A Two-Wave Death History:
Fentanyl Overdoses in the US, Bullets in Mexico

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Abstract

We establish a link between the fentanyl epidemic in the US starting in 2013 and a second wave of drug-related violence in Mexico. We argue that the demand for fentanyl in the US pushed some drug trafficking organizations to reoptimize their trafficking routes, leading to new clashes and violence, often in locations unaffected by the first wave of violence caused by the 2007 Mexican War on Drugs. Exploiting the differential impact that the Mexican War on Drugs and the demand for fentanyl had on different municipalities, we estimate that fentanyl caused between 15 and 20 extra homicides per 100,000 inhabitants.

JEL classification codes: D74, K42, R12

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1. Introduction

It is well documented that the introduction of fentanyl in the United States has been associated with a synthetic opioid epidemic.[1] Figure 1 shows a sharp increase in fentanyl overdoses in the US starting in 2013. It is less known, however, that the arrival of Chinese fentanyl precursors has been associated with a new wave of violence in some Mexican regions, significantly rising homicide rates and even reversing the decline in homicide rates nationwide after the peak of the Mexican War on Drugs. Figure 1 shows a rise in homicide rates starting in 2013. We argue that fentanyl was a substantial demand shock to the Mexican criminal sector; it induced a remarkable change in the strategic value of different nodes and trafficking routes and, crucially, triggered a reallocation of conflicts and a new wave of violence.

The initial eruption of violence in Mexico in 2007 has been attributed to the government crackdown on drug trafficking organizations (hereafter, DTOs), often denoted the Mexican War on Drugs (hereafter, MWD). Several works have convincingly concluded that DTOs targeted by the government became vulnerable to attacks from rivals and were subject to succession internal wars, which sparked conflict outbreaks and violence.[2] This mechanism, however, cannot explain the second wave of violence starting in 2013. After all, violence peaked in 2010-2011; by 2013, the declining trend was evident (Figure 1). Moreover, based on the number of casualties in campaigns against drug trafficking, there is no evidence that the Mexican government launched a new war on drugs or intensified its pressure on DTOs during or after 2013.[3] We argue that fentanyl was the main driver behind this new wave of violence.

Indeed, driven by the demand for synthetic opioids in the US, some relatively new Mexican DTOs on the Pacific coast embarked on a bold endeavor. They sought to establish trafficking

[1] As Hamilton (2021) argues, much of the available evidence identifies China as a major source of fentanyl reaching the hands of Americans, contributing to the fentanyl crisis in the US. Moreover, they refer to Mexico as the entry point of synthetic opioids to the American market.

[2] See for example Osorio (2015), Calderón et al. (2015), and López Cruz and Torrens (2023).

[3] Figure A.1 in the Appendix shows the number of military casualties in the context of the MWD according to the National Defense Secretariat records. No systematic growth is observed after 2013.

routes from Mexican ports along the Pacific coast to the Mexican-US border. The first component of this strategy was to dominate critical Mexican ports with access to Chinese trade flows. The second component was to bypass routes using South-North highways, which were under the firm control of strong DTOs. Instead, they favored less-contested West-East highways relatively abundant in Central Mexico.[4] This strategic shift in the drug trade triggered a profound reallocation of violence. As DTOs fought for dominance over new drug corridors, clashes over territories that previously held little strategic value for drug trafficking operations increased. Simultaneously, as synthetic opioids replaced heroin, traditional heroin routes lost their strategic value. Nationwide, the rise in homicides in the new contested areas outweighed the pacification of traditional trafficking areas, leading to the second wave of violence observed in Figure 1.

To quantify the effect of the fentanyl demand shock on Mexican homicide rates, we combine data on homicides, drug trafficking activities, the Mexican Road Network (MRN) location, DTOs' territorial control, and law enforcement measures. Specifically, we resort to data collected by Signoret et al. (2021) to create a travel cost index (TCI) at the municipality-year-DTO level. We employ INEGI's (2014) highway network map to measure the distance between any two points in the country and combine it with Signoret et al.'s (2021) DTOs' territorial presence index. Then, we employ these calculations to retrieve the TCI between locations m_1 and m_2 at year t for DTO d. Specifically, we compute DTO d's relative presence against its opponents and multiply the latter by the distance between m_1 and m_2.

We use the above method to break our sample into different groups of municipalities. First, we retrieve the stripe of municipalities rich in poppy crops or containing a US border crossing point with the lowest TCI in 2007. We denote such an area as the MWD-treated region.

[4]Ample journalistic evidence has revealed multiple incursions of Pacific-based organizations in Central Mexico attempting to reach locations along the Gulf coast. See section 2 for a more detailed description of these developments.

In these municipalities, violence (measured by homicide rates) erupted after 2007, peaked in 2011, and declined to pre-2007 levels by 2015. Second, we consider municipalities along the cheapest routes between the Mexican ports on the Pacific coast and the US border and further divide them between those municipalities traversed by West-East highways and those traversed by North-South highways. We denote the municipalities traversed by West-East highways as the Fentanyl-treated region, while those traversed by North-South highways are the doubly treated region. Our results indicate that violence increased only after 2013 in the Fentanyl-treated region, while the doubly-treated region experienced two waves of violence. In short, we identify locations affected by the MWD in 2007, which we subsequently divide into locations exhibiting one or two waves of violence.

Contrasting the above subsamples and exploiting the exogenous nature of the fentanyl precursors' geographic origin, we implement a difference-in-differences (DID) procedure to identify the effect of fentanyl on homicide rates in Mexico. Specifically, the doubly affected municipalities constitute our treated group, while the MWD-treated units supply us with a suitable control group. Our identifying assumption is that without fentanyl, violence would have subsided everywhere as it did in the units that only received the MWD shock in 2007. To complement this strategy, we combine three groups of observations, the MWD-treated, the Fentanyl-treated, and a set of never-treated municipalities, to estimate a DID model suitable for staggered treatment adoption settings (Wooldridge, 2021).[5] This specification's causal interpretation assumes that late adopters (Fentanyl-treated) in conjunction with never-treated units form an adequate counterfactual for early adopters (MWD-treated). This specification allows us to, in a single regression, compute the fentanyl effect separately from the MWD effect and test whether they are individually significant.

[5]The set of never-treated units includes all the municipalities from the southernmost Mexican states (Chiapas, Campeche, and Yucatán), which, as we document in Section 4, do not exhibit any reminiscence from the first or second violence waves.

