . . . . .	75
2.2	DID results on cartel presence using the MCO database . . . . .	78
2.3	DID results on dwelling characteristics . . . . .	80
2.4	Results for the anticipation check . . . . .	84
3.1	Summary statistics in municipalities with a fuel or LPG pipeline . . . . .	98
3.2	Results on homicides in municipalities with fuel and LPG pipelines . . . . .	102
3.3	Results on other crimes in municipalities with fuel and LPG pipelines . . . . .	105
3.4	Results on cartel presence in municipalities with fuel and LPG pipelines . . . . .	106
A1	Descriptive Statistics . . . . .	110
A2	Poppy and avocado agro-climatic suitability requirements . . . . .	116
A3	Results on violence with mixed heroin overdoses . . . . .	117

A4	Results on cartel entry and exit . . . . .	118
A5	Results on cartel presence by DTO . . . . .	120
B1	Phases for the introduction of avocados into the U.S. . . . .	123
B2	Available data sources by aggregation level, frequency and periodicity . . . . .	124
B3	Descriptive Statistics . . . . .	125
B4	DID results on cartel presence in Michoacán using the MCO database . . . . .	126
B5	DID results on monthly homicides . . . . .	128
B6	DID results on cartel presence using data from Coscia and Rios (2012) . . . . .	129
B7	DID results on cartel presence in Michoacán using data from Coscia and Rios (2012) . . . . .	130
C1	Results on homicides restricted to states with access to fuel and LPG pipelines .	132
C2	Results on other crimes restricted to states with access to fuel and LPG pipelines	132
C3	Results on cartel presence restricted to states with access to fuel and LPG pipelines	133
C4	Results on homicides in neighbor municipalities . . . . .	133
C5	Results on other crimes in neighbor municipalities . . . . .	134

# Introduction

This dissertation comprises three chapters examining the connection between income and violent crime in Mexico. The first two chapters specifically investigate this relationship within avocado-growing municipalities but during different periods. The first chapter concentrates on a period characterized by intense competition among drug cartels (2011-2019), following the government's war on drugs that caused the fragmentation of major drug cartels. Conversely, the second chapter explores the period before the war on drugs (1990-2006), when the number of drug cartels was fewer, and cartel competition was mainly focused on producing and distributing illegal drugs. The third chapter analyzes the impact of a government policy aimed at combating fuel theft by criminal organizations and its subsequent spillover effects. These chapters help improve our understanding of the behavior of criminal organizations to help improve public policies.

The first chapter of this dissertation investigates the impact of a recent decline in the demand for heroin on drug cartel diversification. This study examines the hypothesis that the introduction of Fentanyl in the U.S. market has led to a decrease in the demand for pure heroin sourced from Mexican cartels. Consequently, this shift has compelled cartels to seek alternative revenue sources, including extracting rents from legal markets. This chapter studies the case of the avocado sector, which, over the past decade, has been the target of criminal organizations. I find evidence that the introduction of Fentanyl is associated with an increase in homicides and violent theft in avocado-growing municipalities. Complementarily, I find that municipalities suitable for the production of opium poppies experience fewer incidences of crime. Contrary to my initial hypothesis, I find no evidence of cartels moving

from poppy-growing municipalities to avocado municipalities.

The second chapter of this dissertation examines the relationship between economic shocks and crime by investigating the impact of the North American Free Trade Agreement (NAFTA) on violence within the avocado sector of Mexico. This study analyzes the consequences of a policy that gradually allowed the entry of Mexican avocados into the U.S. market. Employing a difference-in-differences strategy along with municipality-year-level data on homicide and presence of drug cartels, I assess the effects of the NAFTA opening on violent crime between 1990 and 2006. The findings of this study indicate that the liberalization of the avocado trade led to a substantively and statistically significant decrease in homicide rates by 33.6% in avocado-growing municipalities. Furthermore, these findings provide evidence that the reduction in violent crime cannot be attributed to changes in drug cartel dynamics.

Chapters 1 and 2 provide a detailed analysis of the intricate relationship between income and violent crime, particularly focusing on how varying levels of drug cartel competition can influence this relationship. In Chapter 2, I examine the effect of increasing demand for avocados from the U.S., which results in higher avocado prices. This results in lower violence through a substitution effect, where the opportunity cost for committing crimes increases.

Chapter 1, on the other hand, investigates the impact of rising avocado prices relative to heroin prices due to declining heroin demand. Contrary to findings from Chapter 2, in Chapter 1, the relative increase in avocado prices leads to more violence, as drug cartels exploit the avocado sector to generate income. The main distinction between these two chapters lies in the periods they analyze and the different levels of drug cartel competition that characterize each period.

Before the War on Drugs, Mexico experienced a relatively stable equilibrium in which there were only a few drug trafficking organizations competing in the market, each having well-defined territories. Therefore, Chapter 2 focuses on the avocado sector during a period when a limited number of strong criminal organizations specialized in the production of

drugs. In this context, I demonstrate that the relative increase in avocado prices can actually lead to a reduction in crime, primarily due to the low level of competition among criminal organizations.

In contrast, Chapter 1 explores the same sector in the years following the War on Drugs: a period marked by the fragmentation of established drug cartels and the emergence of new criminal organizations. In this context, Chapter 1 reveals that in a highly competitive drug cartel environment, the relative increase in the price of a legal good compared to an illegal good can prompt these criminal organizations to diversify their activities.

In the third chapter, coauthored with Erik Katovich, we study the effect of a government strategy against fuel theft on homicides and other violent crimes in municipalities with access to fuel pipelines. Moreover, we look into the spillover effects of this government strategy. As surveillance of fuel pipelines increased, criminal organizations shifted their efforts to the theft of liquefied petroleum gas (LPG), which emerged as an appealing alternative to traditional fuel theft. We combine geospatial data on the presence of fuel and LPG infrastructure with longitudinal data on crime and cartel presence to estimate the effects of enforcement on local levels of violence. Our findings indicate that the government's crackdown on fuel pipeline theft led to a shift in cartel presence and raised violence in municipalities with LPG pipelines. Moreover, our analysis reveals that the government's efforts to curb fuel theft did not reduce cartel presence or violent crimes in municipalities with fuel pipelines.

# Chapter 1

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

### 1.1 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.<sup>1</sup>

*“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.<sup>2</sup>

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 orga-

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<sup>1</sup>Financial Times (2020).

<sup>2</sup>The Guardian (2019).

nizations (DTOs)<sup>3</sup> is the avocado industry, whose exports have contributed over 2.5 billion U.S. dollars every year since 2016.<sup>4</sup> 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 (Centers for Disease Control and Prevention, 2021; Financial Times, 2020; Le Cour Grandmaison et al., 2019). 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).

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<sup>3</sup>In this paper, I use drug cartel and drug trafficking organizations (DTOs) as interchangeable terms.

<sup>4</sup>Source: Own estimates based on information from the Mexican Secretariat of Agriculture and Rural Development (SAGARPA).

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 (Dube et al., 2016; Sobrino, 2019). However, using this strategy has several problems in this context; for instance, heroin prices measured through undercover purchases are 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; Dube and Vargas, 2013; Parker and Vadheim, 2017). 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 models 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 (Herrera and Martinez-Alvarez, 2022; Jones, 2013; Magaloni et al., 2020).<sup>5</sup> 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 chapter is organized as follows. Section 1.2 describes the background. This includes information on the U.S. opioid crisis and its effect on violence in Mexico. Section 1.3 describes the conceptual framework. Sections 1.4 and 1.5 include a description of the data used and the empirical strategy. Finally, Section 1.6 contains the main results on violence and cartel presence.

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<sup>5</sup>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).

## 1.2 Background

### 1.2.1 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.<sup>6</sup> 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.<sup>7</sup> 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 out 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, 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

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<sup>6</sup>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 pulp, and high oil content (Hofshi, 2001).

<sup>7</sup>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).

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).

### 1.2.2 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 (de Córdoba, 2014; Linthicum, 2019; 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 Córdoba, 2014; Linthicum, 2019).<sup>8</sup> 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 Córdoba, 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 (Agren, 2019; García Tinoco, 2019).<sup>9</sup> 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).

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<sup>8</sup>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).

<sup>9</sup>The estimates are based on an exchange rate of 20 Mexican pesos per U.S. dollar.

### 1.2.3 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).<sup>10</sup> Usually, two hectares of poppy flowers will produce around 22 kilograms of opium paste, which can yield about a kilogram of heroin (Hartman, T., 2019). As a reference, in 2013, the price offered to farmers for a kilogram of raw opium paste was about 15,000 pesos (USD\$1,175),<sup>11</sup> 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

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

<sup>11</sup>This dollar estimate is based on a 2013 exchange rate.

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, suggesting that diluting pure heroin at the wholesale level is not currently part of the distribution strategy (Drug Enforcement Administration, 2021).<sup>12</sup>

### 1.2.4 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 2.1). The first one has its origin in the 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% (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 1.2 shows the evolution of overdose deaths in the U.S. by the type of opioid after each wave.

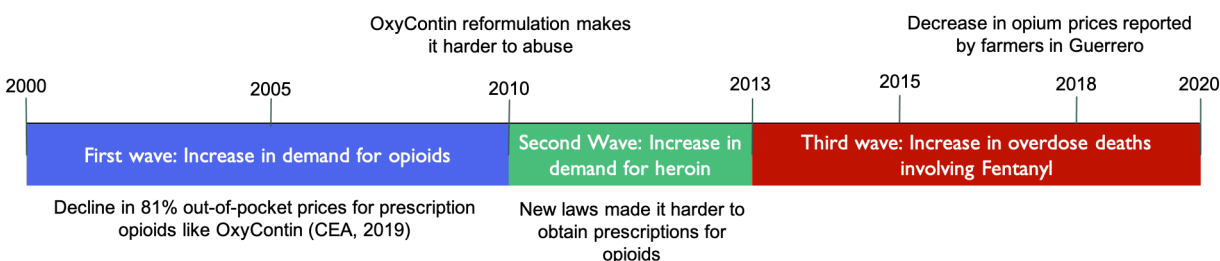
The second wave began in 2010 after the U.S. increased restrictions on opioids (CEA, 2019). As a result, people substituted heroin for prescribed opioids. An increase in heroin

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<sup>12</sup>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).

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).<sup>13</sup> 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% of new heroin users had previously taken prescription pain relievers without having them prescribed (Muhuri et al., 2013).

Figure 1.1: Timeline of the U.S. opioid crisis.

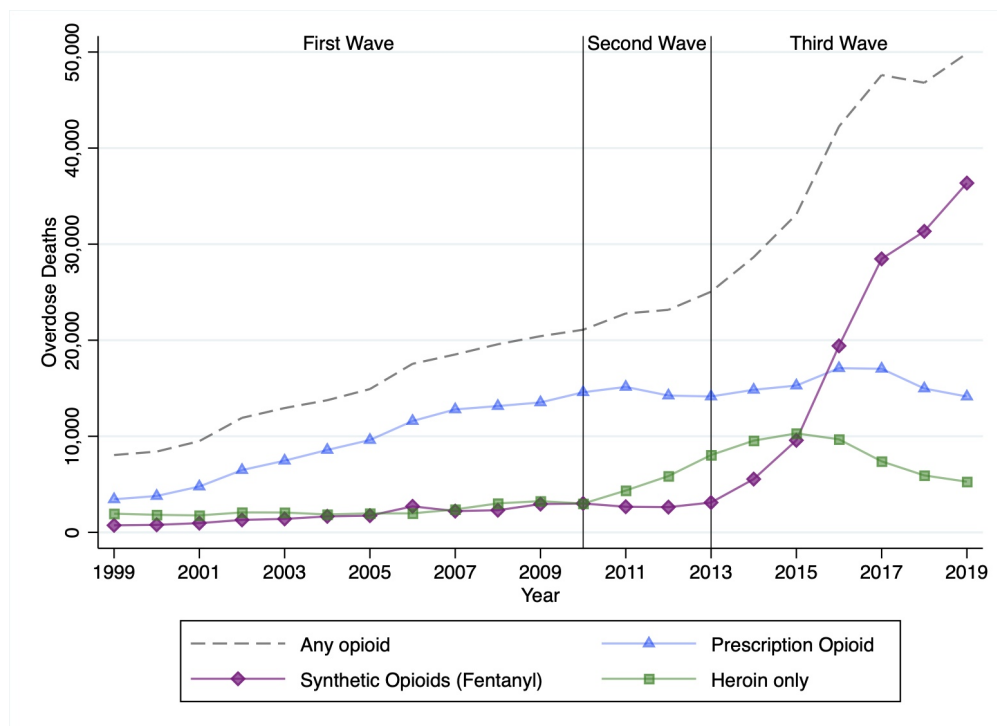


Finally, during the third wave (2013-2021), the U.S. saw an increase in overdoses involving a mix of heroin with Fentanyl (CDC, 2021). Fentanyl is a synthetic opioid analgesic often used to treat severe pain, since it is between 50 and 100 times more potent than morphine (Centers for Disease Control 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

<sup>13</sup>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).

number of overdose deaths from Fentanyl increased by tenfold, from 3,105 overdose deaths in 2013 to over 36,300 in 2019.<sup>14</sup>

Figure 1.2: 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.

### 1.2.5 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% 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 1.3). Guerrero alone accounts for around 60% of the country’s opium production (Le Cour Grandmaison et al., 2019).

<sup>14</sup>Source: Own estimates with information from the National Center for Health Statistics (NCHS).

Mexico is also the major exporter of heroin to the U.S. It accounts for 90% of all heroin 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 1.3: Production of poppy in Mexico.



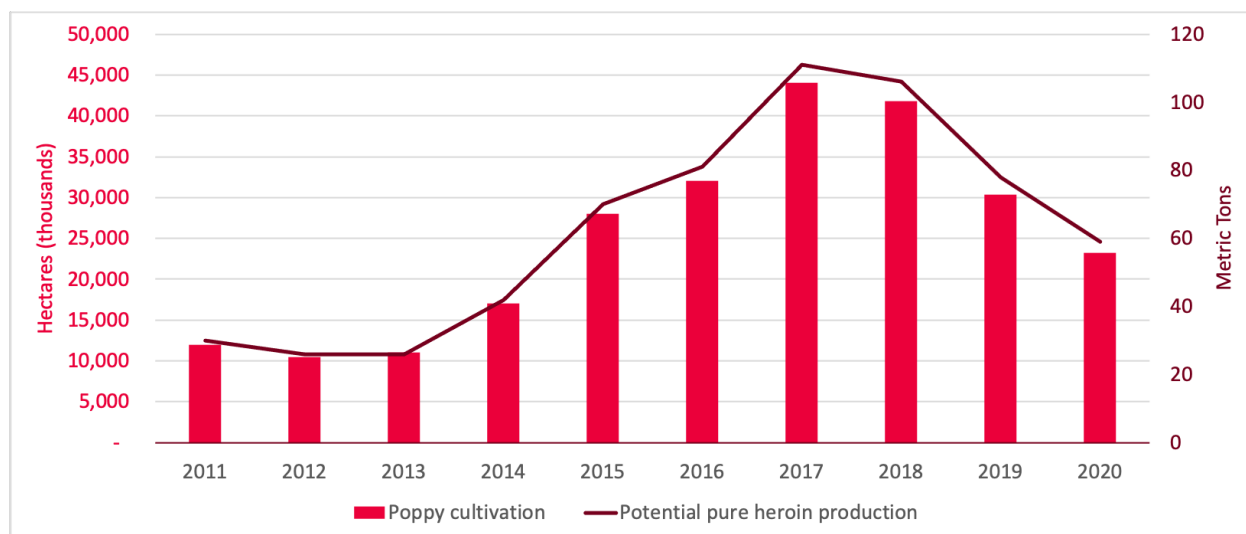
Source: Borrowed from Le Cour Grandmaison et al. (2019).

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% 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% decrease (UNODC, 2020). Similarly, the White House Office of National Drug Control Policy (ONDCP) estimates a 24% decrease between 2019 and 2020, with an overall fall of 47% compared to 2017 (see Figure 1.4, 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 1.4: 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).

## 1.3 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 drug cartels that behave as profit-maximizing firms and decide on: i) entry into and exit from municipalities, and ii) whether they employ violence.

### 1.3.1 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<sup>15</sup> 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

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

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 exploit. Consequently, the losses incurred by remaining in the same municipality may serve as a strong incentive for cartels to venture into other highly productive markets, such as municipalities engaged in avocado production. If the expected returns in these communities are substantial enough to outweigh the associated costs of entry (including potential conflicts with rival cartels for territorial control), it is anticipated that there will be an upsurge in cartel presence within municipalities specializing in legal crop production, as the demand for illegal crops diminishes. 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 the demand for 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.*

**Long run vs short run.** Note that hypotheses 1 and 2 predict cartel movement by comparing the entry cost to the expected profitability of entering a territory. In the long run, cartels have the potential to acquire additional capital, enabling them to expand and relocate their operations. However, in the short run, cartels operate with a fixed amount of capital. Consequently, limited capital may hinder their ability to move into a particular location, thus leading to little to no changes in cartel presence in the short run.

### 1.3.2 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 use of violence increases homicide rates in affected municipalities. I argue that DTOs have no incentives to use 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 rents 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.*

**Long run vs. short run.** It is important to note that while capital remains fixed in the short run, drug cartels are still able to utilize labor. Consequently, even if cartels have limited mobility to other territories due to high entry costs and fixed capital, they can resort to violence as a means to extract profits from their existing territories. As mentioned earlier, in this model, violence associated with drug cartels can arise from territorial disputes between cartels or from their use of violence to extract rents. Therefore, in the short run, with fixed capital and limited cartel mobility, instances of violence perpetrated by drug cartels are more likely to stem from changes in their behavior along the intensive margin (by becoming more violent towards civilians) rather than from conflicts with other cartels for territorial control (extensive margin).

## 1.4 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.<sup>16</sup> These states are contiguous and 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).<sup>17</sup>

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 in 2013. Second, after 2010, the behavior of cartels changed considerably. The government’s “kingpin” strategy during the war on drugs (2006-2012) led to the fragmentation of Mexico’s major DTOs.<sup>18</sup> 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 1.1 provides a detailed summary of the data sources used for this study.

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<sup>16</sup>Source: Own estimates based on information from SAGARPA.

<sup>17</sup>Guerrero accounts for over 60% of the total national opium production (Le Cour Grandmaison et al., 2019)

<sup>18</sup>The appendix A2.1 provides more information on the war on drugs.

Table 1.1: Available data by source, frequency, and aggregation level

Data	Database	Years	Aggregation level	Frequency
<b>Violence &amp; Drug Data</b>				
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
<b>Heroin and Overdose Data</b>				
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
<b>Avocado Production</b>				
Production and prices per ton	SAGARPA	2003-2018	Municipality	Annual
Value of avocado exports	BANXICO	1993-2018	National	Monthly
<b>Weather Data</b>				
Precipitation and temperature data	AgMerra	1990-2010	Municipality	Daily
<b>Other Data</b>				
Party affiliation of municipal mayors	INAFED	1993-2018	Municipality	Annual
Population	INEGI	2010	Municipality	Annual

### 1.4.1 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 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).<sup>19</sup>

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 of the effect on extortion reports are available in Section 1.6.3.

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

## 1.4.2 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).<sup>20</sup> 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).<sup>21</sup> 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.<sup>22</sup>

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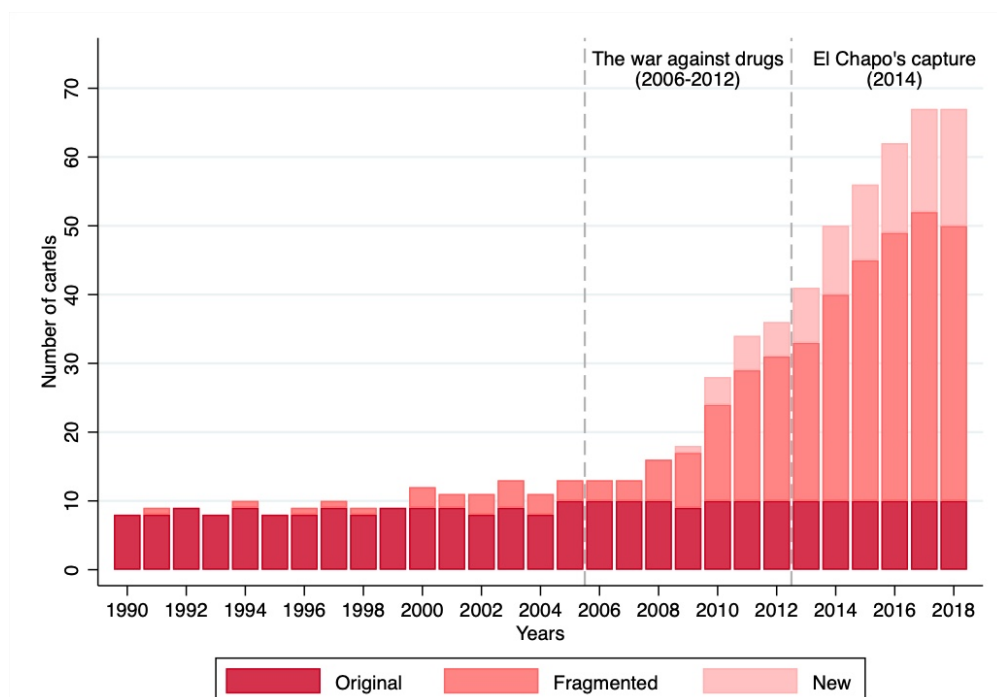
<sup>20</sup>The Mapping Criminal Organization project is supported by the Center for U.S.-Mexico Studies at the University of California San Diego (UCSD), the Mamdouha S. Bobst Center for Peace and Justice at Princeton University, and the Empirical Studies of Conflict Project (see Signoret et al. (2022)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

<sup>21</sup>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 cannot obtain information on the entire fragmentation history for each cartel from the database.

<sup>22</sup>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 no mother group in the data that appeared after 2006.

Figure 1.5 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 on drugs and after the capture of El Chapo (Mexico's most powerful drug lord at that time) 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. Finally, Figure 1.6 shows the average number of cartels present in my sample for 2010-2013 and 2014-2018. This shows a large increase in the number of cartels between these two periods, particularly in Michoacán, Guerrero, and Jalisco.

Figure 1.5: Fragmented and new cartels present by year

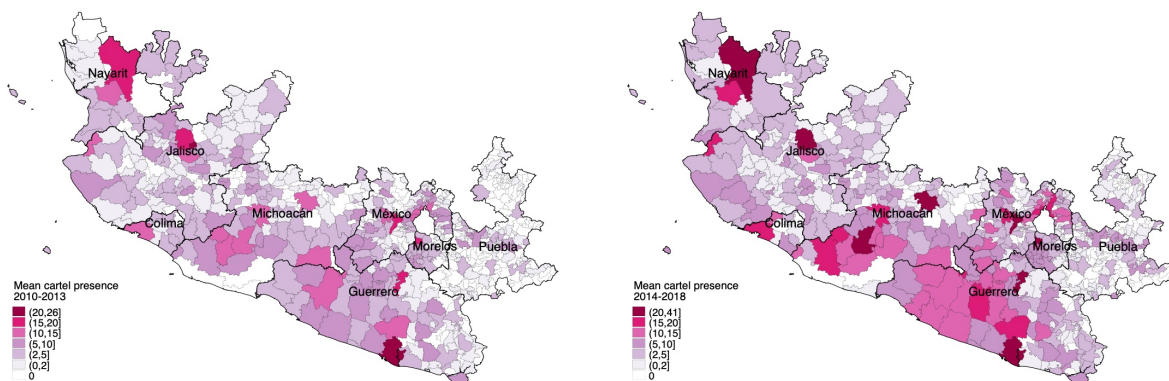


Source: Constructed using data from the Mapping Criminal Organizations project. Fragmented cartels correspond to cartels that originated from another cartel. Original cartels are criminal organizations that existed before 2006 and did not originate from another cartel. New cartels correspond to those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

Figure 1.6: Cartel presence before and after the introduction of Fentanyl in the U.S.

(a) Mean cartel presence (2010-2013)

(b) Mean cartel presence (2014-2018)



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

### 1.4.3 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 of 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 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).<sup>23</sup> 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 A3

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<sup>23</sup>A detailed explanation of this suitability measure can be found in Ramirez-Villegas et al. (2013).

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 suitability 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 all optimal growing requirements and where zero indicates that 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.