When comparing doubly treated with MWD-treated municipalities, we estimate that the increased demand for synthetic opioids in the US caused, on average, 20 additional homicides per 100,000 inhabitants. Consequently, taking the control group as a benchmark (MWD-treated units), we find that conflicts involving cartels vying for access to exporting spots in the Gulf area increased homicide rates, on average, by 167 percent. In contrast, at the national level, homicide rates were only 70 percent higher in the post-treatment period. When comparing the MWD-treated versus the Fentanyl-treated municipalities, we find that fentanyl raised violence levels more than the MWD. Indeed, throughout our specifications, we conclude that the MWD effect was, at most, only 57 percent of that of fentanyl.

We conduct a series of robustness and validation tests to reinforce the credibility of our findings. First, based on López Cruz and Torrens (2023), we acknowledge that central Mexico received another sizeable violence shock in the period of interest: the inter-cartel struggles over the oil pipelines running across the region. Since these are primarily concurrent events, we include their index for oil-valuable municipalities in our regressions as a competing hypothesis for the fentanyl effect. Second, we incorporate a measure of government-induced violence to check if the same forces that triggered the MWD were behind the fentanyl effect. Third, we introduce an indicator of municipal drug production suitability to examine if these municipalities overlap with those receiving the fentanyl treatment. None of these factors affect our estimations.

Finally, we draw upon methodologies established by Benshaul-Tolonen (2019), Depetris-Chauvin and Özak (2020), Guimbeau et al. (2021), and López Cruz and Torrens (2023) to construct a spatial placebo test. This test randomly assigns treatment group membership to spatial units located within a 50-kilometer buffer around the treated units, repeated over one thousand iterations. Subsequently, we execute our Difference-in-Differences (DID) regression one thousand times, resulting in a statistically null effect of fentanyl on violence. Lastly, we undertake a series of robustness and sensitivity checks to rigorously assess the validity of the parallel-trend assumption and the accuracy of our standard errors. These procedures enhance the reliability and robustness of our empirical findings.[6]

1.1 Related Literature

This paper builds upon a substantial body of literature on drug-related violence in Mexico. Notably, Calderón et al. (2015) shed light on how the MWD catalyzed widespread violence in Mexico after 2007. Their research shows that removing criminal leaders weakened specific DTOs, making them prime targets for rivals' attacks, thereby triggering violent clashes among DTOs. Additionally, beheading these organizations produced internal power struggles, leading to more violence. Our paper, instead, focuses on the forces that prolonged violence up to 2019, addressing an unexplored source of violence, namely, fentanyl demand in the US.

We draw inspiration from the work of Dell (2015), whose research employs a network model to study drug trafficking routes. She illustrates how political changes, such as the conservative political party's (PAN) victories, can divert drug traffic, leading to greater violence along alternative drug routes. While her approach shares similarities with ours, as both employ algorithms to calculate optimal routes, our paper diverges by considering territorial control exercised by DTOs rather than crackdowns. Furthermore, our study period (2013-2019) reveals violence outbreaks in locations that remained relatively calm during Dell's study period (2007-2013).

The paper relates to works on violence diffusion mechanisms, such as Galiani et al. (2018) and López Cruz and Torrens (2023). These studies predominantly examine criminal diversification and spatial displacement of violence due to changes in the distribution of security forces. On

[6]We assume that homicide rates in the 2013 new fentanyl routes would have followed a trend similar to the municipalities in the control group. Our analysis is supported by widely-used event-study regression coefficients and Rambachan and Roth's (2022) methods. Additionally, we check our standard errors' robustness by reporting Conley's (1999) standard errors. All these tests confirm our results.

the contrary, we explore violence rise and spatial displacement caused by a demand shock affecting different criminal organizations asymmetrically.

The paper also contributes to an extensive literature on the effect of external economic shocks on conflict. For example, Dube and Vargas (2013) demonstrate how an oil price hike led to conflict in Colombia between 1998 and 2015. Similarly, Castillo et al. (2020) examine the role of cocaine supply shortages in exacerbating violence in Mexican municipalities near the United States. Manotas-Hidalgo et al. (2018) emphasize that under imperfect protection of property rights, income shocks often ignite predatory behaviors as they increase conflict rewards, an effect that ethnic divisions magnify.[7] Two crucial insights from the above literature are (e.g., Berman and Couttenier, 2015): First, the relationship between external shocks and conflict tends to be volatile due to spatial heterogeneity in the impact of income shocks. Second, geographically disaggregated data are essential in capturing local variations that country-level data might overlook. In support of these findings, our paper corroborates the spatially heterogeneous relationship between external shocks and conflict in the context of organized crime and drug trafficking. Moreover, we go one step forward and show how this spatial heterogeneity influences the struggles among DTOs and, therefore, violence dynamics. In particular, we show how seemingly unprofitable ventures, such as territorial expansion to Central Mexico, can become pivotal to take full advantage of external shocks, sparking violence in unexpected regions.

The rest of the paper is organized as follows. Section 2 summarizes basic facts on drug violence in Mexico and its relationship to the fentanyl crisis in the US. Section 3 describes the data. Section 4 presents the empirical strategy. Section 5 formally quantifies the effect of the opioid crisis in the US on violence in Mexico using panel data regression analysis. Section 6 discusses several robustness checks. Section 7 concludes.

[7] See López Cruz (2019), and López Cruz and Torrens (2019) for a theoretical discussion of the impact on conflict levels of changes in the value of contested resources.

2. Background

This section summarizes the first wave of drug-related violence in 2007. Following the literature, we attribute it to the MWD, a major offensive against DTOs launched by the Mexican government. Next, we focus on the second wave of violence and argue that its main driver has been some DTOs' strategies to profit from the demand for fentanyl in the US. Finally, we argue that the spatial pattern of violence is consistent with our explanation.

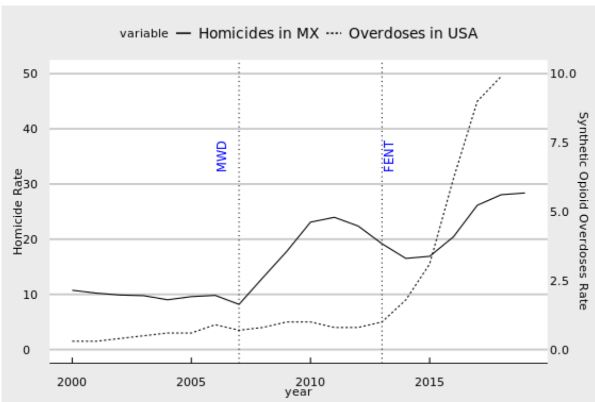

Figure 1. National-level homicide rates in Mexico and overdose death rates due to synthetic opioid consumption in the US. *Note*: This graph shows the evolution of homicides in Mexico and synthetic opioid overdose deaths in the US, both expressed in rates per 100,000 inhabitants. *Sources*: INEGI (2016), CDC (2023)

2.1 The first wave of violence: MWD

Before Mexico transitioned to democracy, the regime led by the Institutional Revolutionary Party (PRI) established a regulatory network involving civilian and military officials, effectively managing narcotics production and trade (Trejo and Ley, 2020). DTOs collaborated with the regime, exchanging bribes for implicit permission to conduct operations while avoiding violent clashes (Trejo and Ley, 2018). DTOs also relied on familial ties, maintaining separation from outsiders, and even formed alliances between various families involved in the trade during the 1960s, a coalition that endured until the 1980s (Astorga, 2016).

This relatively stable environment shifted as Mexico gradually transitioned to democracy in the 1990s, which eroded the central government's control over local security forces. The protection networks enjoyed by DTOs waned, leading them to cease collaboration and establish sizeable armed groups for territorial defense and conquest (Trejo and Ley, 2020). Remarkably, except for some sporadic upticks, homicide rates remained low until the beginning of the MWD in 2007.

After the 2006 presidential election, the Mexican government launched a campaign against DTOs to regain control over criminal-dominated areas. Military campaigns aimed at arresting or eliminating drug lords, the so-called kingpin strategy, resulted in increased violence among and within cartels, causing a nationwide surge in homicides (Figure 1). DTOs resorted to violence to protect their positions, and disruptions in traditional trafficking routes forced them to intensify their efforts to control available routes (Dell, 2015). Weakening organizations holding valuable trafficking locations created power vacuums, sparking violent competition (Calderón et al., 2015). Criminal syndicates fragmented into smaller cells, leading to territorial conflicts and, therefore, more violence (Beittel, 2018). Finally, the violence triggered by the MWD diffused to other locations through several channels. For example, some studies have shown that certain DTOs diversified their criminal activities, such as engaging in oil theft (e.g., López Cruz and Torrens, 2023) or extortion of avocado producers (e.g., Herrera and Martinez-Alvarez, 2022).

By 2011, however, national levels of violence (i.e., homicides) peaked and started to decline. While the mechanisms mentioned above help explain the sharp increase in homicides immediately after the MWD and, to some extent, the spatial diffusion of violence during this period, they do not explain the subsequent decline or revamp after 2013. Notably, to our knowledge, no work has examined the two distinct surges in homicide rates depicted in Figure 1, nor has it explored the spatial distribution of those surges.[8]

[8]Works that study the spatial diffusion of violence during the first wave of violence, such as López Cruz and Torrens (2023), and Herrera and Martinez-Alvarez (2022), do not establish such developments as the

2.2 The second wave of violence: fentanyl

Around 2013, a dramatic increase in synthetic opioid overdoses took place in the United States (Figure 1).[9] At the core of this crisis lies the widespread use and abuse of fentanyl, a synthetic opioid renowned for its potency compared to traditional opioids like heroin (CDC, 2023). The epidemic's primary fuel stemmed from the illicit production and trafficking of fentanyl and its derivatives, originating predominantly from China and Mexico (Hamilton, 2021). Two Mexican DTOs rooted in the Pacific Coast, the Sinaloa Cartel and the New Generation Jalisco Cartel, emerged as the key players behind the smuggling of fentanyl into the United States (DEA, 2020). Crucially, the New Generation Jalisco Cartel's strategy to take advantage of the fentanyl trade played an important role in the second wave of violence.

Jones (2018) dates the New Generation Jalisco Cartel's rapid ascent in 2010 and attributes it to the fragmentation of two other DTOs, the Milenio and Sinaloa cartels. In this context, three critical factors contributed to the New Generation Jalisco Cartel's accelerated expansion. First, it effectively attracted smaller groups that resulted from the government's kingpin strategy. Second, their location in Jalisco, near the Pacific ports of Lázaro Cárdenas and Manzanillo, made it easier to transport illicit drugs to lucrative European and Asian markets. Additionally, the cartel skillfully kept alliances with some players while engaging in conflicts with rival groups across multiple locations.

Given its location near Pacific ports, the New Generation Jalisco Cartel was strategically positioned to receive shipments of fentanyl from China. To satisfy the growing demand for fentanyl in the US drug market, the cartel needed to find reliable trafficking routes. The natural routes would be to employ crossing points in Coahuila and Tamaulipas in the northeast. However, these routes were highly contested by several DTOs. The Pacific Coast

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origins and underlying causes of the second wave of violence, which is the focus of this paper.

[9]The precise start of the fentanyl crisis is subject to debate. For instance, the DEA (2020) maintains that it was not until 2014 that the upsurge in the associated overdoses took place.

northern states would be another possibility. Likewise, using these routes proved unsuccessful due to the Sinaloa Cartel's entrenched presence in the region (Dittmar, 2020). Thus, the New Generation Jalisco Cartel tried a different strategy. It started moving its fentanyl shipments through Central Mexico and fought to control Gulf Coast ports, augmenting its access to the US drug market (Jones, 2018). As a result, the states located on the path connecting the cartel's main base in the Pacific and the Gulf Coast saw conflict upticks. The former was especially true for Guanajuato, Zacatecas, and Michoacán, which were contested by the New Generation Jalisco Cartel and other criminal groups like Los Zetas in a bid for territorial control and trafficking routes (ACLED, 2023). These clashes revamped violence, reversing the nationwide decline from 2010 to 2013.[10]

2.3 Spatial diffusion of violence

The spatial diffusion of violence supports the argument that the second wave of homicides resulted from the New Generation Jalisco Cartel's strategy to move fentanyl to the US market. The reasoning is as follows. We consider three groups of municipalities differently affected by the MWD and fentanyl. The first group is integrated by municipalities traversed by US-headed trafficking routes from poppy-rich regions under the Sinaloa cartel's control. We denote them "MWD-treated" municipalities. The second group is integrated by municipalities along the New Generation Jalisco Cartel Pacific-Gulf new routes that were not previously employed as trafficking routes. These are the "fentanyl-treated" municipalities. Finally, the third group is integrated by municipalities across the New Generation Jalisco Cartel's routes that were also employed by other organizations for poppy transportation. These are the "doubly treated" municipalities.