Table 1.2 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 1.2: Test results for the avocado suitability index

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

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

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

Table 1.3 shows the relationship between the poppy suitability measure and poppy eradication. The estimates were measured using a 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 1.3: Test results for the poppy suitability index

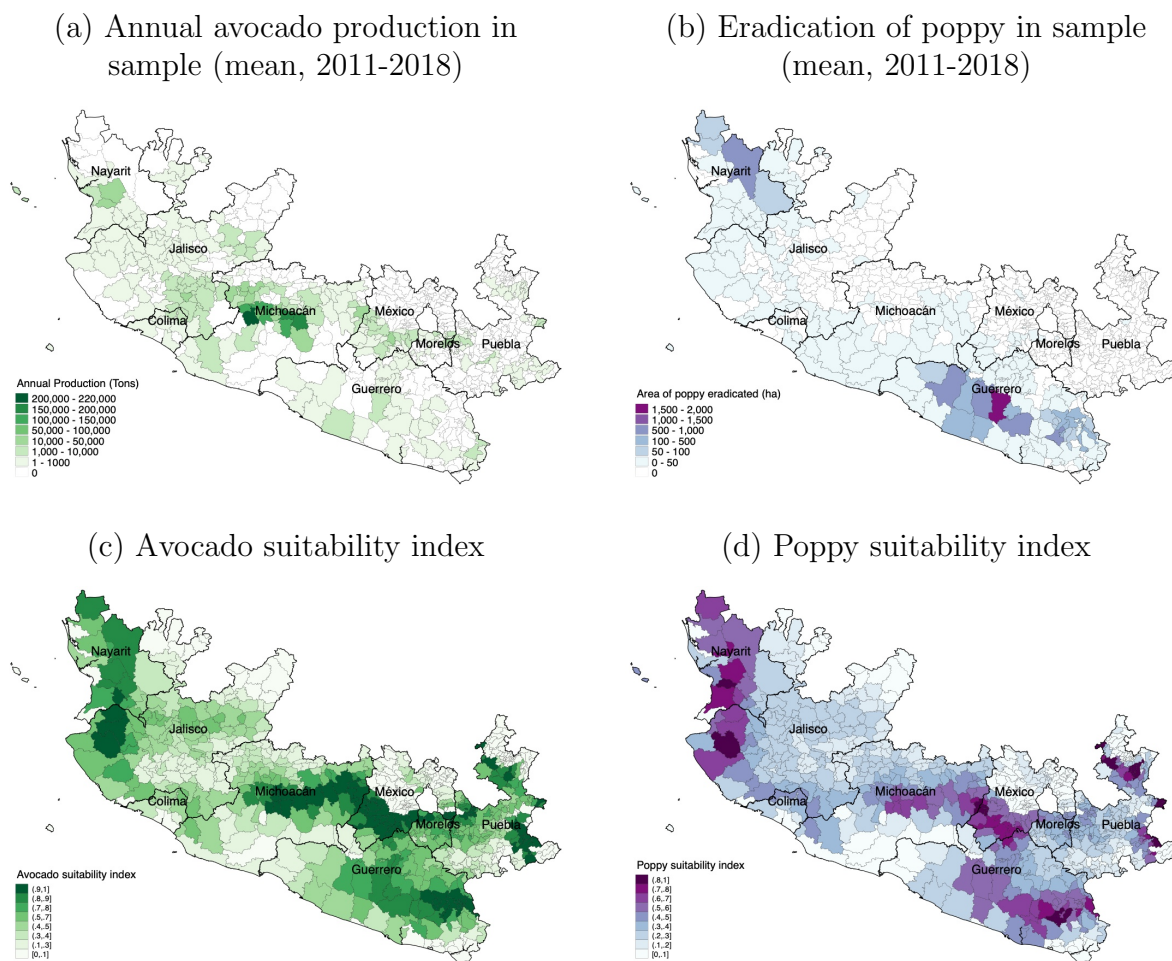
	Whole country		Sample	
	Eradicated fields (1)	Eradicated area (ha) (2)	Eradicated fields (3)	Eradicated area (ha) (4)
Poppy Suitability	270.9*** (85.8)	37.6*** (12.5)	382.7** (151.2)	45.9*** (17.2)
Observations	22,095	22,095	6,516	6,516
Adj. R-squared	0.051	0.055	0.077	0.083
Mean	50.3	5.8	50.3	5.8
Year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

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

Figures 1.7 (a) and (b) depict the average annual avocado production and the geographical distribution of areas where poppy cultivation was eradicated in my sample from 2011 to 2018. It is worth noting that, while both Michoacán and Guerrero engage in the production of avocados and poppy, Michoacán is predominantly an avocado producer, while Guerrero is primarily associated with poppy cultivation. The proximity between the major avocado producer and the primary poppy producer may have played a significant role in the drug cartels' shift towards the avocado industry following a decline in the demand for heroin.

Finally, Figures 1.7 (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 1.7: Spatial distribution of avocados and poppy

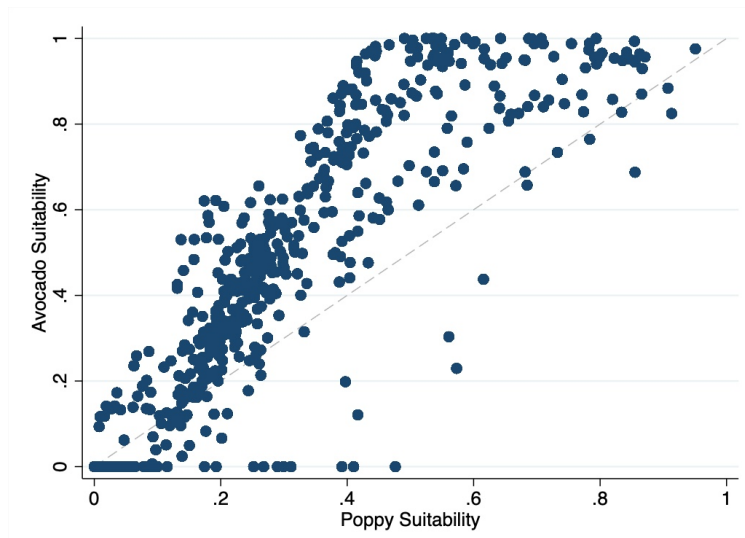


Notes: This figure shows the spatial distribution of the avocado and poppy suitability indices and compares them to production measures for each crop analyzed. Panels (a) and (c) show the mean annual avocado production in 2011-2018 and the avocado suitability index, respectively. Panels (b) and (d) show 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 strong correlation between avocado- and poppy-suitable municipalities. Figure 1.8 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 1.8: 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.

#### 1.4.4 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.<sup>24</sup> Figure 1.9 shows heroin retail prices in the U.S., adjusted by purity, and the price of Afghanistan dry opium paste as a reference.<sup>25</sup> It shows that, without being adjusted for purity, U.S. heroin prices have remained relatively stable over the last two decades, at around USD\$300 per gram, with an increase between 2016 and 2018, reaching USD\$400 per gram. Meanwhile, prices per gram adjusted for purity show significant fluctuations.<sup>26</sup>

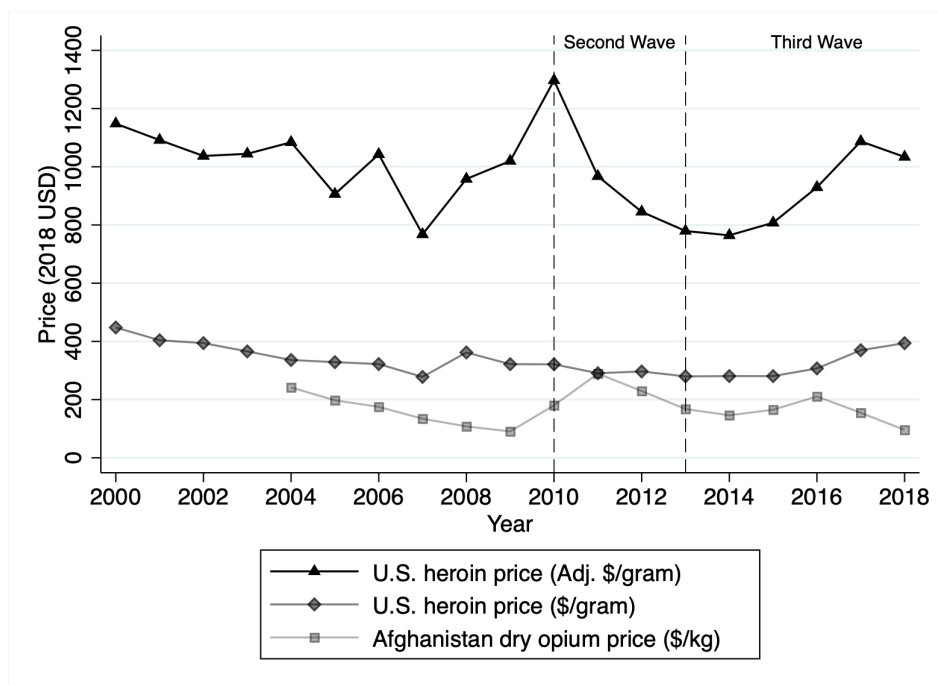
<sup>24</sup>Because heroin is often laced with other substances, such as Fentanyl, it is analyzed in labs to determine its purity, and prices are adjusted to hold quality constant (Anthony et al., 2008; Hughes et al., 2020).

<sup>25</sup>Information on Afghanistan's average farm-gate prices of opium was obtained from the UNODC for 1994-2018.

<sup>26</sup>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 (Hoffer and Alam, 2013; Office of National Drug Control Policy, 2001). For instance, between 1990-2000, a one-milligram bag of heroin would be sold for USD\$20 (Office of

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 (Le Cour Grandmaison et al., 2019; Semple, 2019),<sup>27</sup> the disparity in prices of opium perceived by farmers and heroin prices in the U.S. can be explained by how these prices are obtained.

Figure 1.9: 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.

National Drug Control Policy, 2001). This explains why retail prices (not adjusted for purity) remain stable over 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).

<sup>27</sup>As mentioned in Section 1.2.5, 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 1.9.

While heroin prices in the U.S. are usually used in the literature (e.g., Sobrino (2019)), in this paper, I argue that they may not be representative of prices perceived by DTOs and farmers in Mexico. Prices of heroin in the U.S. are estimated based on purchases by undercover agents and informants of the DEA and state and local agencies (Arkes et al., 2008). However, not all acquisitions are part of this database – only the ones sent to a laboratory. Additionally, these purchases are part of criminal investigations, and, therefore, they do not constitute a random sample of the price paid by consumers (Horowitz, 2001). The price in these purchases also varies significantly between agencies, as local law enforcement may be more acquainted than the DEA with local drug dealers and can obtain heroin at lower prices, which raises questions about the internal validity of this data (Horowitz, 2001).

Moreover, heroin prices reported in undercover deals may be biased, because agents pay higher prices than the average consumer (Caulkins, 2007), since i) they have lower bargaining power and ii) they make larger purchases than the average consumer. For instance, DEA undercover purchases must be of at least one gram to ensure a sufficient amount of 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).<sup>28</sup>

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

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<sup>28</sup>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).

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

### **1.4.5 Fentanyl overdoses**

Data on Fentanyl overdoses in the U.S. was obtained from the National Center for Health Statistics (NCHS). The data 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 1.4.4 for more information).<sup>29</sup> Fentanyl overdose deaths do not suffer from this bias and can be more representative of the presence of Fentanyl in the market. Figure 1.10 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.<sup>30</sup>

## 1.4.6 Other variables

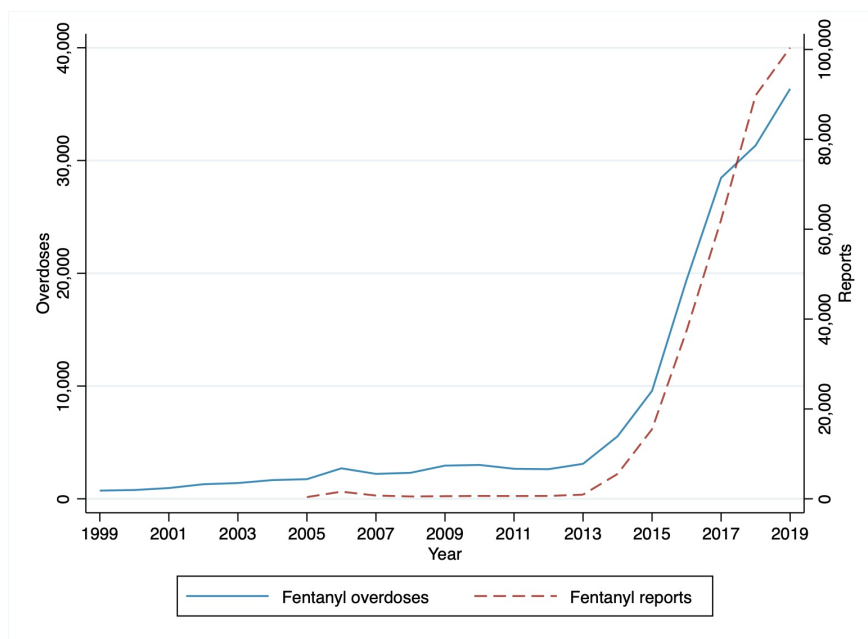
Data on population by municipality was obtained from INEGI National Census of 2010. The municipal mayor party affiliation information comes from the National Institute for Federalism and Municipal Development (INAFED). It includes information on all elected mayors during 1993-2019. I use this as a proxy for enforcement and use of force against drug cartels. Empirical evidence has shown that parties differ in their treatment of DTOs (Dell, 2015; Magaloni et al., 2020). Dell (2015) finds evidence that municipalities governed

<sup>29</sup>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.

<sup>30</sup>The correlation between the number of Fentanyl overdose deaths and DEA reports is 0.98 at a 0.1% significance level.

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.

Figure 1.10: Fentanyl overdose deaths and forensic laboratory reports.



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

## 1.5 Empirical Strategy

### 1.5.1 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 1.4.4). 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%).<sup>31</sup> 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 (Le Cour Grandmaison et al., 2019; ONDCP, 2021; Semple, 2019). This supports the first assumption.

Second, I argue that changes in the demand for heroin resulting from the introduction of Fentanyl are exogenous to violence in Mexico. For one, most of the Fentanyl consumed in the U.S. 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

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<sup>31</sup>Source: Own estimates based on information from the 2020 DEA National Drug Threat Assessment (Drug Enforcement Administration, 2021).

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 1.4.5).

The main specification is as follows:

$$Y_{it} = \alpha_i + \tau_t + \gamma(S_i^a \times F_{t-1}) + \delta(S_i^p \times F_{t-1}) + X'_{it}\beta + v_{it} \quad (1.1)$$

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,<sup>32</sup> an indicator equal to one if the municipal mayor party coincides with the president’s party,<sup>33</sup> and

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

<sup>33</sup>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

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 ( $\alpha_i$ ) and time ( $\tau_t$ ) 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.<sup>34</sup>

The coefficients of interest in the specification are  $\gamma$  and  $\delta$ , where  $\gamma$  measures the impact of Fentanyl on suitable avocado municipalities, and  $\delta$  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  $\delta < 0$ , in line with Hypothesis 4.

Evidence on whether cartels use violence to enforce extortion payments or to fight other

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and could result in lower murder rates.

<sup>34</sup>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 3.3.3.

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

### 1.5.1.1 Cartel presence

To shed light on whether changes in homicides are associated with cartels moving into or out of a territory, I estimate Equation 1.1 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,<sup>35</sup> according to the DEA. These are the main cartels specialized in the trafficking of heroin.<sup>36</sup>

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

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<sup>35</sup>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).

<sup>36</sup>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).

index ranges between zero and one, where one would indicate a full concentration of the market (monopoly) and zero would correspond to perfect competition.

## 1.6 Results

### 1.6.1 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 2.1 shows the effect on homicide rates. All specifications include municipality and time fixed effects, all controls (the municipal mayor party and an indicator variable equal to one if the mayor's party coincides with the president's party), and baseline trends for municipality marginalization and poppy production. Column (1) shows the effect of Fentanyl overdoses on the overall homicide rate. Results show a heterogeneous impact on homicides for avocado- and poppy-suitable municipalities. In particular, I observe that the introduction of Fentanyl in the U.S. led to increases in the homicide rates of avocado-suitable municipalities, while having the contrary effect on poppy-suitable municipalities.

Columns (2) – (4) show the effect on murders of agricultural workers, homicides that are potentially related to cartel violence, and homicides on the rest of the population (non-agricultural workers and non-cartel-related).<sup>37</sup> 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 1.6.3, I expand on this by examining changes in violent theft rates and extortion.

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<sup>37</sup>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 3.3.3.

Table 1.4: Results on the effect of Fentanyl on violence in avocado and poppy municipalities

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

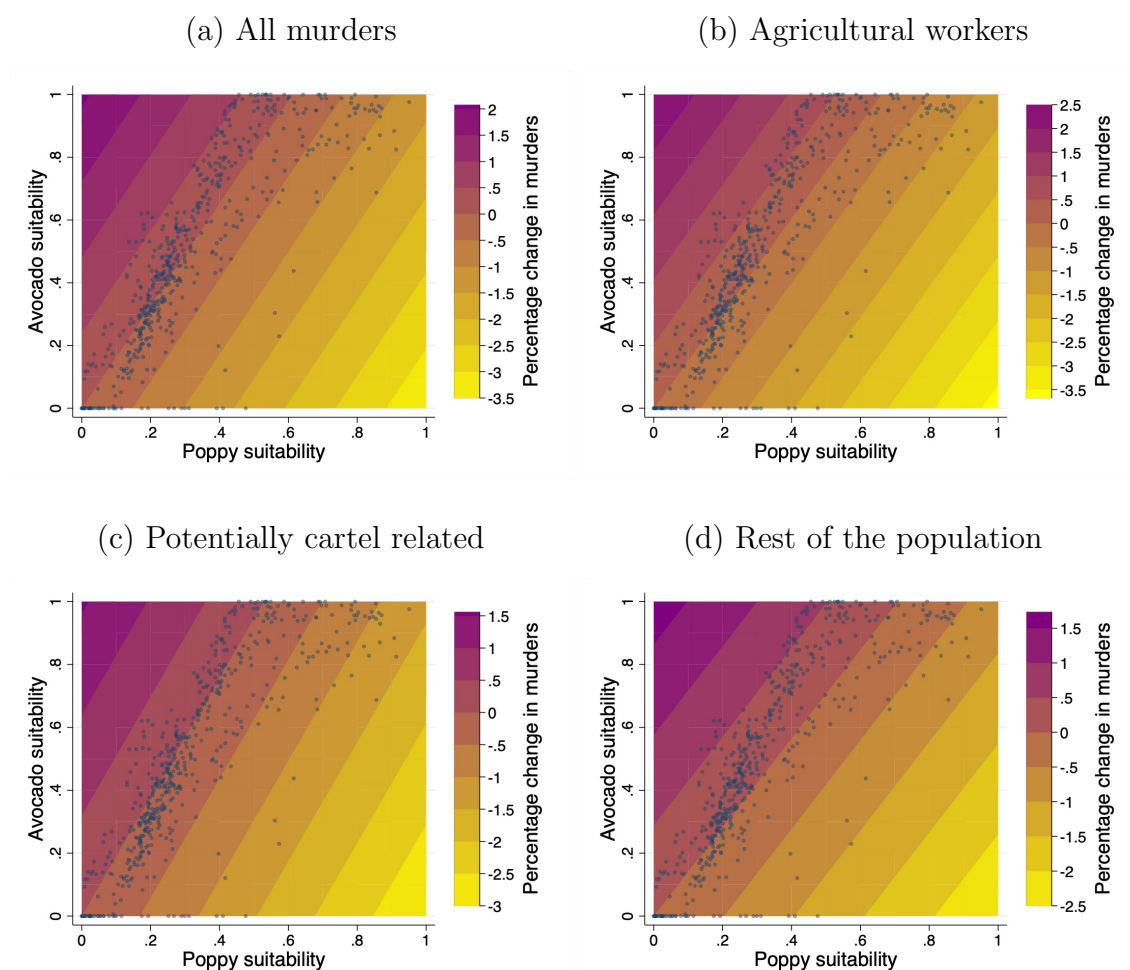
Notes: All outcome variables are the log of the number of murders per 100,000 inhabitants. All regressions control for the municipal mayor party, whether the mayor party was the same as the President's party, and baseline time trends on municipal marginalization and poppy eradication. Potentially cartel-related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

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 1.11

graphs the marginal effect of a 10% increase in Fentanyl overdose deaths on homicides for different degrees of poppy and avocado suitability. For example, Figure 1.11 (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.

Figure 1.11: Marginal effect of a 10% increase in Fentanyl overdose deaths on murders in avocado and poppy suitable municipalities.



Notes: Figure constructed from the coefficient estimates for Table 2.1. Panels (a)-(d) show the marginal effect of a 10% increase in Fentanyl overdoses on murder rates for all combinations of poppy and avocado suitability levels. The scatter plot shows the support for the estimations. Potentially cartel-related murders correspond to the homicide rate of men ages 15-40 killed by a firearm, who did not work in the agricultural sector. The rest of the population includes all homicides except for potentially cartel-related and agricultural workers.

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

### 1.6.2 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 1.5 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.

Overall, the results reveal small and no statistically significant effects on cartel presence and market concentration in municipalities suited for avocados. This suggests that, despite substantial revenue growth in the avocado industry over the past two decades, the potential

profits that cartels can extract are not significant enough for them to move into these municipalities.

Table 1.5: Results on the effect of Fentanyl on cartel presence in avocado and poppy suitable municipalities

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

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

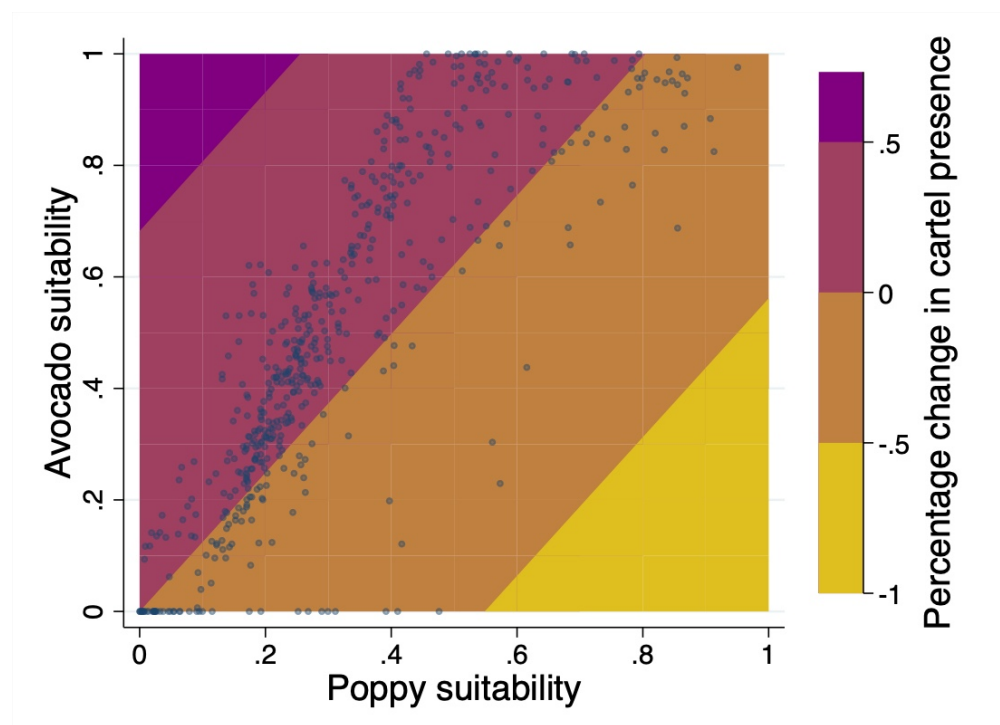
It is plausible that they are unable to extract sufficient revenue or that the entry costs may be too high (e.g., fighting other cartels is expensive). This observation is consistent with short-run predictions regarding cartel mobility. In the short run, criminal organizations have limited capability to increase capital, such as firearms and artillery needed to confront other criminal organizations, thereby impeding their relocation to other municipalities. Since results do not show changes in drug cartel presence, the increased violence observed in avocado-suitable municipalities can be attributed to changes in the behavior of already present cartels, who resort to heightened violence against civilians as a means to extract rents.

When examining municipalities suitable for poppy cultivation, results also show no statistically significant changes in cartel presence. However, these results still show a negative

correlation between Fentanyl and the number of cartels in poppy-suitable municipalities. Although the result does not reach statistical significance, it suggests that cartels may have reduced incentives to maintain a presence in these areas.

Figure 1.12 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 1.11). This provides further evidence of worsened outcomes for avocado-suitable municipalities and improvements for poppy-suitable municipalities.

Figure 1.12: 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 1.5. 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.

### 1.6.2.1 Fragmented and new cartels

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

I use a fixed effects model and estimate Equation 1.1 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 1.6 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 1.6: 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 $\times$ Log(Fentanyl <sub>t-1</sub> )	0.190 (0.153)	0.076 (0.103)	-0.051 (0.036)	0.044 (0.033)	0.065* (0.034)	-0.021 (0.021)
Poppy Suitable $\times$ Log(Fentanyl <sub>t-1</sub> )	-0.251 (0.237)	-0.013 (0.165)	-0.001 (0.053)	-0.055 (0.048)	-0.053 (0.051)	-0.004 (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 eradication. Specifications also include municipality and time-fixed effects. Standard errors clustered at the municipality level in parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

### 1.6.3 Other criminal behaviour

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

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

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

Finally, all measures are expressed as the log number of cases per 100,000 people.