To build these three groups of municipalities, it is crucial to define the trafficking routes of

[10]Indeed, government intelligence documents, news reports, and a few descriptive papers (see, for instance Jones (2018), ACLED (2023), Dittmar (2020)) attribute the post-2013 outbursts of violence in Mexico to the competition for new trafficking routes in otherwise peaceful regions.

the Sinaloa and New Generation Jalisco cartels. Drawing on Dell's (2013) model of route congestion, we employ INEGI's (2020) road network map as an undirected graph, with vertices for locations and edges indicating connections. Utilizing Dijkstra's algorithm, we calculated travel costs, considering distances and DTO presence based on Signoret et al.'s (2021) data. This procedure allowed us to identify the most direct routes to the US, avoiding areas controlled by Sinaloa Cartel and New Generation Jalisco Cartel's rivals.[11]

MWD-treated municipalities: Heroin production and smuggling to the US was one of the primary activities of the Sinaloa Cartel (Torre and Navarrete Escobedo, 2018). Thus, it is not surprising that the MWD and the subsequent clashes between the Sinaloa Cartel and Los Zetas (Correa-Cabrera, 2017) triggered violence in municipalities traversed by routes between the Sinaloa Cartel-controlled poppy crops in Durango and the US border.

Figure 2 depicts the evolution of Sinaloa Cartel's optimal route from its northernmost poppy production area to the US border. Gray lines represent the shortest route, while black lines indicate the optimal route. Before the MWD in 2007, the Sinaloa Cartel faced minimal challenges transporting cargo to the US border in Northeast Mexico. Accordingly, its shortest and optimal routes were almost identical (Figure 2, Panel A). However, by 2010, the optimal route had significantly deviated from the shortest one, indicating increased obstacles (Figure 2, Panel B). In 2013, our model suggests that the Sinaloa Cartel preferred an alternative border crossing point in the Northwest (Figure 2, Panel C).

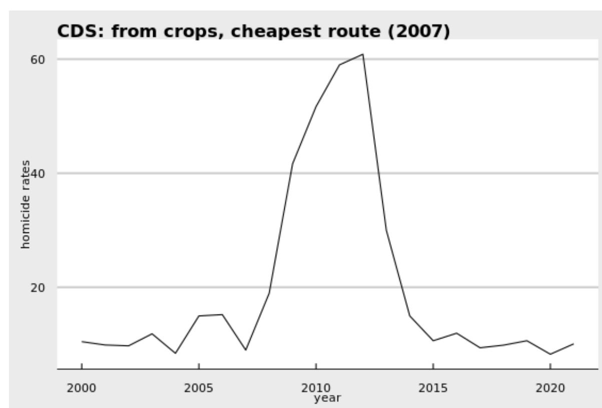
Regarding violence, it is natural to expect conflict to rise in 2010 as the Sinaloa Cartel encountered significant perils transporting heroin across Coahuila and Tamaulipas bordering states in Northeast Mexico. By 2013, the Sinaloa Cartel most likely relinquished control of these corridors, coinciding with the rise of fentanyl as a more lucrative business. Consequently,

[11] In section 3 we provide a description of the cost model. In essence, we create an index based on Signoret et al.'s data on DTO's detected dominance that, in turn, captures the relative weight of each DTO's presence at the state level. Then, we compute the trip cost from any location to the US border for each year and DTO.

(A) Sinaloa Cartel route in 2007

(B) Sinaloa Cartel route in 2010

(C) Sinaloa Cartel route in 2013



(A) Sinaloa Cartel route in 2007

Figure 2. Fastest and cheapest routes from a Sinaloa Cartel-controlled poppy crop area to the US border in 2007. *Note*: This figure shows the cheapest route from the closest poppy production center controlled by the Sinaloa Cartel in 2007 to the US for the period 2007-2013. *Sources*: INEGI (2014), Signoret et al. (2021)

violence significantly dropped in this area. Indeed, Figure 2, Panel D shows homicide rates in municipalities traversed by the Sinaloa Cartel optimal routes in 2007. In these municipalities, there was a single wave of homicides that started in 2007, peaked in 2012, and subsided around 2015.

Fentanyl-treated municipalities: To take advantage of fentanyl shipments arriving on the Pacific Coast, the New Generation Jalisco Cartel had to establish a trafficking route to the US border.[12] Figure 3, Panel A, depicts the 2013 New Generation Jalisco Cartel's optimal route from Lazaro Cardenas Port in the Pacific to the US border. The figure also shows the shortest routes from all poppy production areas to the US border. The New Generation Jalisco Cartel encountered significant resistance when moving northward, as it would have to cross territories controlled by the Sinaloa Cartel and other rival DTOs. Thus, according to our network model, the cartel opted instead to partially circumvent these territories using east-west routes to the Gulf before moving its product north. These routes traversed the central states of Jalisco, Guanajuato, and Hidalgo, barely affected by DTOs disputes or drug-related violence before 2013.[13] Nevertheless, to reach a Northeast crossing point, the New Generation Jalisco Cartel could not entirely avoid using south-north routes, which traversed locations highly contested immediately after the MWD.

To identify those municipalities only affected by fentanyl trafficking but not by the MWD, we isolated the flatter route portions from the New Generation Jalisco Cartel's 2013 optimal route (Figure 3, Panel B).[14] Figure 3, Panel C shows homicide rates in the municipalities traversed by those portions and confirms that these municipalities only experienced a single

[12] According to our relative dominance index based on Signoret et al. (2021), the New Generation Jalisco Cartel was in control of this port in 2013.

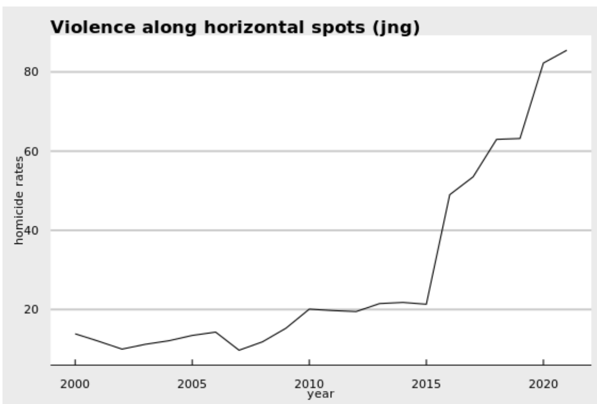
[13] As Osorio (2015) and Castillo et al. (2020) highlight most MWD-related violence is concentrated in the north.

[14] We computed the azimuth of the New Generation Jalisco Cartel's route in Figure 2 and selected those portions of it whose angle with respect to the Equator is no greater than 10 degrees. Section 5 presents alternative specification comprising distinct routes.

wave of violence around 2015.