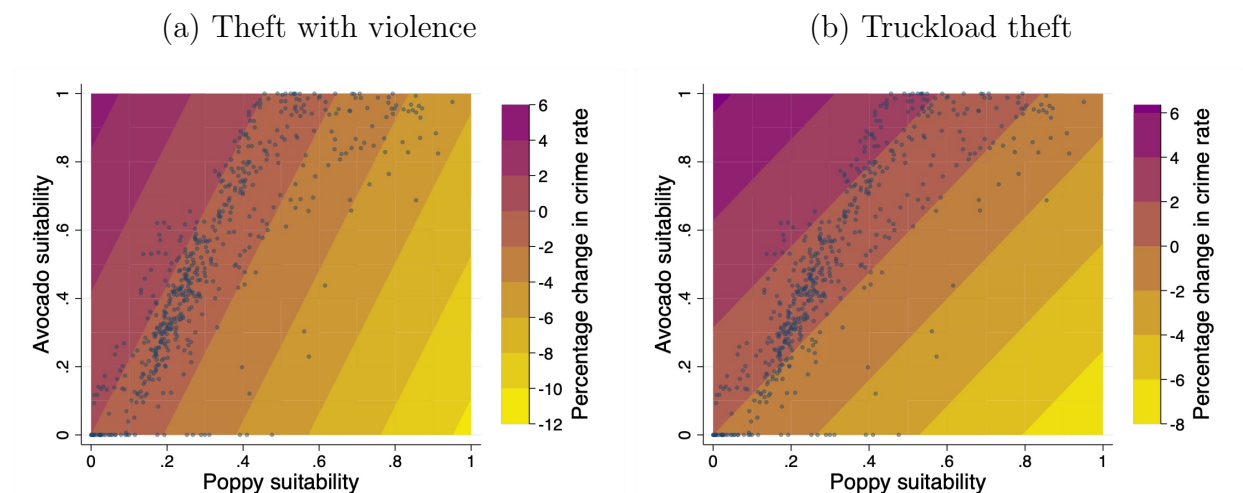
Table 1.7 shows the coefficient estimates for these three types of crimes. In general, the results show that the introduction of Fentanyl increased violent thefts and truckload thefts in avocado-suitable municipalities. The latter coincides with reports on thefts of trucks transporting avocados in Michoacán (Agren, 2019; García Tinoco, 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 1.13 shows the marginal effects of a 10% increase in Fentanyl overdose deaths in rates of thefts with violence and truckload thefts.

Table 1.7: Results on the effect of Fentanyl on other crimes in avocado and poppy suitable municipalities

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

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

Figure 1.13: Marginal effect of a 10% increase in Fentanyl overdose deaths on crime rates in avocado and poppy suitable municipalities



Notes: Figure constructed from the coefficient estimates for Table 1.7. 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.

Column (3) shows estimates of the extortion reports. In general, they show that Fentanyl decreased extortion cases in avocado-suitable municipalities compared to municipalities that cannot grow avocados. This contrasts with the other results that show an increase in homicides and thefts in these municipalities. Meanwhile, there have been numerous news reports that farmers and packinghouses are targets of extortion, as well as the threats to USDA officials discussed above (de Córdoba, 2014; Linthicum, 2019; 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.

## 1.7 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 (Agren, 2019; Avilés, 2015; de Cordobá, 2014; Herrera and Martinez-Alvarez, 2022; Jones and Sullivan, 2019; Linthicum, 2019; Padgett, 2013; Rainsford, 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 avocado-growing communities, mainly by targeting civilians, rather than through conflict between cartels. This is supported by evidence that Fentanyl has led to higher rates of other types of violent crime, such as theft with violence and truckload theft. Finally, since I find no evidence of cartels entering avocado-suitable municipalities, I conclude that the overall profits from targeting civil society in these areas do not overcome the potential entry costs

(e.g., fighting against existing criminal organizations over control of the territory).

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

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

## Chapter 2

# The effect of NAFTA on violence in Mexico's avocado sector

### 2.1 Introduction

Despite the relevance of the relationship between economic shocks and crime, there is little consensus on the mechanisms through which a positive economic shock can affect violent crime. This paper seeks to contribute to this literature by looking into the impact of the North American Free Trade Agreement (NAFTA) on violence in the avocado sector of Mexico.

The signing of NAFTA in 1994 by Mexico, the U.S., and Canada opened new trade opportunities for Mexico. In particular, it allowed Mexican avocados to enter the U.S. market. Before NAFTA, Mexican avocados had been banned in the U.S. in an effort to avoid the propagation of pests in U.S. crops (USDA, 2001). However, with NAFTA, the USDA's Animal and Plant Inspection Service (APHIS) allowed for reconsideration on the gradual introduction of avocados into different states of the U.S and, by 2005, avocados were available all year round in the U.S. 50 states, and the District of Columbia (Carman and Sexton, 2011).

Mexican avocados soon became one of the favorite fruits consumed in the U.S. Their properties as a superfood became more widely known, and the global demand for avocados

increased. This rise in demand has been particularly important for Mexico, the world's major producer and exporter of avocados. Mexico is also a country that suffers from high crime levels, including an increasing number of homicides, thefts, kidnappings, and extortion. In 2018, the crime incidence was over 37,000 crimes per 100,000 people, with the top crimes being theft in public transportation and/or in the street<sup>1</sup>, and extortion (INEGI, 2020). Thus, the relevance for Mexico and other countries that suffer from high crime levels to understand more about the relationship between income and crime.

In this study, I investigate the impact of the avocado boom on violence between 1990-2006, a period in which Mexico experienced little competition among Drug Trafficking Organizations (DTOs). This allows me to measure the effect of a resource boom in a context in which DTOs were few and strong and mainly focused on producing and distributing drugs. In De Haro Lopez (2023), I look into the relationship between violence and the increase in DTOs' competition that resulted from the fragmentation of cartels during the war against drugs. In that paper, I look into the period between 2011-2018.

Other papers have looked into the relationship between crime and trade liberalization. Dix-Carneiro et al. (2018) studied the effects of the 1990s trade liberalization in Brazil. They find a positive correlation between trade liberalization and crime. In particular, they observe that regions with larger tariff reductions experienced a rise in crime. They tested different mechanisms and found that over 70% of the effect was through changes in the labor market. In regards to Mexico, Dube et al. (2016) also find a positive correlation between trade liberalization and higher crime levels. They studied the effect of NAFTA on corn prices and its effect on the drug trade in Mexico. Like avocados, the signing of NAFTA opened the trade of corn across Mexico and the U.S. After NAFTA, Mexico started importing corn from the U.S., and corn prices in Mexico decreased. As a result, Dube et al. (2016) found evidence of corn farmers switching to more profitable crops, such as marijuana and opium, which contributed to the drug trade in Mexico and increased violence. My paper differs from

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<sup>1</sup>The 2018's theft incidence was 10,000 per 100,000 people and the extortion rate over 6,000 per 100,000 people (INEGI, 2020).

their study by looking instead into the effects of a positive impact on avocado prices after NAFTA and its effects on violent crime and cartel presence.

My paper also contributes to the literature studying the relationship between income and violence. 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). In this paper's context, a change in the prices of agricultural products can affect the farmer's opportunity cost for specializing in the cultivation of illicit drugs such as marijuana and poppy (Dube et al., 2016), or engaging in other criminal activities. Chassang and Padró i Miquel (2009)'s theoretical model predicts a negative relationship between income and civil conflicts. Their model shows that poorer countries are more likely to suffer from civil war as the opportunity cost of fighting is lower. Empirical evidence of this effect has been found by Bazzi and Blattman (2011), Berman and Couttenier (2015), Brückner and Ciccone (2010), and Miguel et al. (2004), who have also found evidence of a negative relationship between prices of exports and economic shocks on civil conflicts in Sub-Saharan African countries.

On the other hand, more income increases the returns to appropriation (Angrist and Kugler, 2008; Chimeli and Soares, 2017; Parker and Vadheim, 2017). In other words, individuals have higher incentives to try to tap into avocado revenues by engaging in criminal activities. Evidence of a positive relationship between income and violence has been found by Angrist and Kugler (2008), Chimeli and Soares (2017), and Dube and Vargas (2013).

Moreover, theoretical and empirical evidence supports that the relationship between income and violence can depend on the commodity type. Dal Bó and Dal Bó (2011)'s general equilibrium model and Dube and Vargas (2013)'s study on changes in oil and coffee prices in Colombia found a negative relationship between income shocks and violence in labor-

intensive industries and a positive relationship in capital-intensive industries. This study seeks to contribute to this literature by providing further evidence on the relationship between income shocks and violence, and its mechanisms.

To analyze the relationship between a change in avocado prices and violence, I use municipal-level information on violence and avocado prices obtained from the National Institute of Statistics of Mexico (INEGI) and the Secretary of Agriculture (SAGARPA) from 1990 to 2010. To estimate the effect on violence, I use the annual number of murders per 100,000 people present in each municipality. Additionally, I use municipal level precipitation and temperature data between 1990 and 2010 obtained from AgMerra to build a measure of Agro-climatic suitability for avocado growing.

NAFTA provides a unique opportunity to identify the effect of a resource boom on violence, as it exogenously increased the demand for Mexican avocados and, as a result, the national prices of this crop. I take advantage of each NAFTA opening to test whether avocado prices increased violence in municipalities suitable for avocado growth. I use a difference-in-differences strategy to determine whether changes in avocado demand had a higher impact on violence in municipalities suitable for avocado production. I hypothesize that this was not the case. Higher avocado revenues may have instead led to a decrease in violence by increasing the opportunity cost of engaging in a criminal activity by providing new employment opportunities and more competitive wages.

For this analysis, I use data for only the states of Jalisco, Estado de México, Michoacán, and Guerrero, as they share similar weather and socioeconomic conditions, are geographically close to each other, and account for over 90% of Mexico's annual avocado production in 2018 (SAGARPA). As of 2020, Michoacán is the only state in Mexico authorized to export avocado to the U.S. Mexican avocados' success in the global market is attributed to this state's ability to produce avocados all-year-round.<sup>2</sup> This gives it a unique advantage against its competitors

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<sup>2</sup>Michoacán's rich volcanic soil, consistent temperatures, and abundant rainfall provide the ideal setting for avocados. Besides, the presence of a wide range of different elevations allows for four different blooming cycles in each avocado tree during a given year (Salazar-García et al., 2005). The specific months during which avocados bloom and can be harvested will depend on the elevation at which the tree has been

in the U.S. market (California, Chile, and Peru), which are only able to produce avocados during the summer months (Ambrozek et al., 2018).

The results reveal a statistically significant decrease in homicide rates by 33.6% in avocado-growing municipalities during the first wave of NAFTA. Importantly, this effect does not appear to be limited to avocado-exporting municipalities in Michoacán. This suggests that NAFTA raised income levels in avocado-exporting areas while stimulating avocado demand across the country.

Furthermore, my research findings do not show changes in the presence of cartels throughout the studied period. This implies that the observed decrease in violence cannot be attributed to shifts in cartel dynamics. Finally, my results show that the opening of NAFTA improved dwelling characteristics in avocado-growing municipalities. These findings suggest that the mechanism through which NAFTA improves violence in avocado-growing municipalities was through higher opportunities for employment in the avocado production and exporting industry.

This is the first study to look into the relationship between an increase in the demand for avocado and violence, to the best of my knowledge. Other studies have looked into the effects of an increase in individuals' demand for superfoods, such as Bellemare et al. (2018)'s study on quinoa. They found that an increase in quinoa prices led to higher welfare for Peruvian households through an income effect.

Similarly, other studies have looked into the effects of NAFTA on the avocado sector. However, most of these studies have focused on measuring the impact of the sanitary and phytosanitary regulations that originated from NAFTA and the welfare effects of opening the U.S. market to Mexican avocados. For instance, Peterson and Orden (2008)'s general equilibrium model studies the welfare effects resulting from a possible increase in pest risk after the U.S. eased seasonal and geographical restrictions on Mexican avocados in 2005.<sup>3</sup>

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cultivated. This overlap between blooming and harvesting periods at different elevations allows avocados in Michoacán to be harvested all-year-round (Salazar-García et al., 2005).

<sup>3</sup>The 2005 opening eliminated the seasonal restriction to Mexican avocados and allowed them to be exported to all states in the U.S. except for California and Florida.

Carman et al. (2009), in contrast, evaluate the impact of promotion investments on the demand for avocado in the U.S.

This chapter is organized as follows. Section 2.2 describes the context. This includes the gradual opening of avocados into the U.S. after NAFTA and information on the production of avocados in Mexico. In Section 2.3, I describe the model and the conceptual framework. In Sections 2.4 and 2.5, I present the data and the empirical strategy. Lastly, Section 2.6 describes the results.

## 2.2 Background

### 2.2.1 NAFTA ease of regulations on Mexican avocados

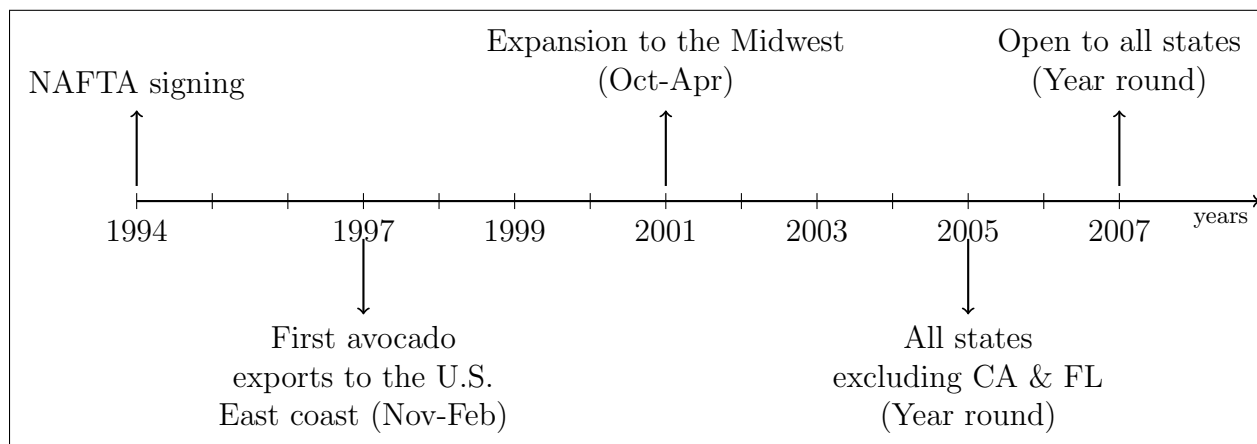
Before 1997, Mexican avocados were banned in the U.S. to prevent the introduction of pests, such as the avocado screwworm. However, the signing of NAFTA allowed the Mexican government to submit requests for consideration on the introduction of avocados in the U.S. In July 1994, the Ministry of Agriculture submitted a request to the USDA's Animal and Plant Inspection Service (APHIS) to evaluate the importation of fresh avocados from approved orchards in Michoacán (USDA, 2001).

In January 31, 1997 the USDA's Animal and Plant Inspection Service (APHIS) authorized the introduction of Mexican avocados to 19 Northeastern states (see Table B1 in the Appendix for the list of states) for the months of November-February (see Timeline in Figure 2.1) provided that orchards met the phytosanitary requirements (Carman and Sexton, 2011). These limitations had the intention to minimize the probability of a pest infestation in avocado growing areas by only allowing the introduction of avocados during the winter months and to states that were far from the U.S. main avocado producers: California and Florida. Additional strategies were put in place to avoid pest infestation such as field surveys<sup>4</sup> and fruit inspections both at packing houses and at ports of arrival (Bredahl, 2001).

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<sup>4</sup>Farmers need to go through a certification process in order for their avocados to be exported to the U.S.

Figure 2.1: Timeline on NAFTA openings to U.S. avocado market



In 2001, the APHIS authorized shipments to 12 additional states and extended the period to October 15 - April 15. In 2005, it eased the restrictions on Mexican avocado exports to all states, except for California and Florida and it allowed, for the first time, year-round shipments. Lastly, in 2007, the APHIS authorized the introduction of Mexican avocados to all U.S. states. Figure B1 in the Appendix shows how Mexican exports expanded with each opening phase. In particular, we observe a higher increase in exports in 2005 and 2007.

### 2.2.2 Production of avocados in Mexico

Mexico is the largest producer of avocados in the world with a total production in 2018 of over 2.18 million tons. It is also the world's largest exporter of avocados, followed by the Dominican Republic with a production of over 380 thousand tons per year (SENASICA, 2017). Currently, Mexico produces over one-third of the world's avocados. The total value of exports in Mexico has increased dramatically since 2004, reaching almost 3 billion USD in 2017 (see Figure B1 in Appendix). At the same time, cultivated areas have increased from 100,000 hectares in 2004 to 240,000 in 2018, while harvested areas have risen to 200,000

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Their orchards get certified on the basis of their field survey results. In addition, to the field certification, each municipality has to be pest free at a 95% confidence interval (Bredahl, 2001).

hectares (see Figure 2.8). Additionally, yields measured as tons produced per hectare have increased from 3,500 in 2010 to over 5,200 by 2018.

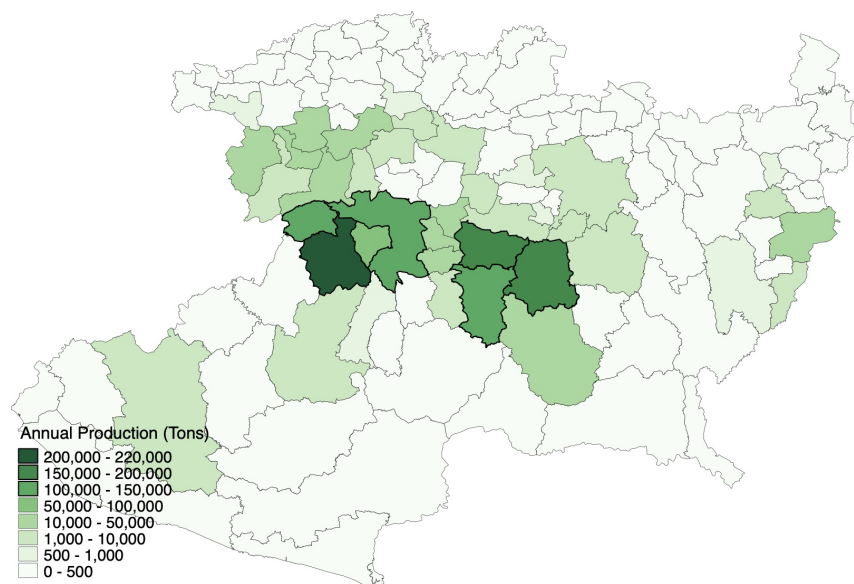
Most of the avocados in Mexico are grown in the state of Michoacán, located in the west-center area of Mexico (see Figure 2.2). As of 2018, Michoacán, Jalisco, Estado de México, and Guerrero account for over 90% of the total national avocado production. The state of Michoacán is the leading producer with over 76% of the total production, followed by Jalisco with 9.2%. The area where avocados are the most fruitful in Michoacán is called the *franja aguacatera* (see Figure 2.3). It consists of over 7,000 square kilometers over 22 municipalities and corresponds to 13% of the total state area (Salazar-García et al., 2005). The main producer in Michoacán is the municipality of Tancítaro with an average annual production of over 200,000 tons of avocado per year, followed by Tacámbaro with over 150,000 tons per year.

Figure 2.2: Annual average production of avocado (2011-2018)



Source: own using information from SAGARPA.

Figure 2.3: Annual average production in Michoacán municipalities (2011-2018)



Source: own using information from SAGARPA.

### 2.2.2.1 Mexican avocados in the global market

In recent years, the global demand for avocados has increased as avocados' health benefits have become known. In particular, the growth in per capita consumption of fresh avocados in the U.S. has been remarkable. In 1997, avocado consumption was at around 1.6 lbs per capita; in 2010, it had reached 4 lbs, and by 2018 it had doubled to 8 lbs (USDA-ERS, 2019). As demand for avocados has increased in the U.S., Mexico's share of the U.S. fresh avocado market in 2018 has expanded to about 89% (and over 76% of all Hass avocados consumed in the U.S. (Ambrozek et al., 2018)), while shares from other competitors such as California, Chile, and the Dominican Republic have declined. In recent years, Peru has also experienced an expansion in the U.S. market, becoming the second-largest import supplier with 8% of total imports (USDA-ERS, 2020).

The difference in blooming seasons between California, Chile, and Peru shifts the availability of avocados in the U.S. For instance, Peruvian and Californian avocados are only present in the U.S. market during the summer months. Moreover, Peruvian exports mainly target states on the East Coast to avoid competition with Californian avocados. Meanwhile,

Chile's flowering period is counter-seasonal to California's and Peru's, and its exports target the West Coast (Ambrozek et al., 2018). In contrast, Mexico's favorable conditions for avocado growth allow it to supply avocados all-year-round, giving it a unique advantage against its competitors.

As of 2020, the only state in Mexico authorized to export avocado to the U.S. was Michoacán, with about forty-five eligible packing houses. Avocados from Michoacán account for 90% of the country's avocado exports. Meanwhile, other producing states export to countries such as Japan, Canada, and the European Union (USDA, 2018).

### 2.2.2.2 Michoacán

The success of Mexico in the global market is attributed to the state of Michoacán's ability to produce avocado all year-round. The state's rich volcanic soil, annual temperatures ranging between 45°F to 90°F, and abundant precipitation (63 inches annually) provide an ideal setting to grow avocados. Moreover, the blooming cycles and the presence of zones at different elevations (ranging 1,500 – 2,200 meters above the sea) make it possible for orchards to bloom throughout the year. This is particularly true for the avocado Hass variety (Hofshi, 2001)<sup>5</sup>.

Hass avocados represent 90% of the total cultivated area in the state (Hass Avocado Board, 2019). The blooming and harvesting of avocados are highly influenced by elevation. The variety of altitudes in Michoacán and its suitable weather all year long allows for up to four blooming cycles in the same tree or orchard. While the specific months at which avocados can bloom will depend on the elevation at which they were cultivated, these blooming cycles are usually defined as Loca (August-September), Avanzada (October-December), Normal (December-February), and Marceña (February-March). Meanwhile, the

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<sup>5</sup>This variety of avocados was discovered in California in 1926 and is preferred in the global market due to its high resistance to plagues, the high quality of its pulp, and its high oil content. Hass trees also have a long flowering period and can bloom two to four times a year. They are also able to remain in the tree for months, even after they have matured, and will only ripe after being picked. This allows farmers to plan when to harvest according to the current market conditions.

harvest periods for each blooming cycle are July-August, September-October, November-February, and March-June, correspondingly (Hass Avocado Board, 2019). This overlap in the blooming and harvesting periods at different elevations allows avocados to be harvested all year-round. Moreover, each blooming cycle can result in different yields: Loca blooms can account for between 5-20% of the total annual production, Avanzada for 10-25%, Normal for 60-80%, and Marceña for 15-30% (Salazar-García et al., 2005).

According to the Hass Avocado Board (2019), most of the production in Michoacán is carried out by small producers. Plantations of less than 10 hectares account for 65% of the cultivated surface, while 26% of the total surface area belongs to medium-size orchards between 10 and 30 hectares. Finally, out of the approximately 30,000 producers in the state, 70% of them own land or rent it, while the rest have access to community land (Hass Avocado Board, 2019).

Regarding production, farmers of avocado are in charge of the cultivation and fertilization of the avocado trees. Because avocados mature after being picked and can be stored in the tree for several weeks, the avocados are usually sold at the tree. Exporters buy the fruit from the orchards, and they pay a fixed price on the avocados, regardless of the fruit's quality or size. Picking of the avocado is carried out by contractors hired by the exporters, who choose the avocados that have the required size for exportation and leave the rest to mature in the tree (Hass Avocado Board, 2019).

## 2.3 Model and Conceptual Framework

To test the mechanism through which the opening of NAFTA, and the subsequent increase in the demand for avocados, affect crime I follow Dal Bó and Dal Bó (2011)'s simple three-sector conflict model, as well as the Dube and Vargas (2013) predictions based on this model.

In this paper, I assume the existence of two productive and legal sectors. Both of these  $i$  sectors use capital  $K_i$  and labor  $L_i$  as factors. One sector is capital-intensive (e.g. corn), and

the other one is labor-intensive (e.g. avocados), and both have constant returns to scale and produce output  $y_i$ . Each output is traded at a price  $p_i$ . I assume the price of sector 2 ( $p_2$ ) as numeraire and denote the relative price of sector 1 as  $p$ . This economy has an endowment of capital  $\bar{K}$ , and of labor  $\bar{L}$ , which are mobile between sectors and have a rental price  $r$  and wage  $w$ , correspondingly.

Additionally, there is a third sector that is illegal and does not produce output. Similar to Dal Bó and Dal Bó (2011), I denote this as the *appropriation* sector. For this model, I assume no competition in the appropriation sector<sup>6</sup>. The appropriation sector has an objective to steal a proportion of the other two sectors' output, resulting in crime and violence in the economy. This sector only employs labor  $L_A$ . The fraction stolen by the appropriation sector is denoted by  $A(L_A)$  and is a concave function of  $L_A$ , meaning that it is increasing in labor ( $A'(L_A) > 0$ ) and has diminishing marginal productivity ( $A''(L_A) < 0$ ). The total amount appropriated by this sector will be given by  $A(L_A)[py_1 + y_2]$ . Under constant returns to scale, this will equal a fraction of the total amount paid for capital and labor used in the productive sectors:

$$A(L_A)[w(\bar{L} - L_A) + r\bar{K}]$$

In this model, workers can choose to work between the productive sectors and the appropriation sector. If they choose to work in the productive sector, they get paid  $[1 - A(L_A)]w$  (after appropriation), and if they go into the appropriation sector, they earn:

$$\frac{A(L_A)}{L_A}[w(\bar{L} - L_A) + r\bar{K}]$$

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<sup>6</sup>In this paper, I abstract from the complexities of DTOs since, during the period reviewed, there was little fragmentation of drug cartels. In De Haro Lopez (2023), I analyze the scenario where there is competition among DTOs.

The equilibrium in this model is characterized as follows. First, given unit factor requirements  $a_{ki}$  for input  $k$  in sector  $i$ , profits in the productive sectors must be zero:

$$ra_{1K} + wa_{1L} = p \quad (2.1)$$

$$ra_{2K} + wa_{2L} = 1 \quad (2.2)$$

$$(2.3)$$

Moreover, factor markets must clear:

$$a_{1K}y_1 + a_{2K}y_2 = \bar{K}$$

$$a_{1L}y_1 + a_{2L}y_2 = \bar{L} - L_A$$

Lastly, the no arbitrage condition must hold, such that the returns to labor in the productive sector net of appropriation are the same as in the appropriation sector:

$$\frac{A(L_A)}{L_A} [w(\bar{L} - L_A) + r\bar{K}] = [1 - A(L_A)]w \quad (2.4)$$

Moreover, I add a last component where I assume that the frequency of violent crimes given by  $V(L_A)$  increases with the size of the appropriation sector  $L_A$ . This is relevant since the model described by Dal Bó and Dal Bó (2011) has the following two important predictions for the interpretation of this paper's results, as shown by Dube and Vargas (2013).

First, Dal Bó and Dal Bó (2011)'s model predicts that the Stolper-Samuelson Theorem holds: an increase in the capital-intensive good price will increase the price of capital  $r$  and decrease the price of labor  $w$ . Similarly, an increase in the labor-intensive good price will result in higher wages and lower rental prices. In other words, when sector 1 is relatively more labor intensive  $\frac{a_{1K}}{a_{1L}} < \frac{a_{2K}}{a_{2L}}$ ,  $\frac{dw}{dp} > 0$  and  $\frac{dr}{dp} < 0$ . Similarly, when sector 1 is more capital-

intensive ( $\frac{a_{1K}}{a_{1L}} > \frac{a_{2K}}{a_{2L}}$ ),  $\frac{dr}{dp} > 0$  and  $\frac{dw}{dp} < 0$ . This can be demonstrated by differentiating conditions (1) and (2):

$$\frac{dw}{dp} = \frac{-a_{2K}}{a_{1K}a_{2L} - a_{1L}a_{2K}} \quad (2.5)$$

$$\frac{dw}{dp} = \frac{a_{2L}}{a_{1K}a_{2L} - a_{1L}a_{2K}} \quad (2.6)$$

Second, an increase in the price of the labor-intensive good decreases the size of the appropriation sector. This can be demonstrated by differentiating the size of the appropriation sector  $L_A$  with respect to the relative price of sector 1  $p$  using condition (3):

$$\frac{dL_A}{dp} = - \frac{\frac{\bar{K}L_A}{\left(\frac{r}{w}\bar{K} + \bar{L}\right)^2} \frac{d\left(\frac{r}{w}\right)}{dp}}{\left[A' - \frac{1}{\frac{r}{w}\bar{K} + \bar{L}}\right]} \quad (2.7)$$

From the previous condition, it follows that the denominator is negative from the concavity of  $A(L_A)$ , and the sign of the equation is given by  $\frac{d\left(\frac{r}{w}\right)}{dp}$ . Therefore, when output in the productive sector 1 is capital intensive  $\frac{d\left(\frac{r}{w}\right)}{dp} > 0$  and  $\frac{dL_A}{dp} > 0$  (i.e., the size of the appropriation sector increases). Conversely, when the sector is labor-intensive  $\frac{d\left(\frac{r}{w}\right)}{dp} < 0$  and  $\frac{dL_A}{dp} < 0$ , which implies a decrease in the size of the appropriation sector.

Based on the above, we expect that an increase in the price of the labor-intensive good would increase the size of the appropriation sector. Since with some positive probability ( $\theta \in (0, 1)$ ) appropriation efforts would result in violent crime, we expect that an increase in the appropriation sector's size will lead to more violence.

This model predicts that an increase in the price of avocados (a labor-intensive good) would increase the price of labor  $w$  and reduce the size of the appropriation sector  $L_A$ . This, in turn, would decrease violence. The model delivers the following predictions: i)

the NAFTA openings increased the prices of avocados, ii) the NAFTA openings led to an increase in wages of the agricultural sector in municipalities that are avocado suitable, iii) higher demand for avocados led to higher employment in the avocado sector and a decrease in the size of the appropriation sector, and iv) higher employment decreased violent crimes in municipalities that are suitable for avocado growing. Since the appropriation sector's size is not observable for the researcher, I analyze the direct effect of each of the NAFTA openings on violence outcomes in avocado-suitable municipalities.

**Long run vs. short run.** A key assumption of this model is that factors are mobile between sectors. Since, in the long run, capital is mobile, the predictions of this model can be thought to be long-run predictions. In the short run, however, capital is fixed. In the case of a labor-intensive industry, such as the avocado sector, an increase in the price of avocados will still lead to higher wages and lower violence in the short run, as capital does not change. In this case, the assumption of the capital being fixed would not change the model's predictions for a labor-intensive industry.

Conversely, in the case of a capital-intensive industry, Dal Bó and Dal Bó (2011) expanded on the model and demonstrated that a shock in the capital-intensive sector that raises wages can be associated with higher, rather than lower, levels of violence. They find that even with fixed capital, the returns for appropriation outweigh the increase in the opportunity cost of engaging in criminal activities.

## 2.4 Data

In this paper, I look into the effect of NAFTA on violence in avocado-growing municipalities. To do this, I restrict my sample to municipalities in the main avocado producer states: Michoacán, Jalisco, Estado de México, Guerrero, Morelos, Nayarit, and Colima. All of these

states (except for Colima<sup>7</sup>) were the leading avocado producers during my research period. These states account for over 95% of all avocados in Mexico<sup>8</sup> and are geographically close to each other (see Figure 2.2).

Additionally, in this study, I restrict the analysis period to 1990 through 2006. The main reason is that the war on drugs led by President Felipe Calderón in 2006 significantly changed DTOs' dynamics. Before 2010, fewer and larger drug cartels benefited from little surveillance and resistance from corrupt authorities. However, the capture of drug cartel leaders led to instability inside major cartels and to their fragmentation. As a result of the increased competition, DTOs in the country became more violent (Atuesta and Ponce, 2017; Calderón et al., 2015; Jones, 2013). To put this into perspective, the war against drugs increased national homicides from less than 10 murders per 100,000 people to more than 22 by 2012. One of the states that experienced higher levels of violence was Michoacán, which saw the emergence of the La Familia Michoacana cartel in 2006 (Beittel, 2020).

Because of how the war against drugs changed the dynamics of drug cartels, I cannot attribute changes in violence following 2006 solely due to NAFTA. Therefore, by restricting this study to the period from 1990 to 2006, I can estimate the effect of NAFTA without the confounding factors following the war against cartels. Moreover, I can study the impact of NAFTA in a setting with little cartel fragmentation and limited competition between DTOs. This means I will only have estimates for the first three openings (that is, I will be excluding the 2007 wave). My resulting sample has 8,619 observations and includes information for 507 municipalities, of which 113 correspond to Michoacán.

### 2.4.1 Data on crime and cartel presence

To estimate the effect of an increase in avocado demand on violence in Mexico, I use the information on homicides as a proxy for the incidence of crime. I estimate the annual

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<sup>7</sup>Colima was added to the sample because it is located between two avocado growing states. Estimates are robust to adding or not Colima.

<sup>8</sup>Own estimates based on data from SAGARPA, 2006.

homicide rate in each municipality using data reported by the National Institute of Statistics and Geography of Mexico (INEGI). This database includes the total number of murders registered each month per municipality from 1990-2018. It contains information on the victim (age, gender, marital status, nationality, occupation), as well as the cause of death and the place where it occurred (see Table B2 in the Appendix for a detailed summary on the data sources used for this study).

Police records on other types of crimes, such as extortion, kidnappings, and thefts, are, unfortunately, only available from 2011 (four years after the last NAFTA opening), rendering them unsuitable for this analysis. Nevertheless, homicides are considered a more reliable proxy for violent crimes in countries like Mexico, where citizens rarely report crimes. According to estimates from INEGI's National Survey of Victimization and Perceptions of Public Security (ENVIPE), in 2018, 93.2% of total crimes in Mexico were not reported by individuals or filed by the police. In 31.7% of the cases, individuals answered that they considered reporting a crime a waste of their time, and in 17.4% of the cases, they mentioned that they distrusted the police (INEGI, 2019a). Citizens also underreport violent crimes. To put this into perspective, INEGI estimates that in 2018 there were 79,315 kidnappings in the country, but the Ministry of Public Security (SSP) only has a record for 1,327.

To evaluate if the opening of NAFTA increased the presence of DTOs in municipalities that grow avocados, I use the information on cartel presence from the Mapping Criminal Organizations project (MCO) (Signoret et al., 2022). This database uses a web crawling technique to obtain information on news related to cartels on Google and Google News. It identifies the number of paragraphs in which a cartel was mentioned along with a municipality in a given year. The MCO database has information on 75 different DTOs in Mexico for the years between 1990 to 2020. Information on cartel presence at the municipality level is also available from Coscia and Rios (2012). This database has municipal-level information on annual cartel presence from 1991 to 2010. It uses an algorithm that identifies news on drug cartels and famous drug traffickers. It uses data from the Google News API, which was

closed in 2011. It provides information on the presence of seven major cartels,<sup>9</sup> including La Familia Michoacana, which was prominent in Michoacán before 2006. I use the MCO database to present my main results and use Coscia and Rios (2012)'s database to perform a robustness check on my results.

## **2.4.2 Information on the production of avocado and suitability measure**

Annual production and prices of avocado were obtained from the Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food of Mexico (SAGARPA). This database includes the annual production in tons, prices per ton, the number of hectares cultivated, and the hectares harvested by municipality from 2003 to 2018. Data on the annual production and farmgate prices per ton by state is available from SAGARPA between 1990 and 2002. Moreover, information on the national value of avocado exports is available for each month from 1993 to 2018 from Mexico's Central Bank (BANXICO).

Precipitation and temperature data at the municipality level was estimated using information from AgMerra. The database includes daily maximum, minimum, and average temperature, as well as daily precipitation for each municipality between 1990-2010. I use this information to build an avocado suitability measure for each municipality in the sample. In the next section, I explain how I built it.

### **2.4.2.1 Avocado Suitability Measure**

To estimate the impact of violence on municipalities that can produce avocado, I constructed an avocado suitability measure to identify avocado-growing areas. I use this index rather than municipal-level information on avocado production since the suitability index can iden-

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<sup>9</sup>Coscia and Rios (2012)'s database contains information on the following cartels: Beltran Leyva, La Familia Michoacana, Golfo, Juárez, Sinaloa, Tijuana, and Los Zetas.

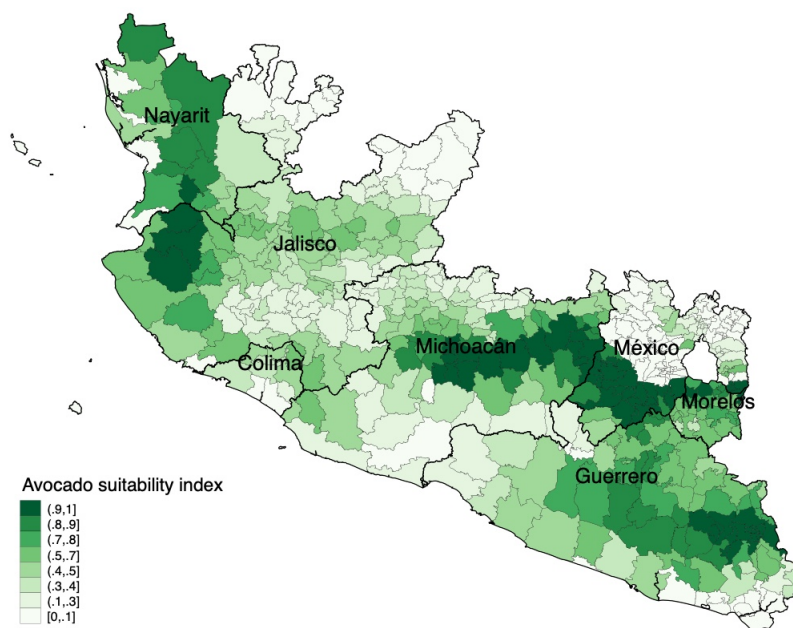
tify municipalities where avocados have the potential to grow uniquely based on weather characteristics, which are exogenous to changes in the demand for avocados.

Moreover, while the Food and Agricultural Organization (FAO) of the United Nations has information on agro-climatically attainable yields for some crops, it does not exist for avocados. However, FAO's Ecological Crop Requirements (Ecocrop) database does provide information on the minimum and optimal requirements for avocado growing which I use to estimate a municipal-level avocado suitability index.

To build this index, I use the Ecocrop suitability model proposed by Hijmans et al. (2017), a mechanistic but well-established model for crop suitability commonly used by agronomists (Møller et al., 2021). In contrast to machine learning approaches to building crop suitability indices, the Ecocrop model uses data on the minimum and optimal agro-climatic requirements for crop growing based on academic research from experts in the area. This model has also been proven to be more accurate than machine learning techniques at predicting ecological suitability (Møller et al., 2021), as it relies only on agro-climatic data to determine suitability. Meanwhile, methods that measure suitability based on realized crop yields can integrate unobserved socio-economic factors that predict whether a suitable place develops, which makes this type of measure potentially endogenous to the model.

The Ecocrop suitability index uses data on temperature and precipitation and compares it to the crop's agro-climatic requirements throughout the growing season. To estimate this index, I used municipal-level temperature and precipitation data obtained from AgMerra. Moreover, since avocados have particular elevation requirements to grow, I added a secondary restriction, where I considered municipalities with no localities within the suitable altitude range unsuitable. The resulting index is a continuous measure that takes on values between zero and one, with one corresponding to a municipality with optimal conditions for avocado growing and where zero indicates that the municipality is unsuitable. Figure 2.4 shows the sample's spatial distribution of the suitability index. Meanwhile, the specifics on how I built this index can be found in Chapter 1.

Figure 2.4: Avocado suitability



Notes: Graph shows the distribution of the avocado suitability index. The index goes from zero to one, where one indicates an area with optimal conditions for avocado growing, and zero is unsuitable.

### 2.4.3 Other variables

Information on population by municipality was obtained from INEGI's National Censuses of 1990, 2000, and 2010, and the National Population Count of 1995 and 2005. Finally, the party affiliation of municipal mayors was obtained from the National Institute for Federalism and Municipal Development (INAFED). This database contains information on all the elected mayors between 1993 and 2018. I use party affiliation as a proxy for enforcement and to account for differences in how parties engage with criminal groups at the municipal level. For instance, Dell (2015) finds evidence of an increase in drug-related violence in municipalities with a PAN mayor following the election of President Felipe Calderón in 2006.

Finally, information on sociodemographic characteristics was obtained from the National Censuses of 1990, 2000, and 2010, and the National Counts of 1995 and 2005. This includes data on the provision of public services and dwelling characteristics. Table B3 in the Appendix shows the descriptive statistics for all variables.

## 2.5 Empirical Strategy

### 2.5.1 Difference-in-Differences estimation

The signing of NAFTA between Mexico, the U.S., and Canada allowed Mexican avocados to enter the U.S. market. In turn, the U.S. government implemented protective measures to slowly introduce Mexican avocados to avoid the introduction of pests and competition with Californian avocados. The slow introduction of avocados from Mexico provides a unique opportunity for identification, as each expansion exogenously increased the demand for Mexican avocados.

In estimating the effect of an increase in the demand for avocados on violence, the main identification challenge is the endogeneity between crime and avocado prices. High levels of violence can severely change farmers' production costs by increasing the risk of growing avocado and/or transportation costs. At the same time, changes in the prices of avocados can lead to higher levels of violence if criminal organizations try to tap into avocado revenues. To circumvent the endogeneity of prices and violence, I take advantage of how the gradual opening of the U.S. market created exogenous increases in the demand for avocados for both municipalities that can export avocados to the U.S. (located in the state of Michoacán) and those that sell domestically. To measure the impact of each NAFTA opening, I use a difference-in-differences (DiD) regression, where  $Y_{it}$  is the log transformation of the number of murders per 100,000 people in municipality  $i$  at year  $t$ ;  $S_i$  is an avocado suitability measure, and  $NAFTA_i$  is a dummy variable equal to one for the years between each opening (see Timeline in Figure 2.1). In this case, the baseline category is the period between 1990 and 1996. The main specification is as follows:

$$\begin{aligned}
 Y_{it} = & \alpha_i + \tau_t + \gamma_1(S_i * NAFTA_{1997 \leq t \leq 2000}) + \gamma_2(S_i * NAFTA_{2001 \leq t \leq 2004}) \quad (2.8) \\
 & + \gamma_3(S_i * NAFTA_{2005 \leq t \leq 2006}) + \varepsilon_{it}
 \end{aligned}$$

The specification includes municipality ( $\alpha_i$ ) and time ( $\tau_t$ ) fixed effects to account for time-invariant municipal characteristics and possible shocks in time.

### 2.5.1.1 Parallel trends assumption

Note that to ensure the internal validity of the DID regression, I need the parallel trends assumption to hold. In other words, I need that in the absence of treatment (NAFTA), the difference in violence between municipalities that are suitable for avocado production and those that are not would remain constant over time. Figure 2.5 shows the annual number of murders per 100,000 people by suitability. Between 1990 and 1996, the number of murders for all suitable measures seems to follow a similar trend to the unsuitable municipalities in my sample, except for an increase in murders in 1992.

To test the parallel trends assumption, I look into the trends in homicides before and after the first opening in 1997. I do this by estimating the following regression:

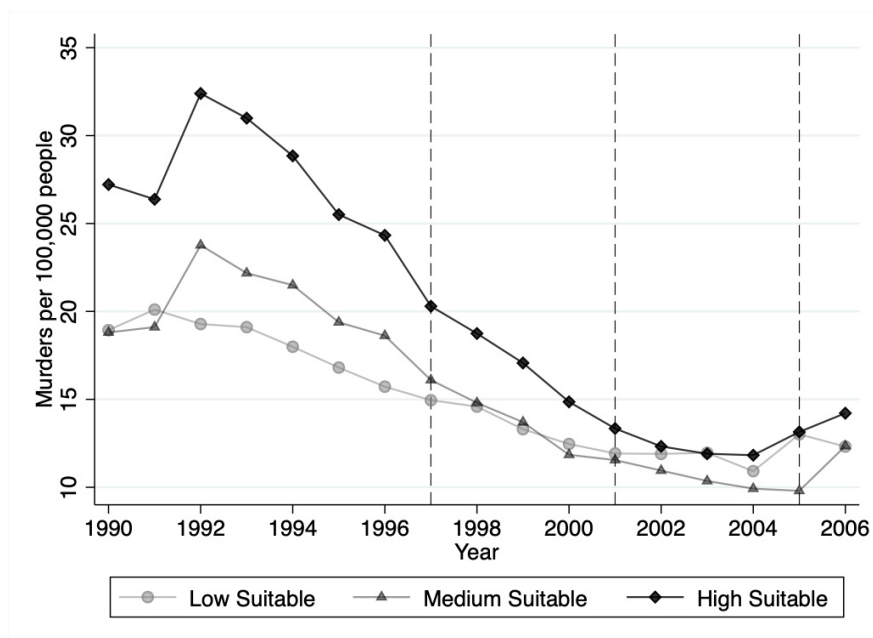
$$Y_{it} = \alpha_i + \tau_t + \sum_{j \neq k} \lambda_j (S_i \times \text{Year}_{t=j}) + \epsilon_{it} \quad (2.9)$$

where,  $Y_{it}$  is the logarithm of the number of murders per 100,000 people in the municipality  $i$  at year  $t$ ,  $S_i$  is the avocado suitability measure corresponding to the municipality  $i$ , and  $\text{Year}_t$  is a dummy equal to one if the current year  $t$  is equal to  $j$ . Moreover,  $\alpha_i$  and  $\tau_t$  are municipality and time fixed-effects. I estimate this equation for the period between 1990-2010, where  $k$  is the year the municipalities became treated (1997). In this case, the coefficient of interest is  $\lambda_j$ .<sup>10</sup> If the parallel trends assumption holds, we should observe no effect on the suitability measure on violence before 1997. In other words, that  $\lambda_j$  is not statistically different from zero for  $j < k$ .

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<sup>10</sup>Note that non-interacted terms  $S_i$  and  $\text{Year}_t$  are not included in the regression since they are absorbed by the municipality and time fixed effects, respectively.

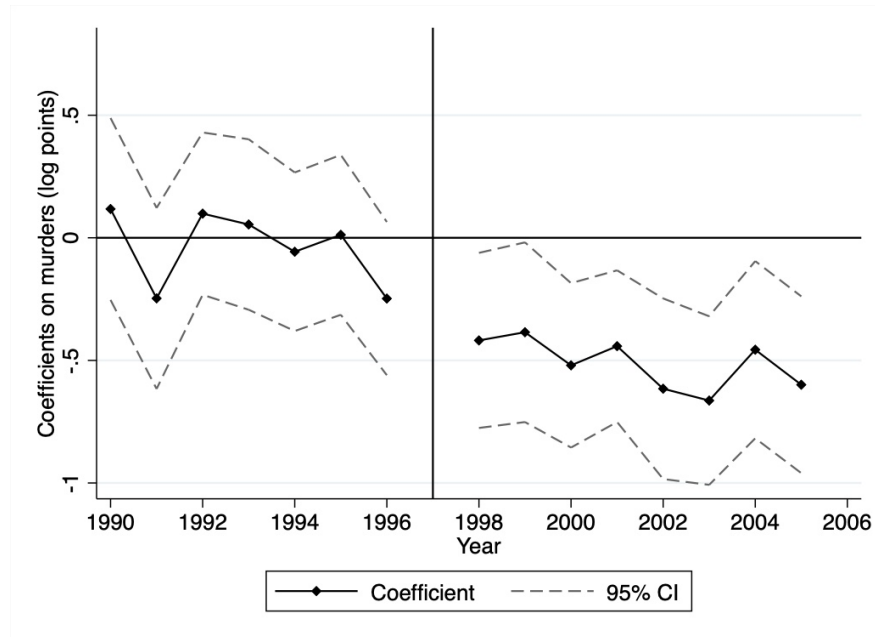
Figure 2.5: Murders by suitability (1990-2010)



Source: own using information from INEGI.  
Vertical lines represent each of the NAFTA openings.

Figure 2.6 shows the interaction coefficient estimates  $\lambda_j$  along with their corresponding 95% confidence intervals. Meanwhile, the vertical line indicates when the U.S. first allowed imports of Mexican avocados (i.e., the 1997 wave). The results show that coefficients for the pre-treatment period are not statistically different from zero. In other words, I find evidence to support the parallel trends assumption. Figure 2.6 also shows a negative and significant relationship between avocado suitability and homicides after 1997, which indicates that effectively avocado suitable municipalities experienced a decrease in murders after the first opening.

Figure 2.6: Parallel trend test with avocado suitable municipalities



## 2.5.2 Event Study

To estimate the short-term effect of each NAFTA event, I use an event study design. This event study takes as a baseline the year of 1997, and the main specification is as follows:

$$Y_{it} = \alpha_i + \tau_t + \sum_{\substack{y=-8 \\ y \neq -1}}^{10} \delta_y S_i \times I(t - 1998 = y) + v_{it} \quad (2.10)$$

where  $Y_{it}$  is the log number of murders per 100,000 people,  $S_i$  is a suitable measure, and 1998 is the first year the effect started. I choose 1998 as the first year rather than 1997 since the 1997 opening happened at the very end of the year; therefore, any changes in the annual homicide rate are likely not attributed to the opening to Mexican avocado imports. In this specification, the coefficients  $\delta_y$  provide an estimate of how much murders have increased or decreased relative to 1997.

## 2.6 Results

In this section, I analyze the effect of each of the NAFTA openings on murders in municipalities suitable for avocado growth. Table 2.1 shows the results for the main estimation. Column (1) shows the regression for the main specification. The results show that suitable municipalities experienced a decrease in 0.29 log points (33.6%) in the number of murders per 100,000 people following the first wave. It also shows a substantial and statistically significant decrease in homicides following the 2001 and 2005 openings.