(A) New Generation Jalisco Cartel routes in 2007

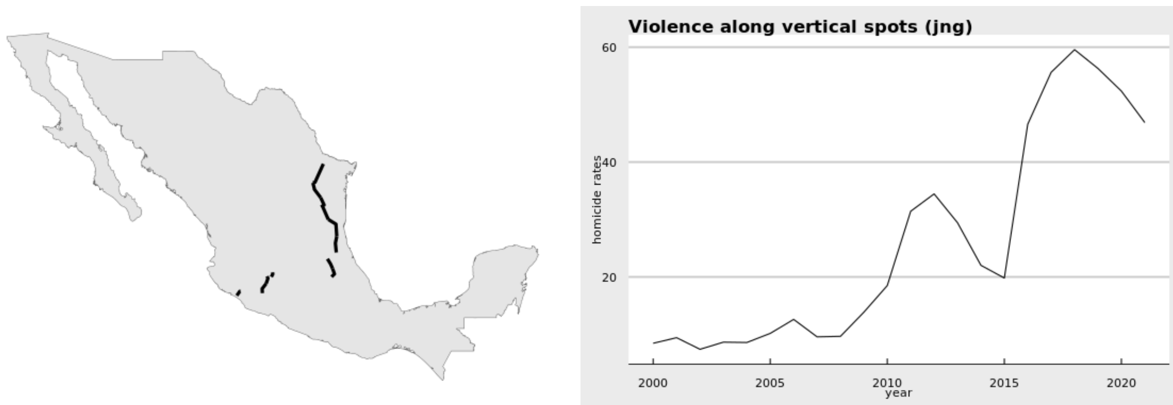
(B) New Generation Jalisco Cartel horizontal segments



(C) Homicide rates in horizontal segments

Figure 3. Fastest and cheapest routes from the 2013 busiest New Generation Jalisco Cartel-controlled international port to the US border (horizontal segments). *Note*: In Panel A, the orange line represents the cheapest route from the busiest New Generation Jalisco Cartel-controlled port to the US border in 2013. The route was computed using Dijkstra's algorithm, where the edge costs come from our travel cost index. See section 4 and Appendix for details. Panel B, shows the most horizontal segments along panel A's orange route (those exhibiting an angle with respect to the Equator no greater than 10 degrees). Panel C shows the homicide rates in the municipalities traversed by panel B's segments. *Sources*: INEGI (2014), Signoret et al. (2021), INEGI (2016)

Doubly treated municipalities: Figure 4, Panel A, depicts the southern-to-northern sections of the New Generation Jalisco Cartel's 2013 optimal route from the Pacific to the US border. Figure 4 Panel B shows the corresponding homicide rates. Contrasting the maps in Figures 3 and 4 reveals that the vertical segments of the route closely align with the shortest routes from poppy cultivation, which helps explain the two-peaked pattern in homicide rates seen in Figure 4, Panel B. In other words, the proximity and overlap of the vertical segments with poppy routes suggest these municipalities were affected by both shocks, the MWD, and becoming part of the New Generation Jalisco Cartel's fentanyl route.

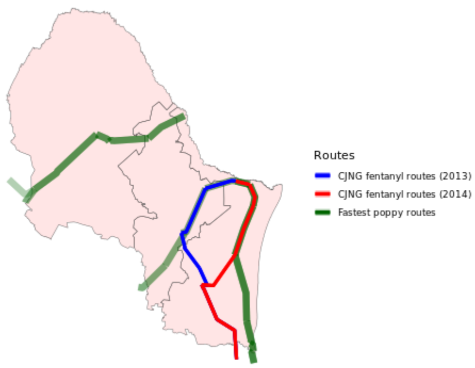


(A) New Generation Jalisco Cartel routes in 2007 (B) New Generation Jalisco Cartel horizontal segments

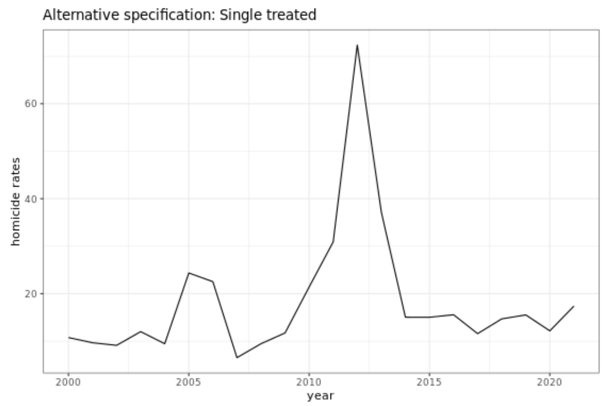
Figure 4. Fastest and cheapest routes from the 2013 busiest New Generation Jalisco Cartel-controlled international port to the US border (vertical segments). *Note*: Panel A shows the most horizontal segments (those exhibiting an angle with respect to the Equator no greater than 10 degrees). Panel C shows the homicide rates in the municipalities traversed by panel B's segments *Sources*: INEGI (2014), Signoret et al. (2021), INEGI (2016)

Evidence from Northeast Mexico: A similar pattern in the spatial distribution of violence can be observed if we focus on Northeastern Mexico, specifically in the states of Coahuila, Nuevo Leon, and Tamaulipas. Figure 5, Panel A, shows the shortest poppy-related routes to the US (marked in green) and the optimal routes for the New Generation Jalisco Cartel according to our algorithm (marked in blue for 2013 and red for 2014). Homicide rates across poppy routes further from the New Generation Jalisco Cartel's optimal paths should show only one wave of violence. At the same time, municipalities traversed by routes used for poppy trafficking and by the New Generation Jalisco Cartel should exhibit two waves of violence. Figure 5, Panels B and C, confirm this pattern.