Table 2.1: DID results on violence

	<i>Dependent variable: Log(murders)</i>	
	(1)	(2)
	Suitable	Suitable - Mich
1997-2000 × Suitable	-0.291*** (0.093)	-0.293*** (0.105)
2001-2004 × Suitable	-0.500*** (0.109)	-0.448*** (0.117)
2005-2006 × Suitable	-0.680*** (0.139)	-0.732*** (0.157)
1997-2000 × Michoacán		-0.569*** (0.128)
2001-2004 × Michoacán		-0.246 (0.174)
2005-2006 × Michoacán		-0.168 (0.201)
1997-2000 × Suitable × Michoacán		0.310 (0.220)
2001-2004 × Suitable × Michoacán		-0.0864 (0.305)
2005-2006 × Suitable × Michoacán		0.308 (0.354)
Observations	8619	8619
Adj. R-squared	0.453	0.456
Mean dep. var.	2.316	2.316
Year FE	YES	YES
Municipality FE	YES	YES

Notes: Clustered standard errors at the municipality level in parentheses. Suitable is a measure ranging between zero and one, where one indicates that a municipality has optimal conditions for avocado growing. Michoacán is a binary variable equal to one if a municipality is part of that state. All estimations control for political affiliation of the municipal mayor by including a dummy for each of the major parties in the period analyzed (PAN, PRI, PRD), and a binary variable equal to one if the municipal mayor party coincides with the president party.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

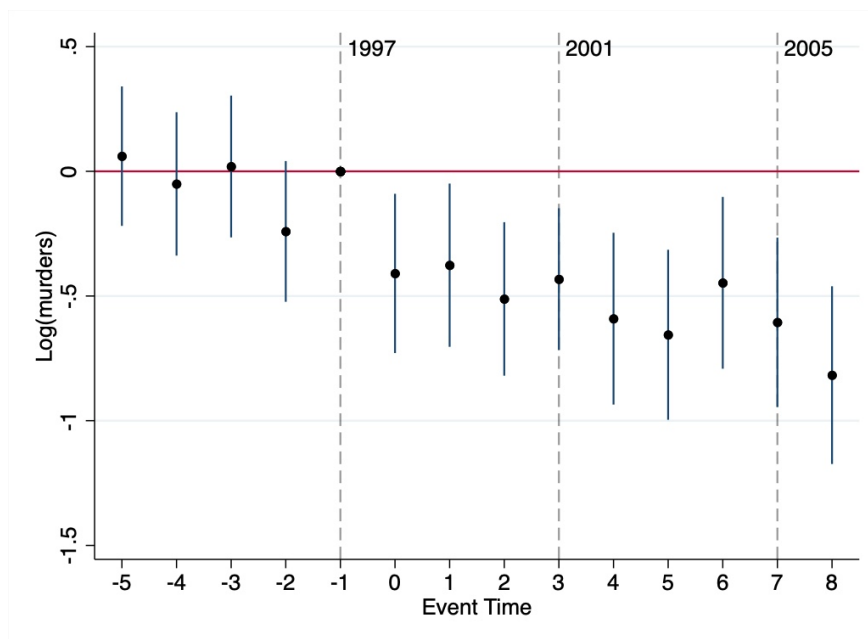
Since Michoacán is the only state allowed to export to the U.S., I test whether municipalities that produce avocados in Michoacán experienced a higher reduction in violence levels than other municipalities. Column (2) shows the results for the interaction of each wave with the avocado suitability measure and a binary variable equal to one if the municipality corresponds to the state of Michoacán. The results indicate that the effect of NAFTA does not affect avocado-growing municipalities in Michoacán differently than any other avocado-suitable municipality. This implies that NAFTA had a broader impact on violence, most likely due to an increase in national avocado prices that resulted from the exceeding demand for avocados following NAFTA.

A particular concern for my analysis is whether NAFTA had spillover effects for municipalities unsuitable for avocado production. Suppose these municipalities also experienced increased revenues due to the increase in the profitability of avocados, which also reduced homicides. In that case, my estimates would be upward biased; therefore, they can be considered a lower bound of the actual effect.

### 2.6.1 Event Study Results

To look into the effect of NAFTA on violence across the years, I estimate an event study taking as baseline 1997. Figure 2.7 shows the event study results for avocado-suitable municipalities. This is the coefficients  $\delta_y$  in Equation 2.10. The event study provides further evidence of the effect of NAFTA. In particular, it shows that the 1997 opening substantially decreased violence in avocado-suitable municipalities. It also shows that it has long-lasting effects with lower homicide rates for these municipalities and further, although smaller, reductions following the 2001 and 2005 waves.

Figure 2.7: Event study avocado suitable coefficient estimates on log murders (Baseline year: 1997)



## 2.6.2 Mechanisms

### 2.6.2.1 Drug cartels presence

In this section, I look into whether the decrease in violence observed in suitable municipalities is driven by the declining presence of drug trafficking organizations. To do this, I use data from the Mapping Criminal Organizations project (MCO) to measure the effect of NAFTA in avocado-suitable municipalities on three measures of cartel presence. The first one corresponds to the number of cartels present in a municipality. The second is the log transformation of the number of cartels, and the third is a binary variable equal to one if any cartel is present in a municipality in a given year. These estimations include all covariates and include year and municipality-level fixed effects.

Table 2.2 shows the results for these estimations. My results show virtually no impact of the first and second waves on cartel presence, except for a positive increase in the probability of cartels being present in a municipality after the second wave (see Column (3)). For the third wave, they show a statistically significant increase in the number of cartels present in

avocado-suitable municipalities. Contrasting this with the evidence of a decrease in violence, I conclude that a decline in cartel presence did not cause the observed fall in homicides. In fact, despite some evidence of cartels entering these municipalities, my estimates consistently show statistically significant declines in murder rates after the third wave.

I look into whether my results are robust to using another data source for cartel presence. In Table B6 in the Appendix, I estimate this same specification using Coscia and Rios (2012)'s database. I find no effect of each of the NAFTA waves on cartel presence, thus, providing evidence to support that the observed declines in homicide rates are not due to lower cartel presence. Finally, I also find no change in cartel presence in avocado-suitable municipalities in the state of Michoacán (see Table B7 in the Appendix).

Table 2.2: DID results on cartel presence using the MCO database

	<i>Number of cartels</i>		<i>Log(number of cartels)</i>		<i>Cartel presence (1/0)</i>	
	(1)		(2)		(3)	
	Suitable		Suitable		Suitable	
1997-2000 × Suitable	-0.005	(0.028)	0.000	(0.013)	0.006	(0.013)
2001-2004 × Suitable	0.081	(0.057)	0.038	(0.024)	0.041*	(0.023)
2005-2006 × Suitable	0.229*	(0.132)	0.073*	(0.043)	0.051	(0.034)
Observations	8,619		8,619		8,619	
Adj. R-squared	0.618		0.573		0.416	
Mean dep. var.	0.182		0.088		0.084	
Year FE	YES		YES		YES	
Municipality FE	YES		YES		YES	

Notes: Clustered standard errors at the municipality level in parentheses. Cartel presence is a binary variable equal to one if a municipality has at least one cartel in that year. Suitable is a measure ranging between zero and one, where one indicates that a municipality has optimal conditions for avocado growing. All estimations control for political affiliation of the municipal mayor by including a dummy for each of the major parties in the period analyzed (PAN, PRI, PRD), and a binary variable equal to one if the municipal mayor party coincides with the president party. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

### 2.6.2.2 Household characteristics

To further explore the mechanisms through which the increase in the demand for avocados led to fewer homicides in avocado-suitable municipalities, I looked into changes in the quality of dwellings and provision of basic services. Using data from the 1990, 1995, 2000, and 2005 National Censuses, I look into changes in the percentage of households that have access to basic services such as water, sewage, and electricity and that have floors made out of a material different than dirt. I use this to proxy for changes in household income, as there is no municipal-level data on employment available for the period I am analyzing.

Given the Census' timing, I have some information pre and post-treatment that I can use to look into changes in the quality of dwellings. In particular, the 1990 and 1995 Censuses provide pre-treatment information as both took place before the first opening in 1997. Meanwhile, the 2000 and 2005 Census data correspond to periods before and after the 2001 wave. To shed light on this, I estimate a simple difference-in-differences regression by interacting the suitability index with a binary variable equal to one for each Census year between 1995 and 2005. In other words, I measure the changes between each wave by estimating the effect on avocado-suitable municipalities in each Census year compared to 1990 (the omitted Census year). I include all covariates and control for time-invariant characteristics and time shocks by including municipality and year fixed effects.

Table 2.3 shows the results for this estimation. In Columns (1)-(3), I estimate changes in the provision of basic services, such as water, sewage, and electricity. Meanwhile, Column (4) shows the results on the percentage of households with a non-dirt floor. Note estimates for 1995 are not available for this outcome since there is no information on it for that year.

For estimates in Columns (1)-(3), I use information from the 1995 Census as a robustness check for my results. Since 1995 precedes the start of the first wave, I can look into whether there were any changes in dwellings characteristics in avocado-growing municipalities before Mexican avocados were allowed into the U.S. If the only factor changing the provision of essential services to households in avocado municipalities is NAFTA, I would expect to

observe no effect in 1995.

Table 2.3: DID results on dwelling characteristics

	% water (1)	% sewage (2)	% electricity (3)	% non-dirt floor (4)
1995 × Suitable	0.024* (0.013)	-0.010 (0.017)	0.079*** (0.014)	
2000 × Suitable	0.034* (0.018)	-0.005 (0.015)	0.111*** (0.018)	0.046*** (0.010)
2005 × Suitable	0.005 (0.022)	0.045** (0.022)	0.130*** (0.023)	0.060*** (0.015)
Observations	1,998	1,998	1,998	1,500
Adj. R-squared	0.873	0.915	0.807	0.944
Mean dep. var.	0.754	0.626	0.884	0.728
Ho: $\hat{\beta}_{1995} = \hat{\beta}_{2000}$ (p-value)	0.455	0.758	0.000	-
Year FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES

Notes: Clustered standard errors at the municipal level in parentheses. All estimations include municipality fixed effects. Columns (1)-(3) show estimates on the percentage of households with access to basic services: water, sewage and electricity, respectively. Column (4) provides estimates on the percentage of households with floors different to dirt. All estimates are compared against data from 1990. Information on floor quality is not available for 1995. All estimations control for political affiliation of the municipal mayor by including a dummy for each of the major parties in the period analyzed (PAN, PRI, PRD), and a binary variable equal to one if the municipal mayor party coincides with the president party. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Estimates show a statistically significant increase in the provision of water and electricity in avocado municipalities between 1990 and 1995. This shows evidence of other factors pre-NAFTA that resulted in improvements in the provision of these services. One potential explanation is the improvement of household services from increasing revenues of an already growing sector.

While I cannot conclude that NAFTA is responsible for improving households' access to water and electricity in avocado municipalities, I can test whether the effect differed between 1995 and 2000. By performing a t-test on the  $1995 \times Suitable$  ( $\hat{\beta}_{1995}$ ) and  $2000 \times Suitable$  ( $\hat{\beta}_{2000}$ ) coefficients, I find no statistically difference between these for the provision of water. Meanwhile, I find these coefficients to be statistically different in the case of electricity. Therefore, these results provide evidence of further improvements in the provision of electricity after NAFTA.

Finally, Column (4) shows the percentage of households with a non-dirt floor. In contrast to my previous estimates, I could not estimate a robustness check using data from 1995. Unfortunately, the National Count of 1995 does not include this question in the main questionnaire. Despite this, results show improvements in the percentage of dwellings with non-dirt floors in avocado-suitable municipalities compared to others.

### **2.6.3 Threats to Identification**

One concern in my empirical strategy is the presence of spillover effects. For one, that municipalities not authorized to export to the U.S. could sell avocados to exporters in Michoacán. While it may be possible for farmers from other states to sell their avocados to packinghouses, the USDA's strict regulation prevents imports of avocados from unauthorized orchards. Avocados for export follow a strict set of requirements that include certifications of orchards and packinghouses, and inspections at all levels of the export process: in orchards, packinghouses, and ports of arrival. For instance, avocados can only come from orchards in municipalities that have been directly approved by Mexico's National Plant Protection Organization (NPPO). To meet this requirement, each municipality must be surveyed at least once per year to ensure the avocados are pest-free. Additionally, only packinghouses that meet the APHIS requirements can pick avocados from farmers in authorized orchards. The harvested avocados must be placed in containers labeled with the orchard's registration number and must include a field record (USDA, 2020).

Another concern is the presence of anticipation effects. That is that farmers were able to plan accordingly to export avocados to the U.S. The signing of NAFTA and the subsequent authorization of the USDA to export to the U.S. led to an exogenous increase in the demand for avocados, increasing avocado prices and farmers' revenues. If farmers could anticipate this increase in the demand and adjust production accordingly, this would bias my results. If this were the case, we would observe an increase in the cultivated area in the years before each wave.

A particular characteristic of avocados is that adjusting the supply of avocados in the short run is difficult for farmers for two reasons. First, avocado trees take at least five years to grow and produce fruit. Second, new orchards require five years to get authorized for export to the U.S (USDA, 2020).<sup>11</sup> Given this information, if farmers could anticipate the opening of the avocado exporting sector and decide to increase production by planting more avocado trees, we would observe an increase in the number of hectares cultivated five years before each opening. Figure 2.8 shows no evidence to support this for the first and second waves (1997 and 2001). Between 1992 and 2001, the number of hectares cultivated increased only by 0.54 percent. After 2001, the number of hectares increased slightly, up to the start of the third wave (2005), where we can observe a jump in the number of hectares cultivated. Looking further into that opening, I found out that the amendment to the regulation to allow the importation of Mexican avocados to all states in the U.S., except for California, Florida, and Hawaii, was published in November 30<sup>th</sup>, 2004 (USDA, 2004). This new regulation came into effect on January 30<sup>th</sup>, 2005 (Carman et al., 2009). Therefore, the observed increase in hectares cultivated in 2005 most likely resulted from the announcement, rather than farmers anticipating the new opening.

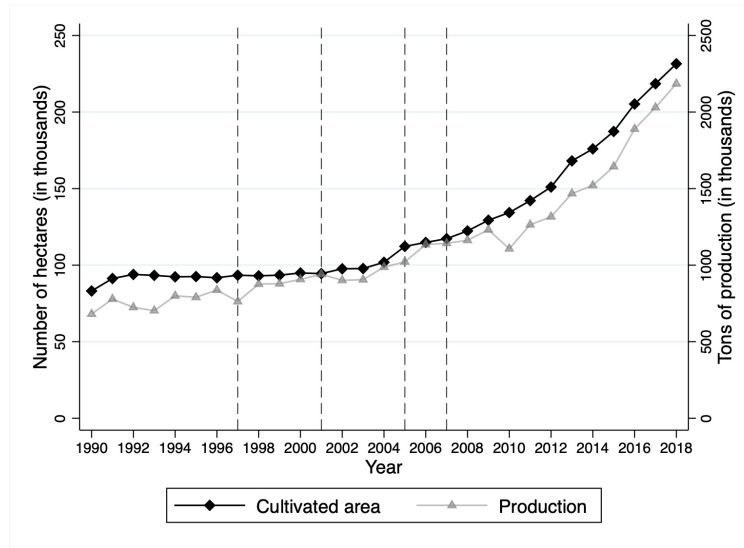
Alternatively, farmers can expand production by making investments in other inputs. While I do not have information on investments made by farmers, I can observe changes in the production of avocados (see Figure 2.8). Between 1990 and 1997, I see no overall increases in production. However, between 1996 and 2001, I observed a 12 percent increase in production. This could indicate the presence of investments made to increase yields, such as pesticides, fertilizers, and the introduction of an irrigation system. It can also suggest that farmers are improving their pruning timing.<sup>12</sup> Given the information I have, I cannot distinguish between capital investments or improvement in farming techniques. However, I

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<sup>11</sup>New orchards (and any contiguous orchards) must be surveyed twice a year and found pest-free for five years to get authorization from the APHIS (USDA, 2020).

<sup>12</sup>Timing for pruning is vital for avocados. Some variants, such as Hass avocados, only mature after being picked. This means that farmers can control production by deciding when to cut them (Hass Avocado Board, 2019). The cutting of avocados allows for more flowers to grow and give fruit. In Michoacán, avocado trees have up to four blooming cycles per year (Salazar-García et al., 2005).

Figure 2.8: Annual hectares of avocado cultivated and production in tons (National estimate, 1990-2018)



Source: Own using information from SAGARPA.  
Vertical lines represent each of the NAFTA openings.

can assess whether each wave was preceded by an increase in production or in the number of hectares cultivated.

The main challenge to verifying anticipation effects on my data is the availability of information. Unfortunately, municipal-level information on production and extension of land cultivated by crop type is not available for the years before 2003. Up to that year, SAGARPA only has estimates on production by crop at the state level. Taking into account the availability of my data, I propose the following estimation:

$$Y_{s(t-k)} = \alpha_s + \tau_t + \phi_1 NAFTA_{1997 \leq t \leq 2000} + \phi_2 NAFTA_{2001 \leq t \leq 2004} + \phi_3 NAFTA_{2005 \leq t \leq 2006} + u_{st}$$

where  $Y_{s(t-k)}$  is the log transformation of my outcome in the state  $s$  at the year  $t - k$ , and  $NAFTA_t$  is a dummy variable equal to one for the years between each opening. I estimate regressions with my outcomes of interest (the number of hectares cultivated and the annual production of avocados) lagged up to 6 years. The coefficients of interest are  $\phi_j$ . A positive

coefficient indicates that the corresponding opening  $j$  resulted in an increase in investments made by farmers  $k$  years before it happened.

Table 2.4 shows the result for my anticipation test. My results provide no evidence of an anticipation effect for the 1997 wave. However, I cannot rule out an anticipation effect for the 2001 and 2005 waves. The main disadvantage of my specification is that it cannot distinguish the anticipation effect from the direct effect that followed a previous wave due to how the waves are distributed. For instance, for the 2005 opening, I observe an increase in the production of avocados four years before the event (see Column 3). This could be attributed to an anticipation effect from this wave or the 2001 opening. Therefore, my current specification cannot completely tease out the anticipation effect for the waves following the first opening (2001 and 2005). Therefore, estimates following the first wave should provide the most accurate estimations of the effect of NAFTA on violence.

Table 2.4: Results for the anticipation check

	<i>Dept. variable: Tons produced (thousands)</i>						<i>Dept. variable: Hectares cultivated (thousands)</i>					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Lags:	t-6	t-5	t-4	t-3	t-2	t-1	t-6	t-5	t-4	t-3	t-2	t-1
1997-2000	13.54 (13.548)	5.977 (11.346)	9.422 (10.159)	12.42 (9.350)	12.79 (9.451)	14.71 (9.669)	1.625 (1.058)	1.340 (0.835)	0.979 (0.748)	0.887 (0.699)	0.770 (0.715)	0.740 (0.743)
2001-2004	23.62* (13.548)	18.69 (11.346)	21.03** (10.159)	28.57*** (9.350)	27.09*** (9.451)	26.71*** (9.669)	2.070* (1.058)	1.633* (0.835)	1.366* (0.748)	1.803** (0.699)	1.648** (0.715)	1.624** (0.743)
2005-2006	35.91** (14.841)	31.85** (13.101)	30.97** (12.143)	29.69** (11.452)	33.47*** (11.787)	39.84*** (12.230)	2.887** (1.159)	2.449** (0.964)	1.993** (0.895)	2.082** (0.856)	2.326** (0.892)	2.724*** (0.939)
Observations	77	84	91	98	105	112	77	84	91	98	105	112
Adj. R-squared	0.981	0.979	0.979	0.979	0.977	0.975	0.989	0.989	0.989	0.989	0.988	0.986

Notes: This table provides estimates on the anticipation check. Columns (1)-(6) show the effect of each opening on tons of avocados produced  $t-k$  years before the opening, where  $k$  goes from one to six. Columns (7)-(12) show the effect on hectares cultivated. All estimates include state and fixed effects. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

## 2.7 Conclusion

Despite the growing literature on crime, the relationship between economic shocks and violence remains ambiguous. This study sought to contribute to this by looking into the impact of a sudden increase in the demand for avocados on violence in avocado-growing regions of Mexico.

The signing of NAFTA in 1994 paved the way for increased trade opportunities among Mexico, the United States, and Canada. For Mexico, this agreement served as a platform to negotiate the gradual entry of avocados into the U.S. market. As Mexican avocados gained popularity in the U.S., the increase in the demand for this fruit offered new employment opportunities throughout the production and exportation chain (the substitution effect). At the same time, it increased the incentives for extraction for criminal organizations (the income effect).

Taking advantage of the exogenous increase in the demand for avocados that arose from the gradual opening of Mexican avocado exports to the U.S., I measure the effect of a sudden increase in income on homicides and cartel presence. My results show that following the first opening of NAFTA, municipalities suitable for avocado growth experienced a substantial decrease in homicide rates of 33.6%. While subsequent waves do not appear to have decreased homicide rates as substantially as the first wave, they contributed to keeping a steady decrease in murders over the next decade. More importantly, this paper's findings show that the opening of NAFTA allowed for lower violent rates throughout all avocado-growing municipalities with no specific effects to only avocado-exporting areas.

Complementary to the above results, I find no evidence of changes in cartel presence during this period, which implies that the observed decrease in violence cannot be attributed to shifts in drug cartel dynamics. Finally, the results show that the opening of NAFTA improved dwelling characteristics in avocado-growing municipalities. Overall, these findings suggest that the mechanism through which NAFTA improved violence in avocado-growing municipalities was through higher opportunities for employment in the production and ex-

porting avocado sector.

This paper has important policy implications. Firstly, it suggests that increased employment opportunities can serve as effective strategies for crime reduction. Secondly, the opening of NAFTA offered a unique chance to explore the influence of higher income on violence within a specific context characterized by limited competition among criminal organizations. The results suggest that the substitution effect can be the dominant mechanism in such circumstances. Overall, these findings highlight the importance of creating employment opportunities and improving households' income as a means to combat crime. They also provide insights into the relationship between income and crime and point out how this effect was possible in a context with limited competition over scarce resources among criminal organizations.

# Chapter 3

## Pipelines and Crime in Mexico

### 3.1 Introduction

Organized criminal groups are relevant economic actors in contexts with limited state capacity or state capture. Criminal groups respond strongly to economic incentives (Becker, 1968; Berman and Couttenier, 2015; Dube and Vargas, 2013) , but typically rely on violence to overcome missing institutions such as enforceable property rights and dispute arbitration. The actions of criminal groups are often difficult to observe directly but can have major consequences for local levels of violence and economic development outcomes.

We study a particular form of criminal resource extraction that arose in Mexico during the late 2010s: theft of refined oil and liquefied petroleum gas (LPG, also commonly known as propane gas) from pipelines, referred to locally as *huachicoleo*. This activity is dominated by powerful cartels, which generate revenues from a diversified range of criminal activities and exert substantial control over local state actors such as police and state-owned enterprises. According to data from Mexico's Tax Administration Service (SAT), 186 thousand barrels of refined oil and gas products were stolen daily in 2021, amounting to 19% of the total national consumption. Oil pipeline theft is also a significant issue in the Niger River Delta in Nigeria, another major oil-producing area with weak state capacity (Adishi and Hunga, 2017; Rexer, 2022; Rexer and Hvinden, 2023; Yeeles and Akporiaye, 2016).

We identify Mexican municipalities that host fuel and LPG pipelines and related infrastructure and measure criminal activity and cartel presence changes. Specifically, we explore the effects of a major crackdown on fuel pipeline thefts that occurred in 2019 and show that this increase in enforcement led to a shift in criminal activities toward thefts from LPG pipelines, which were not included in the crackdown. This paper aims to achieve two objectives: (i) to investigate whether the government crackdown on fuel theft effectively reduced cartel presence and violence in municipalities with access to fuel pipelines, and (ii) to examine whether this strategy inadvertently led to an increase in violence in municipalities with LPG pipelines.

To do this, we take advantage of the exogenous placement of the pipelines within the Mexican territory and in how the government's crackdown on fuel theft shifted incentives for drug cartels. To explore this, we combine information on the geographical location of the fuel and LPG pipelines with municipal-year-level data on crimes and cartel presence for 2015-2022. We use a difference-in-differences approach to measure changes in violence and cartel presence in municipalities with a pipeline following the government crackdown. In particular, we are able to identify homicides related to military personnel and Pemex employees.

Our findings indicate that the government's strategy effectively reduced the number of illegal taps on fuel pipelines. However, this policy did not result in more secure municipalities. In fact, following the government crackdown in 2019, municipalities with fuel pipelines experienced a significant increase of 24.2% in their homicide rates, accompanied by a higher presence of cartels. This paper also provides evidence of the unintended consequences of the policy, highlighting a shift in criminal organizations' incentives toward the theft of LP gas. We find an increase in cartel presence and an 18% rise in the homicide rate in municipalities with LPG pipelines. Complementary to this, we find no impact on homicides of Pemex employees, which aligns with anecdotal evidence suggesting that corrupt employees work alongside drug trafficking organizations rather than being forced into giving away

information on the placement of the pipelines.

This study contributes to three strands of literature. First, we build on existing studies of pipeline thefts in Mexico and Nigeria. López Cruz and Torrens (2023) document increased pipeline thefts and violence near oil pipelines after a government crackdown on drug trafficking in Mexico in 2007, providing evidence that cartels substituted for lost drug revenues with fuel thefts. Battiston et al. (2022) leverage the same 2007 drug trafficking crackdown to show that upstart cartels leapfrogged incumbent drug trafficking cartels to engage in pipeline thefts, leading to cartel specialization and segmentation of illegal markets. Yeeles and Akporiaye (2016) find negligible effects of oil pipeline theft and sabotage on production and prices in the Niger River delta, reflecting the resilience of the region's oil and gas sector. Rexer (2022) finds that a policy that shifted ownership of Nigerian oil fields to local firms reduced oil thefts, as local firms were better able to strike bargains with armed groups and leverage government connections to increase law enforcement protection. Finally, Rexer and Hvinden (2023) show that an amnesty for armed group commanders in the Niger river delta decreased attacks but increased pipeline thefts, in line with a bargaining model wherein the military allows resource thefts in some areas to reduce overall violence.

Second, we contribute to a body of evidence showing that criminal activities, conflict, and violence respond to price incentives. Dube and Vargas (2013) leverage exogenous changes in world commodity prices to show that violence responds differently to price changes depending on the nature of the commodity. For labor-intensive commodities like coffee, a fall in prices reduced wages and thus the opportunity costs of criminal activity, leading to increased violence. In contrast, an increase in oil prices raised potential gains from resource appropriation in oil-producing areas (a capital-intensive industry), increasing violence through a "rapacity effect." Focusing on the African mining industry, Berman et al. (2017) show that increases in world mineral and metal prices significantly increase localized violence around mines. Our results follow similar findings of increased violence in capital-intensive industries in which the returns to appropriation are high (Angrist and Kugler, 2008; Chimeli and

Soares, 2017; Dal Bó and Dal Bó, 2011; Dube and Vargas, 2013; Parker and Vadheim, 2017).

Finally, our analysis of Mexico's 2019 crackdown on oil pipeline theft contributes to studies of substitution effects and unintended consequences of enforcement action (Chimeli and Soares, 2017; De Haro Lopez, 2023; Herrera and Martinez-Alvarez, 2022; Jones, 2013; Magaloni et al., 2020; Parker and Vadheim, 2017). Parker and Vadheim (2017) show that international policies designed to prevent trade in conflict minerals from the Democratic Republic of the Congo led warlords to substitute critical mineral mining for gold mining and the looting of civilians. Chimeli and Soares (2017) study the prohibition of mahogany harvesting in the Brazilian Amazon and show that illegalization in this market increased violence without reducing the mahogany trade. We add to this literature with evidence that incomplete enforcement during Mexico's 2019 crackdown on oil theft failed to reduce violence in oil pipeline areas and led criminal groups to substitute toward gas pipeline theft, spreading violence further.

This chapter is organized as follows. Section 3.2 describes the background. This includes information on the evolution of fuel theft. Sections 3.3 and 3.4 describe the data used and the empirical strategy. Finally, Section 3.5 contain the main results on violence and cartel presence.

## **3.2 Background**

### **3.2.1 The war against drugs and cartel diversification**

In 2006, the Mexican government launched the War on Drugs campaign to combat drug trafficking organizations. The government employed the kingpin strategy, which involved apprehending the leaders of these criminal organizations. This tactic of capturing prominent drug lords destabilized large drug cartels, leading to their fragmentation and increased competition from newly formed organizations (Calderón et al., 2015). This increase in competition led drug trafficking organizations to diversify into non-drug-related activities, such

as the extortion of agricultural workers (De Haro Lopez, 2023) and the theft of hydrocarbon fuels from Mexico's oil pipeline network (López Cruz and Torrens, 2023).

The increase in competition among drug cartels has driven cartels to diversify into stealing fuel. This has resulted in the proliferation of drug cartels in municipalities with fuel pipelines (Battiston et al., 2022). Moreover, this territorial expansion has led to increased violence in municipalities located along the fuel pipeline network, even in areas with little strategic importance for drug trafficking (López Cruz and Torrens, 2023).

Besides the theft of gasoline, drug trafficking organizations have also branched out to steal other petroleum derivatives, such as crude petroleum and liquefied petroleum gas (LPG).<sup>1</sup> The theft of LP gas became an attractive alternative to drug trafficking organizations after President Andres Manuel López Obrador launched a campaign against fuel theft in December 2018. The government strategy consisted of reinforcing surveillance of the fuel pipelines and shutting all fuel pipelines in the country during January 2019.

### 3.2.2 Illegal fuel theft

Theft of hydrocarbon fuels (gasoline and diesel) is a growing concern in Mexico, with significant economic losses to Pemex, the state-owned petroleum company<sup>2</sup>. In 2021, Pemex reported losses of approximately 350 million USD due to illegal taps, with stolen gasoline accounting for 62.8% of these losses (Pemex, 2021).

The illegal siphoning of gasoline by criminal organizations is a relatively new issue. While there have been reports of illegal taps of fuel pipelines since 2003, the number of illegal taps increased substantially following the Mexican government's war against drugs. Figure 3.1 shows the annual reports of illegal taps on oil-refined products from 2003-2022. Before the

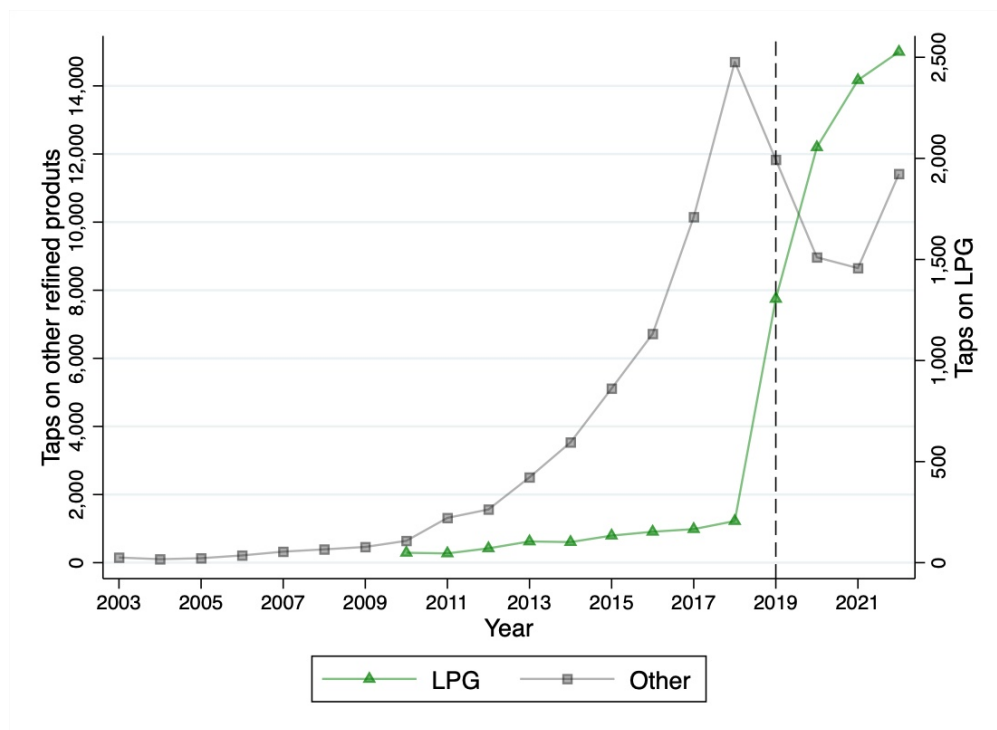
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<sup>1</sup>Liquefied petroleum gas is more commonly known as propane gas.

<sup>2</sup>Pemex is a state-owned petroleum company managed and operated by the Mexican government. In 2017, an Energy Reform allowed private investments in crude oil exploration and gas and gasoline distribution. However, Pemex continues to own the production and transportation infrastructure (e.g., refineries and transportation and production pipelines).

war against drugs (2006), annual reports were less than 200. After 2012, the number of illegal taps increased almost seven times, and by 2018, they had reached 15,000.

Figure 3.1: Reports of illegal taps of refined oil products



Source: Based on information from Pemex obtained through a Freedom of Information Act request. Other refined oil products exclude taps on LPG pipelines. Based on information on economic losses, taps on other refined products consist mostly of taps of gasoline and diesel (these products account for over 99% of total losses due to illegal tapping.)

Criminal organizations have put in place effective fuel extraction methods from Pemex pipelines. They pay corrupt Pemex engineers to share information on the pipelines' location and provide all the necessary equipment and knowledge on how to extract the fuel (Cultura Colectiva, 2019; López Cruz and Torrens, 2023). Moreover, they notify them of the best time to drill the duct to avoid an explosion and the type of fuel (e.g., gasoline or diesel) passing through the pipeline. The stolen fuel is then stored and sold in the market. Among their consumers are factories, transportation businesses, taxi drivers, and gas stations (Ralby, 2017; Torres, 2017).

Figure 3.1 also shows the evolution of illegal reports of LPG taps. It is apparent from this figure that reports of illegal taps in LPG pipelines remained relatively low until 2018. Then, in 2019, the number of illegal taps sharply increased by over 500%. This evidence suggests that criminal organizations shifted their efforts to the theft of a profitable and less surveilled alternative following the government crackdown against fuel theft.

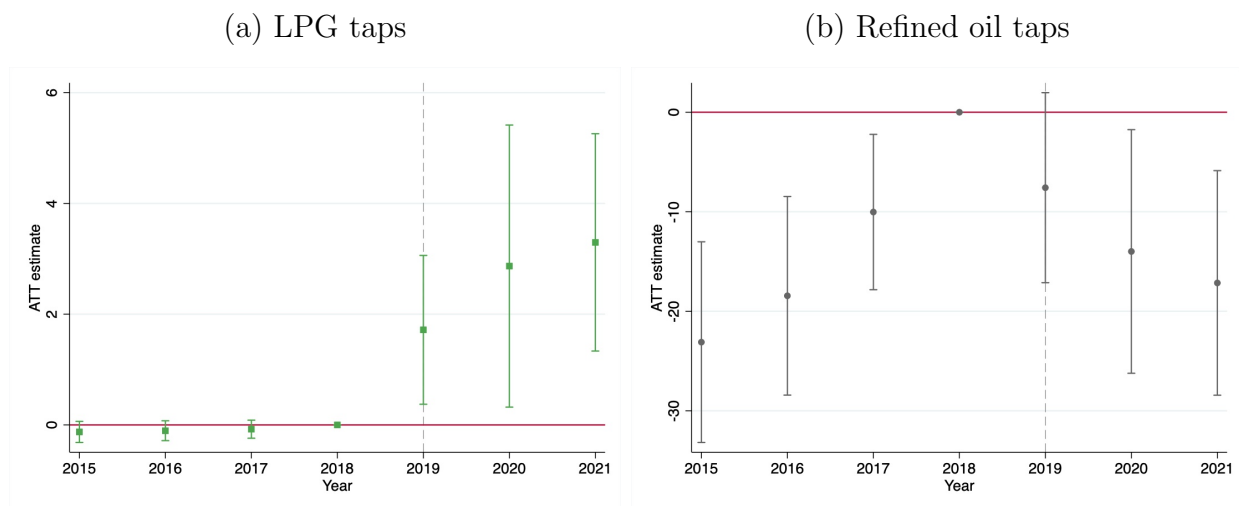
The market of LP gas presents unique opportunities for criminal organizations. In Mexico, over 79% of households use LP gas for cooking and heating<sup>3</sup>. Even though the number of illegal taps reported every year is relatively low compared to fuel taps, approximately 50,000 tons of LP gas are stolen every month. The stolen LP gas is then sold in the black market in gas tanks. According to *Financiero* (2022), approximately 50,000 tons of gas are stolen every month, accounting for 7.6% of the total demand.

Figure 3.2 shows an event study on the effect of the crackdown on illegal taps in refined oil products and LP gas. To do this, we use municipality-year-level information on the reports of illegal taps and include municipality and year fixed effects to control for time-invariant characteristics of municipalities and time shocks. Our estimates confirm a decrease in the number of taps of refined oil products and an increase in LPG taps following the government crackdown. While we cannot distinguish how many reports of illegal taps on refined oil products are specific to gasoline and diesel fuel, we know, based on information on Pemex economic losses, that over 99% of the total losses due to the theft of refined oil products corresponds to the theft of gasoline and diesel.

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<sup>3</sup>Estimate based on information on the National Census of 2022.

Figure 3.2: Event study results on LPG and refined oil taps



Notes: Coefficient estimates and 95% confidence intervals for event study on annual reports of illegal taps of fuel and LPG. Fuel taps information from taps on all other refined oil products, excluding LPG taps. It mostly consists of gasoline and diesel taps. Each estimate includes municipality and time fixed effects.

### 3.3 Data

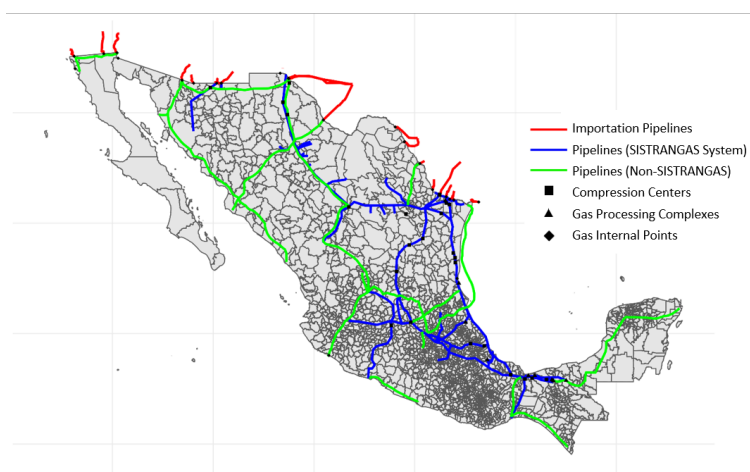
Our sample consists of 2,471 municipalities tracked between the years 2015 to 2021. We use municipal-year-level data on crime rates and cartel presence to analyze the effect of the government's crackdown on the theft of fuel on drug cartel diversification. We combine this information with geographical data on the location of fuel and LPG pipelines to look into changes in homicides and cartel presence in municipalities with a pipeline. We further discuss the data in this section.

#### 3.3.1 Hydrocarbon fuels infrastructure data

We obtained information on Mexico's hydrocarbon fuel infrastructure from the National Commission of Hydrocarbons (Comisión Nacional de Hidrocarburos, CNH). The data includes ShapeFiles with the location of refineries, oil supply terminals, and pipelines used for the transportation of hydrocarbon fuels as of 2019. Additionally, it provides details on the capacity of each pipeline and the type of product transported. Using the latest information,

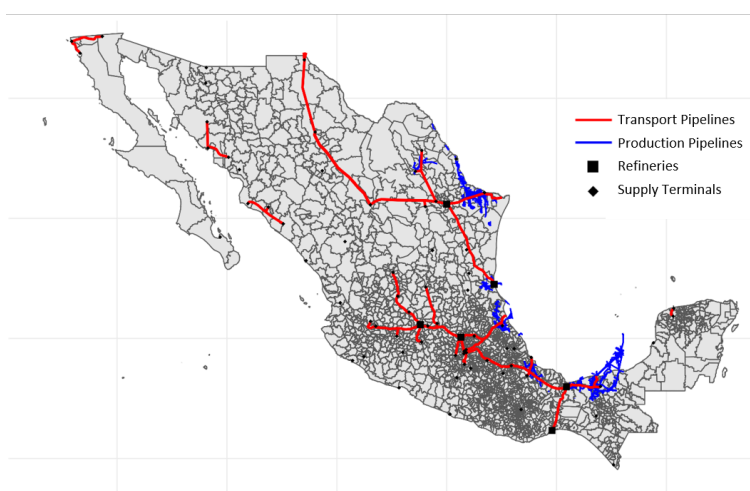
we identified pipelines used for the distribution of refined oil products and LP gas (see Figures 3.3 and 3.4). Among fuel pipelines, we focus on ducts carrying gasoline and diesel due to their high demand and ease of storage and sale in the black market. We exclude ducts carrying other hydrocarbon derivatives that are not attractive to criminal organizations, such as raw petroleum, fuel oil<sup>4</sup>, and jet fuel.

Figure 3.3: LPG distribution infrastructure



Source: National Commission of Hydrocarbons (CNH, 2019).

Figure 3.4: Hydrocarbon fuel production and distribution infrastructure



Source: National Commission of Hydrocarbons (CNH, 2019).

<sup>4</sup>Fuel oil is mainly used in electric plants or for industrial heating (U.S. Energy Information Administration, 2022).

Mexico’s LPG distribution infrastructure comprises government-owned pipelines (SISTRAGAS system) and privately owned pipelines (Non-SISTRAGAS). For our primary identification strategy, we do not differentiate between private and government-owned pipelines. We exclude importation pipelines that are situated outside the Mexican territory from our analysis.

### 3.3.2 Illegal taps of fuel and LPG pipelines

Information on reports of illegal gasoline and LP gas siphoning was obtained from a Freedom of Information Act request to Pemex. The information obtained includes the number of illegal taps reported every month from 2010 to 2022. It distinguishes among reports of illegal taps in LPG ducts and other refined derivatives. Given the information obtained, we can not determine the precise number of taps specific to gasoline and diesel. However, we were able to infer, based on information provided on economic losses, that 99% of all losses from illegal taps of refined derivatives are associated with the theft of gasoline and diesel. As a result, we are confident that we have captured the impact of diesel and gasoline thefts.

Finally, Figure 3.5 shows the geographical distribution of illegal taps at its peak in 2018. As can be seen from the map, most of the illegal taps are located along the central region and the Gulf of Mexico, in states with access to refineries.

Figure 3.5: Geographical distribution of illegal taps in 2018



Source: Based on information from a Freedom of Information Act request to Pemex.

### 3.3.3 Data on violence

To estimate the effect of the 2019 crackdown against fuel theft, we use data on homicides from the National Department of Health Information (Sistema Nacional de Información en Salud; SINAIS). This database includes individual-level information on the cause of death, location of death, and type of weapon used (in the case of homicides). It also contains details on the sex, occupation, marital status, and insurance affiliation of the deceased. We prefer this database to police report data from the Ministry of Public Security (SSP) since it provides more details on the victim, including insurance affiliation, which we use to identify murders of Pemex employees and military personnel. It also doesn't suffer from under-reporting of homicides since it is based on death certificates rather than police investigations.

Using municipal-level data on population from the National Institute of Statistics and Geography (INEGI), we estimated homicide rates per 100,000 people for males, females, potential cartel-related individuals, Pemex employees, and military personnel. Estimates for potential cartel-related individuals were obtained using the information on males between the ages of 15 and 40 who were killed by firearms (De Haro Lopez, 2023). We use this measure since men between those ages are the most vulnerable to criminal violence (Calderón et al., 2015; Herrera and Martinez-Alvarez, 2022). Moreover, possession of firearms is illegal in Mexico. According to Mineo (2022), 70% of all guns recovered at crime scenes in Mexico can be traced back to drug cartel organizations.

To proxy for combats between the military and drug cartels, we identified homicides of individuals whose insurance affiliation was through SEDENA. Since military family members can also be affiliated, we only focused on homicides of working-age individuals (18-60 years old) killed by firearms. Similarly, we identified Pemex employees through their insurance affiliation with Pemex, and we restricted our statistics to individuals of working age who were killed by firearms.

Information on other crimes was obtained from the Ministry of Public Security (SSP). This database includes monthly information on all crimes reported to the police per munic-

ipality. We use this data to identify robberies, kidnappings, threats, extortion cases, and injuries. Table 3.1 shows the summary statistics for municipalities with an LPG or a fuel pipeline, and the rest of the country. It shows that on average, municipalities with a LPG or a fuel pipeline present higher homicide and crime rates than the rest of the country. The only exceptions to this are kidnappings, threats, and extortion.

Table 3.1: Summary statistics in municipalities with a fuel or LPG pipeline

	LPG or fuel			Rest of country			All municipalities		
	Mean	SD	Obs.	Mean	SD	Obs.	Mean	SD	Obs.
<b>Reports of illegal taps</b>									
LPG	1.28	14.50	4,641	0.04	1.70	12,656	0.37	7.67	17,297
Refined petroleum	13.23	51.55	4,641	0.37	5.86	12,656	3.82	27.76	17,297
<b>Homicide rates</b>									
All	25.88	40.89	4,634	19.51	38.32	12,558	21.23	39.13	17,192
Female	2.70	5.18	4,634	2.10	8.83	12,558	2.26	8.01	17,192
Male	22.97	37.64	4,634	17.33	34.72	12,558	18.85	35.62	17,192
Cartel related	11.29	23.33	4,634	7.62	20.16	12,558	8.61	21.12	17,192
Pemex employee	0.06	0.56	4,634	0.01	0.14	12,558	0.02	0.32	17,192
Military	0.09	1.71	4,634	0.03	0.73	12,558	0.05	1.08	17,192
<b>Crime &amp; cartel data</b>									
Robberies	377.66	391.50	4,634	141.40	226.72	12,558	205.08	299.74	17,192
Kidnapings	1.32	3.73	4,634	0.64	3.38	12,558	0.83	3.49	17,192
Threats & extortion	64.24	76.69	4,634	39.61	70.31	12,558	46.25	72.91	17,192
Other violence	134.27	122.95	4,634	77.26	105.22	12,558	92.63	113.14	17,192
No. of cartels	3.75	5.94	4,641	1.39	3.27	12,656	2.03	4.29	17,297

Notes: Homicide and crime rates are expressed as the number of cases per 100,000 people.

### 3.3.4 Presence of drug trafficking organizations

The Mapping Criminal Organization project (MCO) provides municipal-level data for evaluating territorial expansion and competition among drug trafficking organizations. The project employs a web-crawling technique to identify news articles related to drug cartels on Google and Google News. Using the number of times a cartel is mentioned in news

articles, the database determines whether a cartel is present in a particular municipality. The database contains information on the presence of 75 different criminal organizations in Mexico at the municipal level from 1990 to 2020. Additionally, the MCO database includes information on the "mother group" of the cartels, which enables the identification of splintered cartels and newly formed organizations with no previous affiliation to an established drug cartel.

## 3.4 Empirical Strategy

### 3.4.1 Main identification strategy

To estimate the impact of the government's crackdown on fuel theft and its effect on violence in municipalities with LPG pipelines, we used a Difference-in-Differences (DID) estimation approach. We identified changes in crime rates following the government shutdown of the pipelines in January 2019 by comparing municipalities with fuel or LPG pipelines to those without pipelines. Our main specification is as follows:

$$Y_{it} = \alpha_i + \tau_t + \delta(P_i^{LP} \times S_{t \geq 2019}) + \gamma(P_i^F \times S_{t \geq 2019}) + e_{it} \quad (3.1)$$

where  $Y_{it}$  is the crime rate per 100,000 inhabitants in municipality  $i$  and year  $t$ .  $P_i^{LP}$  and  $P_i^F$  are two binary variables used to indicate the presence of pipelines carrying LP gas, and fuel (gasoline and diesel), respectively.  $S_{t \geq 2019}$  indicates the period before and after the government shutdown of the pipelines in 2019. Finally, we control for time-invariant characteristics and time shocks using municipality ( $\alpha_i$ ) and year fixed effects ( $\tau_t$ ).

The parameter of interest is  $\delta > 0$ , which reflects the changes in crime rates in municipalities with an LP gas pipeline. If there is evidence that criminal organizations have diversified into the theft of LP gas, we expect to observe an increase in crime rates in municipalities with an LPG pipeline ( $\delta > 0$ ). A secondary parameter of interest is  $\gamma$ . This coefficient

shows the effect on the crime rates in places with fuel pipelines following the government shutdown. A negative value of  $\gamma$  would provide favorable evidence of the effectiveness of the government's strategy in reducing crime rates in municipalities with fuel pipelines.

For our main specification, we use the number of homicides per 100,000 inhabitants. We prefer to use homicides as our main outcome rather than other crime rates. In countries like Mexico that suffer from organized criminal organizations, crimes are often underreported. According to Mexico's National Survey of Victimization and Perceptions of Public Security (ENVIPE), over 90% of crimes in the country are not reported by civilians or filed by the police.

### 3.4.2 Event study

We use an event study regression design to corroborate our differences-in-differences results.

The specification is as follows:

$$Y_{it} = \alpha_i + \tau_t + \sum_{y \neq 2018} \delta_y P_i^{LP} \times I(t = y) + \sum_{y \neq 2018} \gamma_y P_i^F \times I(t = y) + v_{it} \quad (3.2)$$

In this specification, coefficients  $\delta_y$  and  $\gamma_y$  represent the time-varying impact of crimes after the government shutdown on municipalities with LP gas and fuel pipelines, respectively. Estimates show the change in crime rates for all years, compared to the year of reference, 2018. Besides contributing to our results, the event study also shows the presence of parallel trends in homicide rates before 2019, which supports our differences-in-differences identification strategy.