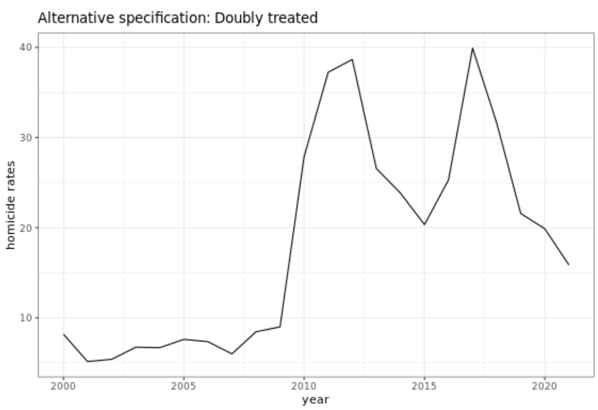
Summing up, we have documented different homicide patterns in municipalities linked to



(A) North Mexico fentanyl and poppy routes



(B) Homicides poppy routes



(C) Homicides along fentanyl routes

Figure 5. Evidence from North Mexico. *Note*: Panel A shows (in blue and red) the segments enclosed in the states of Coahuila, Nuevo Leon, and Tamaulipas of the 2013 and 2014 New Generation Jalisco Cartel's routes departing from the busiest international port to the US border. The green lines represent the fastest routes connecting poppy-related routes to the US border. Panel B shows homicide rates related to the poppy routes in the easternmost part of the map. Panel C shows homicide rates related to the fentanyl routes in Panel A *Sources*: INEGI (2014), Signoret et al. (2021), INEGI (2016)

roads connecting poppy cultivation areas to the US border and municipalities linked to the new routes employed by the New Generation Jalisco Cartel to carry their fentanyl trafficking. Municipalities solely affected by the poppy trade experienced only one wave of violence associated with the MWD in 2007 (Figure 2). Municipalities only affected by the New Generation Jalisco Cartel fentanyl trade also experienced one wave of violence, but in this case, after 2013 (Figure 3). Finally, municipalities affected by both shocks had two waves of violence, one before and another after 2013 (Figure 4). The findings suggest categorizing our sample into these three groups to perform counterfactual comparisons to establish a causal link between the opioid crisis in the US and violence in Mexico.

3. Data and variables

We have collected data on 2,455 Mexican municipalities from 2000 to 2019. The data excludes the years from 2020 onward to avoid contaminating our estimations with the COVID-19 pandemic. Our data set comprises information on violence and socioeconomic factors for each municipality. We have also considered various time-invariant characteristics that reflect the location of alternative sources of violence diffusion.[15] This section describes our primary variables and their corresponding data sources. For a more detailed summary, please refer to Tables B1 and B2 in the Appendix, where we have listed all data sources and provided summary statistics for all variables.[16]

Violence: We use the homicide rate (homicides per 100,000 inhabitants) to measure municipal violence. This information comes from the National Institute of Geography and Statistics (INEGI), covering 1990 to 2019. The data also record the occupation of each homicide victim and the weapon involved. Additionally, the data provide information on the number of

[15]We consider the location of the hydrocarbon pipeline network and an index of local suitability for drug production as presented by López Cruz and Torrens (2023).

[16]For a visualization of the spatial variables appearing below, see Figure A.2 in the Appendix.

military personnel abated by firearms or other weapons, a proxy for clashes between the army and criminal organizations (López Cruz and Torrens, 2023).[17]

Municipalities and highways: The cartographic data corresponding to the Mexican municipalities' polygons and the road network lines come from INEGI (2015, 2014).

DTO's presence and travel cost: We take the Mexican Highways model directly from INEGI (2014). Given the magnitude of the data, we pre-process it as follows. We extracted the network's largest component and eliminated double edges and pseudo-nodes. Finally, we collapsed roundabouts.[18]

To construct DTOs' optimal routes, we employed Signoret et al.'s (2021) presence index, which measures DTOs' presence in Mexican states based on municipality-month data assembled through machine-aided data collection and hand-coding procedures. The index incorporates distinct measures of DTO's territorial dominance. Using this index, we proceed as follows as follows. Let $ind_{d,s,t}$ be DTO d's presence in state s at time t. For DTO d, we define a measure of all other groups' presence in state s at time t as $ind_{-d,s,t} = \sum_{k \neq d} ind_{k,s,t}$. Next, we define d's travel cost associated with state s as $c_{d,s,t} = ind_{-d,s,t} - ind_{d,s,t}$. Finally, we assign the preceding travel cost to all municipalities within state s. This gives us the traveling cost structure for the pair (d, t) for any two locations on the Mexican map. Importantly, we say that DTO d dominates municipality m if $c_{d,s,t} \leq 0$.

To obtain the best route from points i and j along the Mexican Road Network in year t, we first identify the municipalities hosting these points and what DTO dominates the departure point i. Then, we compute the entire cost structure for the dominant DTO and use it to

[17]Our homicide data come from INEGI's annually updated Mortality Dataset. The data is derived from death certificates held by Civil Registry Offices, Public Prosecution Agencies, and Forensic Medical Services and is classified according to the World Health Organization's CIE-10 classification. We also identify victims who were part of the Mexican Armed Forces through their association with the Armed Forces Health Services.

[18]In particular, we clustered the nodes with the DBSCAN spatial clustering algorithm such that nodes within a distance of 15 meters from each other are grouped together.

weigh all the segments in the Mexican Road Network according to the municipalities they cross.[19] Next, we use Dijikstra's algorithm to retrieve the dominant DTO best route from i to j. Since we are mainly interested in uncovering the optimal paths to the US border, we take the set of US border crossings as endpoints. Finally, we apply the Lin-Kernighan heuristic to determine which crossing is optimal for DTO d.

Poppy cultivation: Our data on poppy cultivation regions come from Resa (2016), who provides information on the number of destroyed poppy plantation hectares for Mexican municipalities from 2007 to 2015. To create a proxy for the poppy production index at the municipality level, we select the maximum value of this variable. Given the substantial variation in municipality sizes, we apply a grid of 50-kilometer cells to convert the poppy production values into a raster format. Subsequently, we chose the cell centroids with values falling within the top 25% of the distribution.

Entry ports for fentanyl-related ingredients: Existing evidence strongly indicates that most fentanyl precursors entering Mexico originate from Asia and arrive through Pacific Coast ports. To identify the specific ports involved in the trafficking of fentanyl precursors, we rely on Gonzalez's (2020) route map based on drug confiscation data. Gonzalez's work highlights the relevance of seven ports as key entry points for these illicit substances. We categorized these ports into three distinct groups. The first group comprises ports open to international trade and ranking within the top 5 nationally regarding commercial traffic, as Juárez (2021) reported. The second group consists of ports open to international trade but do not fall within the top 5 nationally. Lastly, the third group includes ports confined to domestic trade. The differentiation between ports oriented toward domestic or international trade is based on information from the Mexico City National Chamber of Commerce (2023).

US-Mexico border crossings: Data on US-Mexico border crossings come from the US

[19]More precisely, for any segment associated with cost $c_{d,s,t}$, we assign a weight of $c_{d,s,t} * \ell$, where ℓ is the segment's length

Department of Transportation (2023), which provides truck traffic figures. We focus on locations that ranked within the top 15% of the truck traffic distribution to identify the most significant crossing points.

Socioeconomic controls: To control for municipal socioeconomic development, we use administrative data available at that level: female deaths per capita due to pregnancy, divorce, marriage, and birth rates. Data come from INEGI (2016).

4. Empirical Strategy

This section explains our identification strategy for the effect of fentanyl on violence in Mexico. The MWD distorted DTOs' relative strength across locations (Dell, 2015; Osorio, 2015), detonating turf wars over drug-valuable spots, among which the poppy-related routes stood out. The resulting violence began subsiding everywhere around 2010-2011, a few years before the outbreak of the synthetic opioid epidemics.[20]

Our first counterfactual contrast compares municipalities treated by both shocks versus municipalities only treated by the MWD. Our key identifying assumption is that what occurred in municipalities traversed by Sinaloa Cartel's poppy-related optimal routes in 2007 (MWD-treated units) constitutes a suitable counterfactual scenario for homicide trajectories from municipalities traversed by the New Generation Jalisco Cartel's fentanyl route also employed for poppy-related trafficking (the doubly treated units). Our second counterfactual contrast compares MWD-treated municipalities versus fentanyl-treated ones. In particular, we consider two treatment exposures occurring on different dates, namely 2007 and 2013. Our key identifying assumption is that the after-2007 homicide rate trajectories would have been similar everywhere had there not been a fentanyl treatment in 2013.

[20]One could hypothesize that such a decrease in violence owed to the territorial consolidation of emerging cartels in the northern Mexican states, in particular Los Zetas (Correa-Cabrera, 2017).

4.1 Difference in differences for the MWD-vs-doubly contrast

We estimate the fentanyl effect on violence through the following two-way fixed effects regression model:

$$Hom\ rate_{m,t} = \alpha_t + \gamma_m + \beta' Sec_{m,t} + \delta FENT_{m,t} + u_{m,t} \tag{1}$$

The outcome variable $Hom\ rate_{m,t}$ is the homicide rate (homicides per 100,000 inhabitants) for municipality m in year t. The model includes year and geographic fixed effects denoted by α_t and γ_m, respectively. Socioeconomic covariates are all grouped in $SEC_{m,t}$. The variable $FENT_{m,t}$ is the treatment status indicator, which equates to 1 when municipality m is being treated in year t. More precisely, $FENT_{m,t} = 0$ if in year t municipality m is traversed by North-South segments (also valuable for transporting poppy to the US) along the New Generation Jalisco Cartel's optimal fentanyl routes in 2013. Finally, $u_{m,t}$ is an error term.

The coefficient of interest is δ, which captures the change in the average homicide rate due to a municipality being traversed by North-South segments along the New Generation Jalisco Cartel's fentanyl routes (and, therefore, also valuable for poppy transportation), taking municipalities along the Sinaloa Cartel's poppy-related routes in 2007 as the control group. We interpret δ as the causal effect of fentanyl trafficking on violence.

We consider several variations of model (1) to evaluate competing hypotheses. First, we include the lagged value of a measure of government-induced violence to determine if pre-existing interventions take away explanatory power from the fentanyl treatment. Additionally, we test the possibility that the violent competition over the hydrocarbon pipelines traversing Central Mexico (López Cruz and Torrens, 2023) could spill over into municipalities along the

New Generation Jalisco Cartel's routes.[21] Finally, we test if fentanyl caused violence or if it was due to the New Generation Jalisco Cartel's routes' proximity to drug production sites.[22]

4.2 Difference in differences for the MWD-vs-FENT contrast

We employ a different estimation approach to analyze the impact of the MWD in 2007 and the fentanyl demand shock in 2013 on municipalities exclusively affected by one of these events. The conventional two-way fixed effect procedure is problematic since these exposures occurred on different dates (Goodman-Bacon 2021). Instead, we adopt Wooldridge's (2021) extended two-way fixed effects approach, which allows us to estimate the effects of interventions that occur at different times for distinct units. Wooldridge's (2021) method relies on the equivalence between two-way fixed effects regressions under staggered adoptions and a pooled OLS specification with time-varying treatment effects and cohort fixed effects instead of their unit-specific counterparts. In particular, we estimate the following model:

$$Hom\ rate_{m,t} = \sum_{z=1}^{T} \mu_z FT_{m,z} + \gamma_t + \sum_{z=1}^{T} \tau_{z,t} FT_{m,z} \iota[t \geq z] + \beta' Sec_{m,t} + u_{m,t} \tag{2}$$

In model (2) $FT_{m,z}$ indicates whether municipality m first turned treated at period z. In other words, $FT_{m,z} = 1$ if m belongs to the cohort that first became treated at time z. $\iota(\cdot)$ is a regular indicator function, μ_z is a fixed effect for cohort z, and $\tau_{z,t}$ measures the treatment effect at time t for municipalities in cohort z. [23] Time fixed effects and socioeconomic covariates are still represented by γ_t and $SEC_{m,t}$, respectively. Finally, T stands for the last

[21]We take the exact location of the hydrocarbon pipelines from López Cruz and Torrens (2023).

[22]We employ the municipal drug production suitability index as presented in Osorio (2015).

[23]For example, $\tau_{2015,2013}$ is the treatment effect in 2015 for municipalities that received the fentanyl treatment from 2013 onward, while $\tau_{2009,2007}$ is the treatment effect for municipalities that received the MWD treatment from 2007 onward. Given these measures, we report in our tables the average treatment effects by cohort

period in the sample.

The control group underlying model (2) consists of not-yet-treated and never-treated units, where the latter group comprises all the southernmost Mexican states' municipalities (i.e., those in Chiapas, Campeche, and Yucatán) whose violence levels remained low and stable throughout the sample period (Figure A.3). The coefficients of interest are the cohort treatment effects $\tau_{z,t}$ which measure annual homicide rates variations due to a municipality's belonging to cohort z.

Two assumptions make it possible to identify the separate effects of the MWD and fentanyl on violence. First, there should not be differential trends in pre-treatment homicide rates between treated and untreated municipalities after conditioning on covariates. Second, there should not be anticipatory effects. The fact that the fentanyl outbreak is independent of the MWD mitigates our concerns about anticipatory effects. In other words, we see no reason to believe that DTOs acting in not-yet-treated municipalities were expecting an imminent violence outbreak around 2013 in their areas of influence.