## 3.5 Results

This section presents our main empirical results. First, we show our estimates on the impact on homicide rates in municipalities with LP gas and fuel pipelines after the government crackdown. Second, we show results on other crimes, such as robberies, kidnappings, threats, and extortion. Finally, we also look into the effect of changes in cartel presence following the crackdown.

### 3.5.1 Results on homicides

Table 3.2 shows the results of our preferred empirical strategy. Our estimates show that municipalities with LPG pipelines experienced an increase in homicides by 4.1 deaths per 100,000 people (corresponding to an 18% increase), following the government strategy (see Column 1). This is consistent with our initial hypothesis that the government crackdown resulted in criminal organization diversification, increasing violence in municipalities with an LPG pipeline. Meanwhile, our results also show that the policy, on average, resulted in 5.1 more homicides per 100,000 people ( $\sim 24.2\%$ ) in municipalities with fuel pipelines, with males being the main target population. These results show that, despite the government strategy, the increased surveillance and shutdown of pipelines resulted in higher violence in the targeted municipalities.

Our estimates also show that male and cartel-related homicides mainly drive the increase in homicide rates in municipalities with an LPG pipeline, with corresponding increases of 19% and 24%, respectively. This result is consistent with the hypothesis that criminal organizations find fighting over territories with access to an LPG pipeline more profitable following the crackdown. Interestingly, we do not observe significant changes in homicides of military personnel, which could be indicative of less military surveillance along these LPG pipelines. Moreover, our estimates on female homicides provide a placebo test for our specification, as this is a population that we would not expect to be affected if violence is mainly driven by

territorial fighting among criminal organizations.

Table 3.2: Results on homicides in municipalities with fuel and LPG pipelines

	All (1)	Male (2)	Female (3)	Pemex (4)	Cartel (5)	Military (6)
LPG pipeline $\times$ Post 2019	4.197** (1.680)	3.637** (1.555)	0.382 (0.258)	-0.001 (0.013)	2.127** (0.951)	0.062 (0.074)
Fuel pipeline $\times$ Post 2019	5.146* (3.014)	4.667* (2.772)	0.335 (0.331)	-0.006 (0.026)	1.962 (1.751)	0.077 (0.139)
Observations	17192	17192	17192	17192	17192	17192
Adj. R-squared	0.359	0.364	0.0700	0.202	0.324	0.0579
Mean dep. var.	21.23	18.85	2.261	0.019	8.607	0.0479

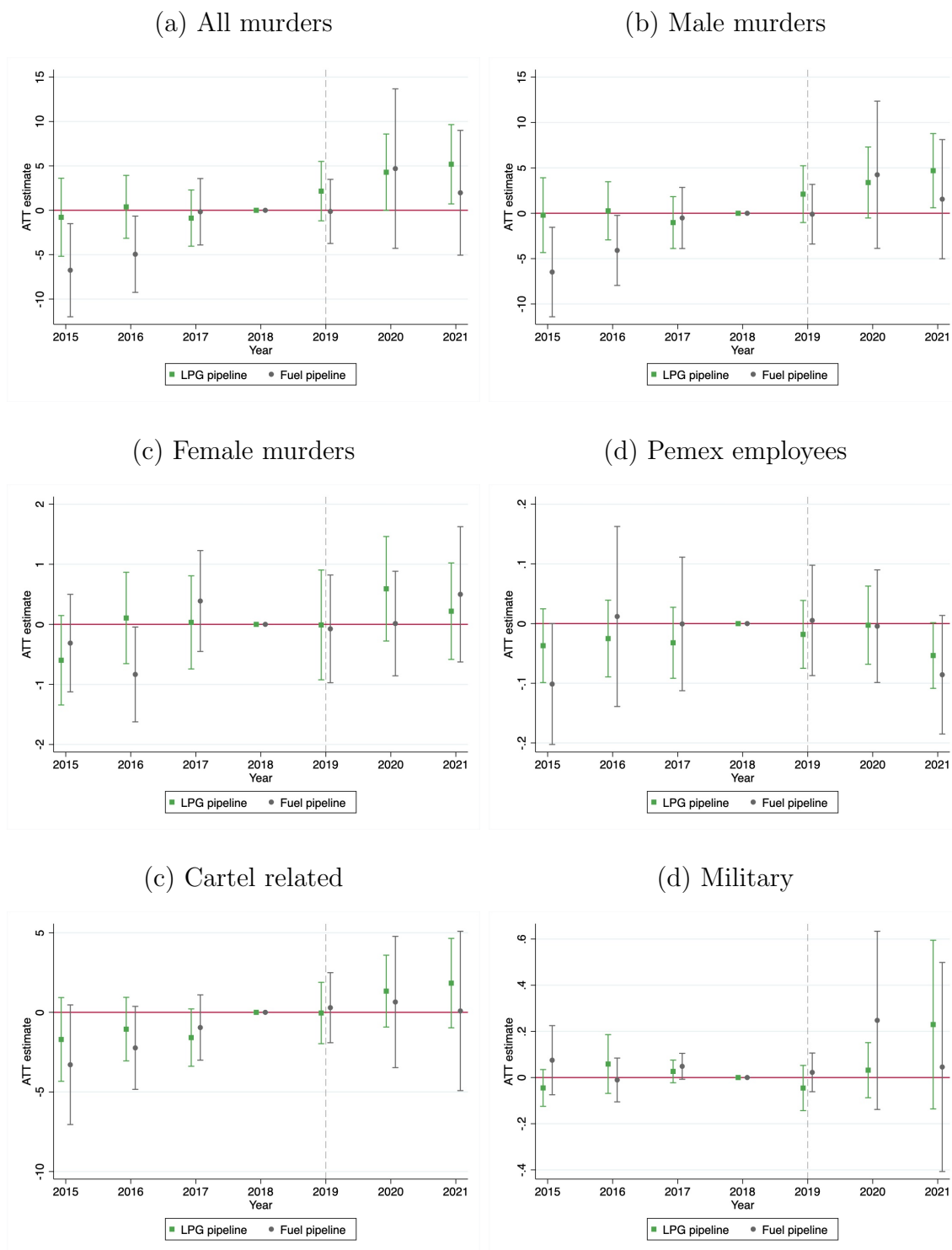
Notes: This table reports the results for Equation 3.1. Dependent variables measured as homicides per 100,000 inhabitants. Homicides of Pemex employees are estimated based on homicides of individuals of working age (18-60 years old) insured through Pemex. Potential cartel-related homicides are males aged 18-40, killed by a firearm. Homicides of military personnel are estimated based on individuals insured through SEDENA, ages 18-60, killed by a firearm. Municipality and year-fixed effects are included in all specifications. Clustered standard errors at the municipality level in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Finally, our results also show no statistical changes in homicides of employees of Pemex. Therefore, we do not find evidence that drug cartel organizations are being disproportionately more violent against Pemex employees to obtain information on the location of pipelines and their expertise in extracting the petroleum derivative. Instead, the absence of an effect could support anecdotal references to criminal organizations working alongside corrupt Pemex employees.

### 3.5.1.1 Event study results

Figure 3.6 shows the coefficients obtained from the event study estimation for all categories of murders. Each graph shows the effect on municipalities with LPG pipelines (in green) and fuel pipelines (in gray) following the crackdown.

Figure 3.6: Event study results on murders in municipalities with fuel and LPG pipelines



Notes: Coefficient estimates from Event Study. Homicides of Pemex employees and military personnel correspond to individuals ages 18-60 that were killed by a firearm and were insured through Pemex and SEDENA, respectively. Cartel-related murders correspond to the homicide rate of men ages 15-40 killed by a firearm. Estimations include 95% confidence intervals.

Panel (a) shows that following the government crackdown in 2019, municipalities with an LPG pipeline experienced an increase in homicides. Estimates show that municipalities with an LPG pipeline experienced, on average, five more homicides per 100,000 people in 2021 ( $\sim 23.5\%$ ), compared to municipalities with no pipelines. Panel (a) also shows no statistically significant differences in homicides for LPG pipelines compared to municipalities with no pipelines before the government crackdown of 2019. This supports the parallel trends assumption needed to identify our differences-in-differences estimates.

The rest of the results confirm our estimates from Table 3.2. For instance, they show no statistically significant increases in homicides in municipalities with fuel pipelines for any of the different categories. Moreover, they confirm our findings that homicides are mainly driven by murders of males (see Panel (b)) and of potentially cartel-related individuals (Panel (c)). Magnitudes are also consistent with results from Table 3.2.

### 3.5.2 Results on other crimes

Table 3.3 shows the effect of the government crackdown on other criminal rates: robberies, kidnappings, threats, extortion, and other crimes that threaten life. In contrast to our results from Table 3.2, we do not observe increases in violence in municipalities with LPG pipelines, except for other physical violence<sup>5</sup>, which shows a slight increase in 3.7 cases per 100,000 habitats ( $\sim 4\%$  increase). Interestingly, our results show a decrease in kidnappings in 0.27 cases (corresponding to a 32% decrease from the mean). However, this result should be taken with caution, considering that kidnappings are less likely to be reported by family members in places with organized criminal organizations.

Results also show a decline in all types of crimes for municipalities with a fuel pipeline. We observe a statistically significant decrease in 43.4 robberies per 100,000 in fuel pipelines, corresponding to a 21% decrease from the mean. Meanwhile, our results show a decrease in other violence of around 14.8%. These results can be explained by higher military presence

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<sup>5</sup>Other physical violence consists mainly on reported injuries.

and surveillance in these municipalities that deter other types of crime. Finally, we observe a non-statistically significant increase in kidnappings. Although, as argued before, the results of kidnaps should be taken with caution.

Table 3.3: Results on other crimes in municipalities with fuel and LPG pipelines

	Robberies (1)	Kidnap (2)	Threats & Extortion (3)	Other violence (4)
LPG pipeline $\times$ Post 2019	-2.532 (8.330)	-0.271* (0.160)	0.555 (2.742)	3.784 (3.026)
Fuel pipeline $\times$ Post 2019	-43.39*** (12.642)	-0.279 (0.261)	-0.259 (3.852)	-13.72*** (4.317)
Observations	17192	17192	17192	17192
Adj. R-squared	0.841	0.134	0.514	0.744
Mean dep. var.	205.1	0.825	46.25	92.63

Notes: This table reports the results for Equation 3.1. Dependent variables are measured as crimes per 100,000 inhabitants. Other physical violence consists on injuries and other crimes that threaten life. Municipality and year-fixed effects are included in all specifications. Clustered standard errors at the municipality level in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

### 3.5.3 Cartel presence

We use the information on cartel presence to verify whether the observed effects on violence are due to changes in the presence of drug cartels. Table 3.4 shows results on changes in the log number cartels and on a binary variable equal to one if more than one cartel is present. We estimate these results by cartel type. We differentiate between fragmented and new criminal organizations with no previous relationship to a cartel. Original is defined by drug cartels established before 2003 and did not originate from another cartel. Our results suggest that regardless of the cartel type and type of pipeline, there is an increase in presence for all municipalities. The number of cartels in an LPG pipeline increased by 9.2%, while cartel presence increased by 10.5%.

Table 3.4: Results on cartel presence in municipalities with fuel and LPG pipelines

	Number of cartels				Cartel presence (1/0)			
	All (1)	Original (2)	Fragmented (3)	New (4)	All (5)	Original (6)	Fragmented (7)	New (8)
LPG pipeline $\times$ Post 2019	0.088*** (0.020)	0.050*** (0.014)	0.063*** (0.017)	0.035*** (0.011)	0.034** (0.015)	0.028** (0.014)	0.034** (0.015)	0.044*** (0.013)
Fuel pipeline $\times$ Post 2019	0.099*** (0.027)	0.061*** (0.022)	0.067*** (0.022)	0.118*** (0.018)	-0.006 (0.018)	0.036* (0.020)	-0.011 (0.018)	0.083*** (0.019)
Observations	17297	17297	17297	17297	17297	17297	17297	17297
Adj. R-squared	0.821	0.752	0.798	0.652	0.642	0.606	0.639	0.547
Mean dep. var.	0.614	0.309	0.455	0.110	0.409	0.284	0.363	0.119

Notes: Clustered standard errors at the municipality level in parentheses. Columns (1)- (4) are the log number of cartels present in a municipality. Columns (5)-(8) show results using a binary variable equal to one if there is at least one cartel mentioned in a municipality. Municipality and year fixed effects are included in all specifications. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

### 3.5.4 Robustness Checks

One potential concern of our results is that the sample consists of all municipalities in the country. For instance, this would bias our results if states that do not have an LPG or a fuel pipeline have different characteristics than those that do. We restricted our sample to only states with fuel or LPG pipelines and found our results to be robust to that specification<sup>6</sup> (see Tables C1, C2, and C3 in the Appendix).

#### 3.5.4.1 Spillover effects

A potential concern to our identification strategy is the possibility of spillover effects on neighboring municipalities with a fuel or LPG pipeline. If treatment also affects neighbors, we expect our estimates to be biased downward. We test spillover effects by identifying all municipalities that share a border with a municipality that has a pipeline. We estimate Equation 3.1 using as treated the municipalities that have a neighbor with a fuel or LPG pipeline. We exclude municipalities with a pipeline from our analysis to identify the effect on the neighbors versus everyone else.

Tables C4 and C5 in the Appendix show results on the effect on homicides and other

<sup>6</sup>The states included in our sample with no fuel or LPG pipelines are Baja California Sur and Nayarit. Jointly these states account for 25 municipalities.

crimes, respectively. These results show no impact on homicides and other crimes in neighbors of municipalities with LPG pipelines, except for crimes related to threats and extortion. However, we do find that being a neighbor to a municipality with a fuel pipeline increases homicide rates. This could be driven by contending cartels trying to gain access to municipalities with fuel pipelines. Even though we find potential spillover effects for neighbors of municipalities with fuel pipelines, we do not consider these to threaten our main results on increasing violent crime in LPG pipelines. However, looking into what drives these spillover effects around fuel pipelines remains an interesting question we plan to investigate further.

### 3.6 Conclusions

Criminal organizations are sophisticated economic actors that thrive in contexts with limited state capacity. This paper studies how government policies aimed at deterring criminal activities can lead to unexpected consequences, at times exacerbating the problem in places previously not targeted by criminal organizations. In particular, we look into a government crackdown against fuel theft and its effect on violence in municipalities affected by fuel theft and on municipalities with access to LPG pipelines.

Our paper finds evidence that the government crackdown against fuel theft reduced the frequency of illegal taps of fuel pipelines but had limited and contrasting effects on violent crimes. It increased homicide rates and cartel presence but reduced robberies and intentional injuries (other violence). Meanwhile, our results show evidence of cartel diversification into the theft of LP gas following the government crackdown, leading to increased cartel presence and violence in municipalities with access to LPG. Notably, we find no evidence of increased homicides of Pemex employees, which supports anecdotal evidence of collusion between corrupt employees and criminal organizations.

These findings have important policy implications. First, they show that more comprehensive measures are required to tackle organized crime, particularly in areas where the

government has limited surveillance capacity. Second, they highlight the importance of considering potential spillover effects. In this case, diversification of criminal organizations into LPG theft required knowledge of the location of the pipelines and different and possibly more complicated extraction techniques known by Pemex employees. This emphasizes the need for more comprehensive strategies that also address underlying institutional weaknesses.

## Appendix A

Avocados: Mexico's green gold.

The U.S. opioid crisis and its impact  
on Mexico's drug cartel

## A1 Tables and figures

Table A1: Descriptive Statistics

	Mean	SD
<b>Violence data</b>		
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
<b>Drug data</b>		
Fields of poppy eradicated	80.21	894.77
Hectares of poppy eradicated	9.85	104.29
<b>Avocado production</b>		
Avocado production (tons)	1,988.51	14,302.39
Price of avocado (MX per ton)	11,752.69	5,548.84
<b>Suitability measures</b>		
Avocado suitability	0.46	0.30
Hass avocado suitability	0.33	0.34
Poppy suitability	0.27	0.21
<b>Annual level data</b>		
U.S. Fentanyl Overdoses	15,455.11	12,856.85
Observations	6,516	
Num. of municipalities	724	

## A2 Background

### A2.1 The war against drugs

Despite the existence of Drug Trafficking Organizations in Mexico, the combat against cartels was not a top priority for the Mexican government until the mid-1980s (Chabat, 2010). To limit violence, government officials had established ties with drug traffickers. This implicit pact between cartels and the Mexican government became disrupted when the hegemonic party PRI started losing elections in the late 1980s (O’Neil, 2009).<sup>7</sup> 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.<sup>8</sup> Between 2007 and 2012, a total of over 120,000 people were killed, compared to 60,000 in the previous six years (2001-2006). During Felipe Calderon’s presidency, the lowest number of homicides reported was in 2007, with 8,000 murders. In 2011, however, homicides had reached over (INEGI, 2019b).

Additionally, the government’s “kingpin” strategy may have led to an increase in violence. The capture of prominent cartel leaders led to the fragmentation of DTOs, leading to higher levels of violence due to an increase in the competition among cartels (Atuesta and Ponce, 2017; Calderón et al., 2015; Jones, 2013).<sup>9</sup> 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

<sup>7</sup>In 1989, the PRI lost its first election for the governor of the state of Baja California (O’Neil, 2009).

<sup>8</sup>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).

<sup>9</sup>Jones (2013) finds evidence of an increase in homicide and kidnapping rates in Tijuana after cartel leaders are arrested or killed.

Gulf Cartel. However, as of 2020, the DEA recognizes the existence of at least nine major DTOs (Beittel, 2020).<sup>10</sup> Fragmentation of the four major DTOs started between 2009 and 2010, with the split of the Gulf Cartel. Los Zetas, a group of highly trained military that defected and joined the Gulf Cartel, separated from the 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).

## A3 Suitability index

### A3.1 Temperature suitability index

For the temperature suitability index ( $T_C^*$ ) corresponding to crop  $C$ , let  $T_{MIN_C}$  and  $T_{MAX_C}$  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.<sup>11</sup> 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:

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<sup>10</sup>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)

<sup>11</sup>Consistent with (Ramirez-Villegas et al., 2013)'s study, I use the killing temperature plus 4°C since I am 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.

$$T_{Cmi}^* = \begin{cases} 0 & T_{MIN_{mi}} < T_{KILL_C} \\ 0 & T_{MEAN_{mi}} < T_{MIN_C} \\ \frac{T_{MEAN_{mi}} - T_{MIN_C}}{T_{OPTMIN_C} - T_{MIN_C}} & T_{MIN_C} \leq T_{MEAN_{mi}} < T_{OPTMIN_C} \\ 1 & T_{OPTMIN_C} \leq T_{MEAN_{mi}} < T_{OPTMAX_C} \\ \frac{T_{MAX_C} - T_{MEAN_{mi}}}{T_{MAX_C} - T_{OPTMAX_C}} & T_{OPTMAX_C} \leq T_{MEAN_{mi}} < T_{MAX_C} \\ 0 & T_{MEAN_{mi}} \geq T_{MAX_C} \end{cases} \quad (3)$$

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

### A3.2 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:

$$R_{Cgi}^* = \begin{cases} 0 & R_{TOTAL_{gi}} < R_{MIN_C} \\ \frac{R_{TOTAL_{gi}} - R_{MIN_C}}{R_{OPTMIN_C} - R_{MIN_C}} & R_{MIN_C} \leq R_{TOTAL_{gi}} < R_{OPTMIN_C} \\ 1 & R_{OPTMIN_C} \leq R_{TOTAL_{gi}} < R_{OPTMAX_C} \\ \frac{R_{MAX_C} - R_{TOTAL_{gi}}}{R_{MAX_C} - R_{OPTMAX_C}} & R_{OPTMAX_C} \leq R_{TOTAL_{gi}} < R_{MAX_C} \\ 0 & R_{TOTAL_{gi}} \geq R_{MAX_C} \end{cases} \quad (4)$$

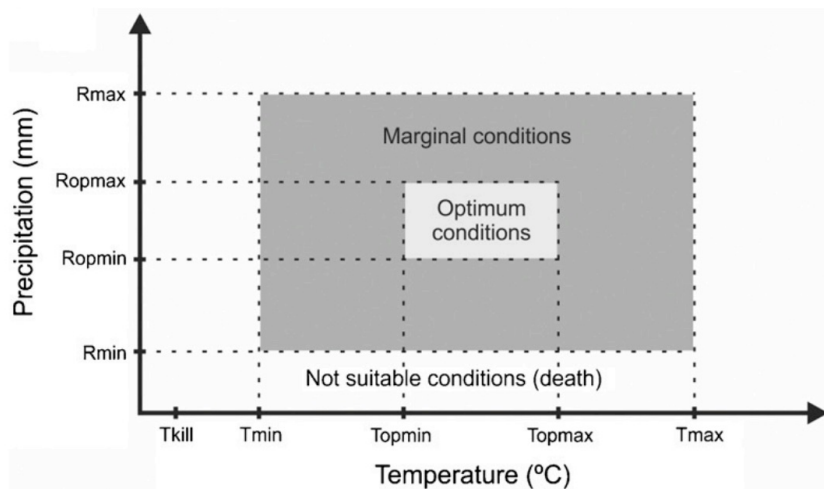
Finally,  $R_{C_i}^*$  is defined as the minimum of the precipitation indices  $R_{Cgi}^*$ , I estimated for each potential growing period  $g$ .

### A3.3 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).

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 precise, growing seasons are defined as a

Figure A1: Diagram of the Ecocrop suitability measure.



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

range (i.e. the avocado growing cycle is between 270 to 365 days). Therefore, for the avocado suitability, I take into account a 12-month growing period since trees require suitable conditions throughout the year. Meanwhile, poppy flowers can die during winter and then grow again in the spring. Therefore, unsuitable conditions during winter do not affect potential growth for the next year. To account for this, I eliminate growing periods that start with the autumn and winter months.<sup>12</sup>

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

<sup>12</sup>I restricted my analysis to the months of March-August.

Table A2: Poppy and avocado agro-climatic suitability requirements

	Avocado	Poppy
<b>Temperature (°C):</b>		
Absolute min. temperature	10	3
Absolute max. temperature	28	28
Min. optimum temperature	14	15
Max. optimum temperature	22	24
Killing temperature	-6	-5
<b>Precipitation (mm):</b>		
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
<b>Altitude (m.a.s.l.):</b>		
Min. altitude:	800	600
Max. altitude:	3,000	2,400
Hass min. altitude:	1,600	-
Hass max. altitude:	2,200	-
<b>Growing season (months):</b>	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).

## A4 Robustness Checks

### A4.1 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 Fen-

tanyl is a mechanism for the changes observed in violence in Mexico. To test this, I estimate Equation 1.1 using overdoses of heroin mixed with Fentanyl.

Table A3: Results on violence with mixed heroin overdoses

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

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

Table A3 shows the estimations for this specification. Consistent with my previous findings, these results show a positive correlation between heroin mixed with Fentanyl overdoses and homicides in avocado-suitable municipalities and a negative relationship for poppy municipalities. In particular, I find that mixing heroin with Fentanyl led to a rise in homicides of agricultural workers in avocado municipalities, and a decrease in poppy municipalities. The main difference with the previous specification is that I find a statistically significant increase in potentially cartel-related murders in avocado municipalities, and no effect on homicides in the rest of the population for both types of municipalities. However, the signs remain the same. While these results show evidence consistent with my hypotheses, it is not my preferred specification since heroin is not entirely exogenous to violence in Mexico.

## A4.2 Cartel presence

## A4.3 Entry and exit of cartels

To look more precisely into changes in cartel presence, I estimate Equation 1.1 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 statistically 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 $\times$ Log(Fentanyl $_{t-1}$ )	0.0157 (0.118)	0.0389 (0.037)	-0.00881 (0.099)	0.0173 (0.024)
Poppy Suitable $\times$ Log(Fentanyl $_{t-1}$ )	-0.0863 (0.186)	-0.0674 (0.056)	0.0511 (0.145)	0.0342 (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 parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

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

#### A4.4 Estimates on heroin cartels

In this section, I look into the effect of the introduction of Fentanyl on cartel presence of the cartels identified by the DEA as distributors of heroin (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 statistically significant effects for most of them, except for Los Zetas and Los Rojos. For these two cartels, I observe that Los Zetas and Los Rojos are more likely to be present in avocado-suitable municipalities and less in those suitable for poppy. 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 1.6 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 $\times$ Log(Fentanyl $_{t-1}$ )	0.0224 (0.025)	0.00749 (0.032)	0.00367 (0.015)	0.00463 (0.021)	0.0573** (0.027)	-0.0409 (0.028)	0.0268 (0.026)	0.0548*** (0.015)	-0.0110 (0.019)
Poppy Suitable $\times$ Log(Fentanyl $_{t-1}$ )	-0.0360 (0.036)	-0.0196 (0.050)	-0.0176 (0.021)	-0.00273 (0.035)	-0.0777* (0.043)	0.0271 (0.044)	-0.0142 (0.038)	-0.0666*** (0.018)	0.0122 (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

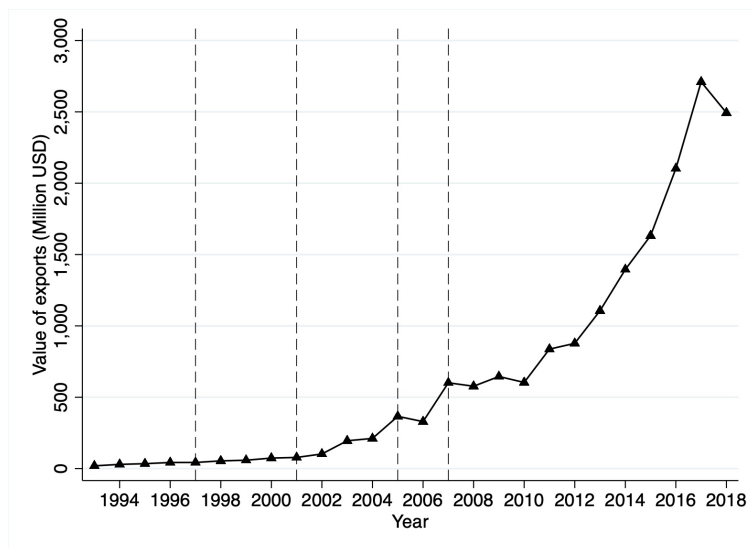
Notes: This table provides estimates on cartel presence for the main DTOs in Mexico linked to the trafficking and cultivation of heroin. All outcomes are binary variables equal to one of a cartel was present in a municipality, and zero otherwise. The cartels in Columns (1)-(7) correspond to the main 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 parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

## Appendix B

# The effect of NAFTA on violence in Mexico's avocado sector

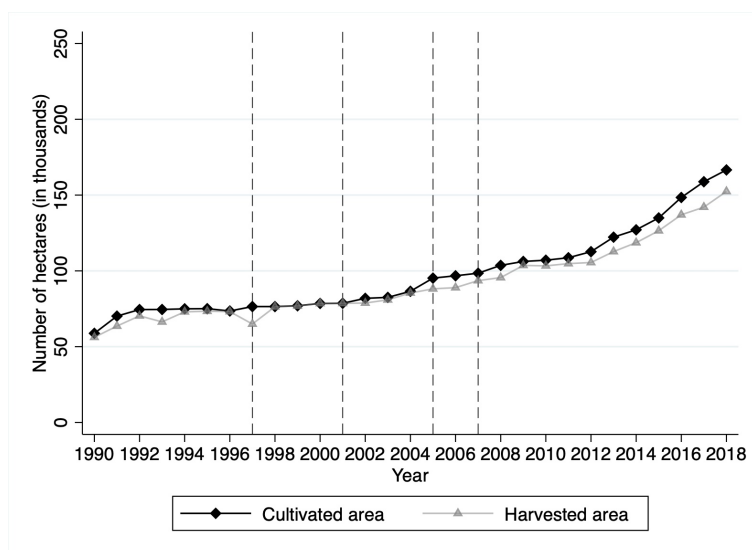
## B1 Figures and Tables

Figure B1: Total value of exports (Million USD)



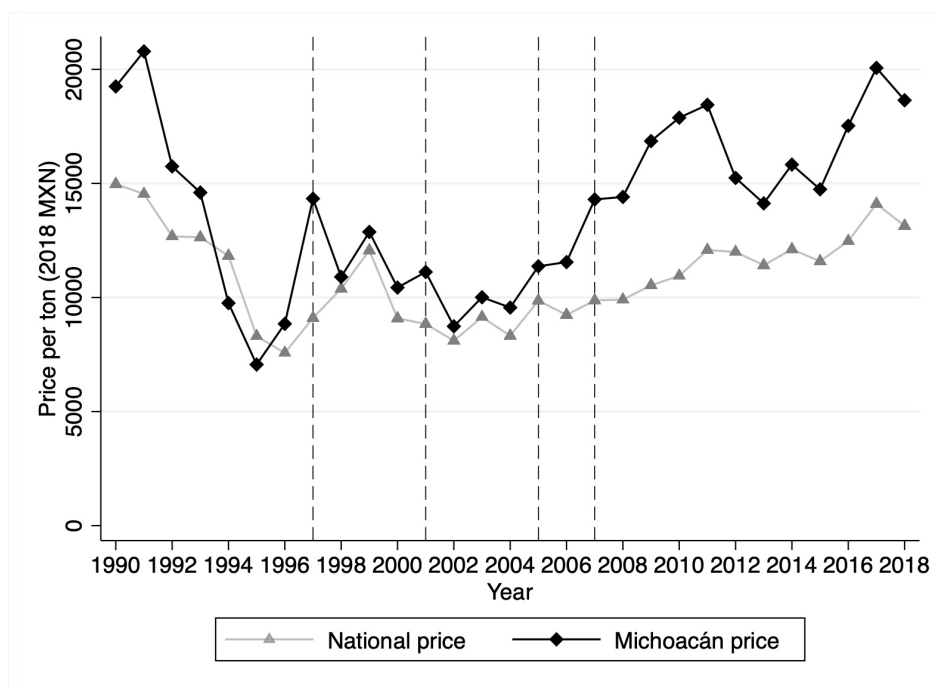
Source: own using information from SAGARPA.  
Vertical lines represent each of the NAFTA openings.

Figure B2: Avocado Hectares Cultivated and Harvested in Michoacán (1990-2018)



Source: own using information from SAGARPA.  
Vertical lines represent each of the NAFTA openings.

Figure B3: Avocado prices in Mexico (1990-2018)



Source: own using information from SAGARPA.  
Vertical lines represent each of the NAFTA openings.

Table B1: Phases for the introduction of avocados into the U.S.

Phase	Years	States Eligible for Mexican Avocado Shipments	Months Authorized
<b>I</b>	1997 - 2000	Connecticut, Delaware, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Wisconsin and Washington, D.C.	November - February
<b>II</b>	2001 - 2004	Colorado, Idaho, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, Utah, and Wyoming	October 15 - April 15
<b>III</b>	2005-2006	All states except California and Florida	Year round
<b>IV</b>	After 2007	All U.S. states	Year round

Source: Carman & Sexton (2011)

Table B2: Available data sources by aggregation level, frequency and periodicity

Data	Database	Years	Aggregation level	Frequency
<b>Violence &amp; Drug Data</b>				
Murders	INEGI	1990-2018	Municipality	Monthly
Presence of nine different cartels	Coscia and Ríos (2012)	1990-2010	Municipality	Annual
Eradicated marijuana crops (# of fields & ha.)	SEDENA	1990-2018	Municipality	Annual
Eradicated crops of poppy (# of fields & ha.)	SEDENA	1990-2018	Municipality	Annual
<b>Socioeconomic Data</b>				
National Census	INEGI	1990, 2000, 2010	Household	Every 5 years
National Population Count	INEGI	1995, 2005	Household	Every 5 years
Election Data	INAFED	1993-2010	Municipality	Annual
<b>Avocado Production</b>				
Production and prices per ton	SAGARPA	2003-2018	Municipality	Annual
Production and prices per ton	SAGARPA	1990-2002	State	Annual
Value of avocado exports	BANXICO	1993-2018	National	Monthly
<b>Weather data</b>				
Precipitation and temperature data	AgMerra	1990-2010	Municipality	Daily

Table B3: Descriptive Statistics

	Mean	SD	Obs.
<b>Violence and cartel presence</b>			
Murders per 100,000 people	19.24	25.59	8,619
No. of DTOs	0.18	0.78	8,619
Cartel presence (1/0)	0.08	0.28	8,619
<b>Avocado production</b>			
Avocado production (tons)	6,045	23,543	640
Price of avocado (MX per ton)	5,735	2,655	640
<b>Household and population characteristics</b>			
HH with non-dirt floor (%)	0.73	0.20	1,500
HH with water (%)	0.75	0.20	1,998
HH with sewage (%)	0.63	0.27	1,998
HH with electricity (%)	0.88	0.14	1,998
Working population (% , 1990)	0.98	0.02	994
Workers in the ag. sector (% , 1990)	0.38	0.21	994
Workers in the manufacturing sector (% , 1990)	0.24	0.11	994
Workers in the services sector (% , 1990)	0.33	0.14	994
<b>Suitability and weather conditions</b>			
Avocado Suitability	0.43	0.32	8,619
Annual mean temperature (°C)	24.95	3.91	8,619
Annual max. temperature (°C)	33.32	3.63	8,619
Annual min. temperature (°C)	18.46	4.29	8,619
Annual precipitation (mm)	944.80	263.89	8,619
Avocado suitable altitude (800-3,000 m.a.s.l.)	0.97	0.18	7,548

Notes: Data on avocado production and prices at the municipal level is only available between 2003-2010. Information on avocado prices is obtained directly from farmers, and, therefore, data is only available for municipalities that grow avocado. Altitude in Mexico is reported at the locality level. Avocado suitability is an index between one and zero. Altitude is a binary variables equal to one if the municipality has a locality within the suitable altitude range for avocado growing. The percentage of the labor force working on each sector is from the 1990 Census.

Table B4: DID results on cartel presence in Michoacán using the MCO database

	<i>Number of cartels</i>		<i>Log(number of cartels)</i>		<i>Cartel presence (1/0)</i>	
	(1)		(2)		(3)	
	Suitable - Mich		Suitable - Mich		Suitable - Mich	
1997-2000 × Suitable	-0.039*	(0.022)	-0.013	(0.011)	-0.002	(0.014)
2001-2004 × Suitable	0.040	(0.056)	0.019	(0.023)	0.026	(0.024)
2005-2006 × Suitable	0.159	(0.118)	0.054	(0.042)	0.043	(0.036)
1997-2000 × Michoacán	-0.023	(0.061)	-0.010	(0.025)	-0.008	(0.018)
2001-2004 × Michoacán	0.080	(0.107)	0.031	(0.047)	0.017	(0.040)
2005-2006 × Michoacán	0.166	(0.230)	0.075	(0.078)	0.061	(0.058)
1997-2000 × Suitable × Michoacán	0.161	(0.120)	0.063	(0.048)	0.037	(0.035)
2001-2004 × Suitable × Michoacán	0.132	(0.195)	0.065	(0.084)	0.054	(0.073)
2005-2006 × Suitable × Michoacán	0.189	(0.493)	0.031	(0.145)	-0.004	(0.102)
Observations	8,619		8,619		8,619	
Adj. R-squared	0.620		0.575		0.417	
Mean dep. var.	0.182		0.088		0.084	
Year FE	YES		YES		YES	
Municipality FE	YES		YES		YES	

Notes: Clustered standard errors at the municipality level in parentheses. Cartel presence is a binary variable equal to one if a municipality has at least one cartel in that year. Suitable is a measure ranging between zero and one, where one indicates that a municipality has optimal conditions for avocado growing. Michoacán is a binary variable equal to one if a municipality is part of that state. All estimations control for political affiliation of the municipal mayor by including a dummy for each of the major parties in the period analyzed (PAN, PRI, PRD), and a binary variable equal to one if the municipal mayor party coincides with the president party. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

## B2 Robustness Checks

### B2.1 Results on violence

During the first two openings, Mexico could only export avocados to the U.S. for specific months. For instance, between 1997 and 2000, they only allowed them from November to February. In 2001, this shifted to October to April (see Figure 2.1). Therefore, a caveat with estimating annual homicides is that I do not consider that between 1997 and 2005, Mexico could only export avocados to the U.S. during specific months. To verify whether decreases in the homicide rates during the specific months in which avocados could be exported drive my annual results, I estimated the effect of each wave on monthly homicide rates. In this specification, I estimate the effect on on-season and off-season months, that is, during the months in which avocados could be or not be exported to the U.S. The omitted period encompasses the months preceding the start of the first wave (before November 1997). To control for seasonal effects, I include monthly fixed effects. I also add municipality and year-fixed effects to control for time-invariant characteristics and time shocks. All estimations include covariates.

Table B5 shows the results for this specification. Column (1) shows the results for the whole sample. It shows that NAFTA resulted in lower homicide rates throughout the year, not only for the specific months in which the U.S. imported Mexican avocados. I also cannot conclude that coefficients from the on-season and off-season months are statistically different from each other for the first and second waves. This shows evidence of the existence of temporal spillovers. Two explanations for this come to mind. First, the increase in the demand for avocados could have positively affected employment throughout the year and not only during high demand periods. Second, even if there were employment peaks, the increase in income provided opportunities for individuals to opt-out of criminal activities. Unfortunately, due to the unavailability of employment data for this period, I cannot test NAFTA's impact on employment in the avocado sector.

Finally, Column (2) in Table B5 shows my results including the triple interaction with Michoacán. I find no evidence of changes in the homicide rates for on-season and off-season months, consistent with my main results.

Table B5: DID results on monthly homicides

	<i>Dependent variable: Log(monthly murders)</i>			
	(1)		(2)	
	Suitable		Suitable - Mich	
1997-2000 [ <b>on-season</b> ] × Suitable	-0.424***	(0.128)	-0.435***	(0.139)
2001-2004 [ <b>on-season</b> ] × Suitable	-0.682***	(0.115)	-0.606***	(0.108)
2005-2006 [ <b>on-season</b> ] × Suitable	-0.762***	(0.130)	-0.733***	(0.127)
1997-2000 [off-season] × Suitable	-0.480***	(0.121)	-0.440***	(0.123)
2001-2004 [off-season] × Suitable	-0.639***	(0.115)	-0.598***	(0.110)
1997-2000 [ <b>on-season</b> ] × Michoacán			-0.484**	(0.204)
2001-2004 [ <b>on-season</b> ] × Michoacán			-0.111	(0.203)
2005-2006 [ <b>on-season</b> ] × Michoacán			0.0913	(0.224)
1997-2000 [off-season] × Michoacán			-0.525***	(0.197)
2001-2004 [off-season] × Michoacán			-0.282	(0.217)
1997-2000 [ <b>on-season</b> ] × Suitable × Michoacán			0.297	(0.358)
2001-2004 [ <b>on-season</b> ] × Suitable × Michoacán			-0.256	(0.399)
2005-2006 [ <b>on-season</b> ] × Suitable × Michoacán			-0.158	(0.442)
1997-2000 [off-season] × Suitable × Michoacán			0.107	(0.377)
2001-2004 [off-season] × Suitable × Michoacán			-0.0238	(0.400)
1997-2000 [ <b>on-season</b> ]	0.381***	(0.098)	0.463***	(0.099)
2001-2004 [ <b>on-season</b> ]	-0.210***	(0.068)	-0.179***	(0.066)
Observations	101184		101184	
Adj. R-squared	0.108		0.109	
Mean dep. var.	1.969		1.969	
Year FE	YES		YES	
Month FE	YES		YES	
Municipality FE	YES		YES	

Notes: This table provides estimates on monthly murders. Each NAFTA opening is a binary variable equal to one for the months during which Mexican avocados were allowed to be imported to the U.S. Suitable is a measure ranging between zero and one, where one indicates that a municipality has optimal conditions for avocado growing. Michoacán is a binary variable equal to one if a municipality is part of that state. All estimations control for political affiliation of the municipal mayor and a binary variable equal to one if the municipal mayor party coincides with the president party. Clustered standard errors at the municipality level in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

## B2.2 Cartel presence

In this section, I test whether the results on cartel presence are robust to using a different data source. As mentioned in Section 2.4.1, information on cartel presence is also available from Coscia and Rios (2012). This database uses information from the Google Search API, deprecated in 2011.

Table B6 shows the estimates for each of the NAFTA waves on three measures of cartel presence. The results show no effect of any of the NAFTA waves on cartel presence. Therefore, this provides further evidence to support my conclusion that the observed decrease in homicide rates of avocado-suitable municipalities is not due to lower cartel presence. Table B7 shows the results for Michoacán. They show no changes in cartel presence, except for a slight increase after the 2001 opening.

Table B6: DID results on cartel presence using data from Coscia and Rios (2012)

	<i>Number of cartels</i>		<i>Log(number of cartels)</i>		<i>Cartel presence (1/0)</i>	
	(1)		(2)		(3)	
	Suitable		Suitable		Suitable	
1997-2000 × Suitable	0.001	(0.014)	0.001	(0.009)	0.003	(0.013)
2001-2004 × Suitable	-0.029	(0.021)	-0.017	(0.013)	-0.020	(0.016)
2005-2006 × Suitable	0.030	(0.078)	0.023	(0.042)	0.027	(0.042)
Observations	8,619		8,619		8,619	
Adj. R-squared	0.261		0.287		0.293	
Mean dep. var.	0.048		0.029		0.034	
Year FE	YES		YES		YES	
Municipality FE	YES		YES		YES	

Notes: Clustered standard errors at the municipality level in parentheses. Cartel presence is a binary variable equal to one if a municipality has at least one cartel in that year. Suitable is a measure ranging between zero and one, where one indicates that a municipality has optimal conditions for avocado growing. All estimations control for political affiliation of the municipal mayor by including a dummy for each of the major parties in the period analyzed (PAN, PRI, PRD), and a binary variable equal to one if the municipal mayor party coincides with the president party. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table B7: DID results on cartel presence in Michoacán using data from Coscia and Rios (2012)

	<i>Number of cartels</i>		<i>Log(number of cartels)</i>		<i>Cartel presence (1/0)</i>	
	(1)		(2)		(3)	
	Suitable - Mich		Suitable - Mich		Suitable - Mich	
1997-2000 × Suitable	-0.001	(0.016)	-0.000	(0.011)	0.000	(0.015)
2001-2004 × Suitable	-0.042*	(0.024)	-0.026*	(0.015)	-0.029	(0.018)
2005-2006 × Suitable	-0.020	(0.068)	-0.009	(0.037)	-0.006	(0.038)
1997-2000 × Michoacán	-0.023**	(0.010)	-0.016**	(0.007)	-0.022**	(0.009)
2001-2004 × Michoacán	-0.044*	(0.023)	-0.029**	(0.013)	-0.039***	(0.015)
2005-2006 × Michoacán	0.334**	(0.167)	0.163**	(0.081)	0.150**	(0.072)
1997-2000 × Suitable × Michoacán	0.026	(0.022)	0.017	(0.015)	0.025	(0.021)
2001-2004 × Suitable × Michoacán	0.081*	(0.042)	0.051**	(0.025)	0.061**	(0.030)
2005-2006 × Suitable × Michoacán	0.017	(0.284)	0.036	(0.146)	0.051	(0.138)
Observations	8,619		8,619		8,619	
Adj. R-squared	0.287		0.311		0.311	
Mean dep. var.	0.048		0.029		0.034	
Year FE	YES		YES		YES	
Municipality FE	YES		YES		YES	

Notes: Clustered standard errors at the municipality level in parentheses. Cartel presence is a binary variable equal to one if a municipality has at least one cartel in that year. Suitable is a measure ranging between zero and one, where one indicates that a municipality has optimal conditions for avocado growing. Michoacán is a binary variable equal to one if a municipality is part of that state. All estimations control for political affiliation of the municipal mayor by including a dummy for each of the major parties in the period analyzed (PAN, PRI, PRD), and a binary variable equal to one if the municipal mayor party coincides with the president party. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

## Appendix C

# Pipelines and Crime in Mexico

## C1 Robustness checks for restricted states

Table C1: Results on homicides restricted to states with access to fuel and LPG pipelines

	All (1)	Male (2)	Female (3)	Pemex (4)	Cartel (5)	Military (6)
LPG pipeline $\times$ Post 2019	4.101** (1.682)	3.547** (1.557)	0.374 (0.259)	-0.00124 (0.013)	2.047** (0.952)	0.0618 (0.074)
Fuel pipeline $\times$ Post 2019	5.098* (3.015)	4.623* (2.773)	0.332 (0.332)	-0.00579 (0.026)	1.923 (1.751)	0.0769 (0.139)
Observations	17017	17017	17017	17017	17017	17017
Adj. R-squared	0.359	0.363	0.0698	0.202	0.324	0.0579
Mean dep. var.	21.21	18.84	2.260	0.0191	8.608	0.0480

Notes: This table replicates the results from Table 3.2 restricting the sample to states that have access to fuel or LPG pipelines. Dependent variables measured as homicides per 100,000 inhabitants. Homicides of Pemex employees are estimated based on homicides of individuals of working age (18-60 years old) insured through Pemex. Potential cartel-related homicides are males aged 18-40, killed by a firearm. Homicides of military personnel are estimated based on individuals insured through SEDENA, ages 18-60, killed by a firearm. Municipality and year-fixed effects are included in all specifications. Clustered standard errors at the municipality level in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table C2: Results on other crimes restricted to states with access to fuel and LPG pipelines

	Robberies (1)	Kidnap (2)	Threats & Extortion (3)	Other violence (4)
LPG pipeline $\times$ Post 2019	-3.938 (8.316)	-0.270* (0.160)	0.251 (2.749)	3.486 (3.033)
Fuel pipeline $\times$ Post 2019	-44.09*** (12.643)	-0.279 (0.261)	-0.410 (3.854)	-13.87*** (4.320)
Observations	17017	17017	17017	17017
Adj. R-squared	0.841	0.134	0.510	0.743
Mean dep. var.	204.2	0.831	46.33	92.81

Notes: This table replicates the results from Table 3.3 restricting the sample to states that have access to fuel or LPG pipelines. Dependent variables are measured as crimes per 100,000 inhabitants. Other physical violence consists on injuries and other crimes that threaten life. Municipality and year-fixed effects are included in all specifications. Clustered standard errors at the municipality level in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table C3: Results on cartel presence restricted to states with access to fuel and LPG pipelines

	Number of cartels				Cartel presence (1/0)			
	All (1)	Original (2)	Fragmented (3)	New (4)	All (5)	Original (6)	Fragmented (7)	New (8)
LPG pipeline $\times$ Post 2019	0.0878*** (0.020)	0.0503*** (0.014)	0.0621*** (0.017)	0.0363*** (0.011)	0.0331** (0.015)	0.0282** (0.014)	0.0338** (0.015)	0.0454*** (0.013)
Fuel pipeline $\times$ Post 2019	0.0996*** (0.027)	0.0608*** (0.022)	0.0664*** (0.022)	0.118*** (0.018)	-0.00660 (0.018)	0.0356* (0.020)	-0.0113 (0.018)	0.0835*** (0.019)
Observations	17122	17122	17122	17122	17122	17122	17122	17122
Adj. R-squared	0.820	0.751	0.797	0.651	0.642	0.606	0.639	0.547
Mean dep. var.	0.608	0.304	0.451	0.109	0.405	0.280	0.360	0.118

Notes: This table replicates the results from Table 3.4 restricting the sample to states that have access to fuel or LPG pipelines. Clustered standard errors at the municipality level in parentheses. Columns (1)- (4) are the log number of cartels present in a municipality. Columns (5)-(8) show results using a binary variable equal to one if there is at least one cartel mentioned in a municipality. Municipality and year-fixed effects are included in all specifications. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

## C2 Robustness checks on spillovers

Table C4: Results on homicides in neighbor municipalities

	All (1)	Male (2)	Female (3)	Pemex (4)	Cartel (5)	Military (6)
Neighbor with LPG pipeline $\times$ Post 2019	-0.942 (1.840)	-1.229 (1.684)	0.254 (0.389)	-0.00540 (0.008)	-0.619 (0.935)	0.00776 (0.023)
Neighbor with fuel pipeline $\times$ Post 2019	5.352** (2.564)	5.188** (2.281)	0.0765 (0.475)	0.00252 (0.008)	2.457* (1.301)	0.115 (0.090)
Observations	12558	12558	12558	12558	12558	12558
Adj. R-squared	0.339	0.348	0.0519	0.117	0.304	0.00554
Mean dep. var.	19.51	17.33	2.098	0.00526	7.617	0.0319

Notes: This table estimates spillover effects on municipalities that share a border with a municipality that has an LPG or a fuel pipeline. The sample is restricted to municipalities with no fuel or LPG pipeline. Dependent variables measured as homicides per 100,000 inhabitants. Homicides of Pemex employees are estimated based on homicides of individuals of working age (18-60 years old) insured through Pemex. Potential cartel-related homicides are males aged 18-40, killed by a firearm. Homicides of military personnel are estimated based on individuals insured through SEDENA, ages 18-60, killed by a firearm. Municipality and year-fixed effects are included in all specifications. Clustered standard errors at the municipality level in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table C5: Results on other crimes in neighbor municipalities

	Robberies (1)	Kidnap (2)	Threats & Extortion (3)	Other violence (4)
Neighbor with LPG pipeline $\times$ Post 2019	-17.33*** (6.271)	0.150 (0.197)	-11.17*** (3.327)	-9.479*** (3.569)
Neighbor with fuel pipeline $\times$ Post 2019	-17.28* (9.846)	0.00927 (0.360)	3.563 (3.475)	-6.491 (4.488)
Observations	12558	12558	12558	12558
Adj. R-squared	0.797	0.0775	0.428	0.688
Mean dep. var.	141.4	0.644	39.61	77.26

Notes: This table estimates spillover effects on municipalities that share a border with a municipality that has an LPG or a fuel pipeline. The sample is restricted to municipalities with no fuel or LPG pipeline. Dependent variables are measured as crimes per 100,000 inhabitants. Other physical violence consists on injuries and other crimes that threaten life. Municipality and year-fixed effects are included in all specifications. Clustered standard errors at the municipality level in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

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