4.3 Event study regression

To enhance a Difference-in-Differences approach's credibility, a common procedure consists of estimating an event-study regression, which in our case boils down to:

$$Hom\ rate_{m,t} = \sum_{s \neq\ 2013} \delta_s \times\ 1_{t=s} \times\ FENT_m + \alpha_t + \gamma_m + u_{m,t} \tag{3}$$

In model (3), the δ coefficients, indicated by time subscript s, capture the time-varying effects of fentanyl on homicide rates. Figure 5, Panel A, presents these estimates and their corresponding 95 percent confidence intervals, with the reference year set as 2012.

It is reassuring to observe that these estimates hover around zero before the onset of the treatment but become statistically significant shortly after the emergence of the opioid epidemic. Additionally, Table 1 provides the p-value for the Wald statistic related to the pre-treatment period. Consistent with our identification strategy, we find no grounds to reject the null hypothesis of no effect prior to 2013. Further validation tests are presented in Section 6.

5. Results

This section presents the results. First, we estimate the fentanyl effect on violence after the MWD using model (1). Second, we estimate the effects of MWD and fentanyl separately, using model (2). Finally, we explore if the fentanyl effect remains detectable under alternative econometric specifications and/or sample sets.

5.1 Difference-in-differences for the doubly-vs-MWD contrast

Table 1, columns 1 to 6, shows the estimations of model (1). The first column presents the estimates without covariates. Column 2 incorporates socioeconomic covariates. Column 3 also includes three additional control variables representing competing explanations. First, to account for past government-related factors contributing to conflict, we incorporate the lagged number of military personnel killed by firearms as a proxy for military interventions. Second, to account for potential overlaps between the New Generation Jalisco Cartel's fentanyl routes and drug production centers, we include municipal suitability for municipal drug production. Third, we incorporate a variable identifying observations on the Mexican hydrocarbon pipeline network to account for hydrocarbon-related conflicts. For columns 1 to 3, we report municipality-robust standard errors. Column 4 employs Conley's (1999) standard errors to address spatial correlation.

The fentanyl effect on homicide rates is statistically significant and large. It accounts for an average increase of roughly 20 homicides per 100,000 inhabitants. Moreover, adding socioeconomic covariates, control variables for the three competing explanations, or switching to Conley (1999) standard errors barely affects the estimations.

Table 1, columns 5 and 6 report placebo regressions, excluding and including socioeconomic covariates, respectively. Specifically, these regressions restrict the sample to pre-2013 observations and assign a placebo fentanyl treatment status to the genuinely fentanyl-treated municipalities from 2007 onward. Results from columns 5 and 6 show no significance.

Table 1: Effect of fentanyl on homicide rates (DID model)

	Doubly-vs-MWD contrast				Placebo dates		MWD-vs-FENT contrast
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FENT (b.line)	20.258***	19.281***	21.858***	21.858**	0.842	-1.515	
	(5.818)	(6.205)	(7.801)	(9.834)	(6.958)	(5.594)	
FENT (b.line) x drug			14.678	14.678			
			(15.745)	(13.014)			
FENT (b.line) x hpn			-8.050	-8.050			
			(8.740)	(11.587)			
l(gov. vio, 1)			0.518	0.518			
			(0.887)	(0.866)			
Cohort = 2007							10.492***
							(1.905)
Cohort = 2013							15.656***
							(4.354)
Num.Obs.	1360	1360	1292	1292	884	884	5460
R2	0.261	0.269	0.275	0.275	0.239	0.250	0.292
FE: idmun	X	X	X	X	X	X	
FE: year	X	X	X	X	X	X	
FE..first.treat							X
FE..year							X
wald pre-tr.	0.19	.	.	.	.	.	.
SE. type	by: idmun	by: idmun	by:idmun	Conley	by:idmun	by:idmun	Conley
Coefficients	NO	YES	YES	YES	NO	YES	YES

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: This table presents the estimation results of model (1) in columns 1-6 and of model (2) in column 7, with the dependent variable being the homicide rate per 100,000 inhabitants. Each column displays the estimates concerned with separate regressions of the dependent variable on a set of distinct independent variables. The table shows the inclusion of fixed effects, socioeconomic controls, and the employment of distinct standard errors. When we do not use Conley (1999) standard errors, we use robust standard errors clustered at the level indicated in the table. The socioeconomic controls are females' deaths per capita from any cause linked to or aggravated by pregnancy or its handling, marriage rates, and divorce rates. The Wald statistic at the bottom of the table refers to the pre-2013 coefficients from our event-study regression. Significance values: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

5.2 Difference-in-differences for the MWD-vs-FENT contrast

The estimations in Table 1, columns 1 to 6, refer to the doubly-vs-MWD contrast. Table 1, column 7, on the other hand, shows the estimations of model (2), corresponding to the MWD-vs-FENT contrast. In other words, following Wooldridge (2021), we include cohort-time interactions to deal with staggered designs. In this way, we estimate the effect stemming from the 2007 MWD treatment separately from the fentanyl treatment from 2013 onward. The results indicate that while the MWD caused 10 additional homicides per 100,000 inhabitants, fentanyl produced 15 additional homicides per 100,000 inhabitants.[24]

It is worth noticing that the doubly-vs-MWD contrast examines the fentanyl effect in territories previously affected by the 2007 MWD shock. Thus, such a contrast cannot pin down the fentanyl effect net of a potential interaction. On the other hand, the MWD-vs-FENT contrast inspects the fentanyl effect in territories where the 2007 MWD shock is absent, thereby yielding estimates net of interactions. Comparing the results in table 1, columns 1-6, and those in column 7, we observe that the effect of fentanyl estimated from model (1) exceeds the effect of fentanyl estimated from model (2) by 5 additional homicides per 100,000 inhabitants, which suggests the possibility of a positive interaction between the MWD and the opioid crisis.

5.3 Alternative specifications and sample sets

The estimations in Table 1 consider the top 5 busiest international ports on the Mexican Pacific Coast controlled by the New Generation Jalisco Cartel in 2013. Table 2, columns 1 and 2, shows the result of re-estimating models (1) and (2) using all Mexican Pacific Coast ports opened to international traffic. Although the estimated effects of fentanyl are lower than in table 1, we still observe a sizeable and significant impact.

[24] Interestingly, the effect of the MWD 2007 shock coincides with that calculated by Lopez Cruz and Torrens (2023), using a quite different specification.

In addition to considering all international ports, we redefine the MWD-treated group by also including all poppy production locations as potential departure points for routes that the advent of fentanyl most likely made less relevant. This expanded sample represents a diluted version of the MWD-treated group, as many poppy production areas are in the south, resulting in transportation networks that closely align with the 2013 New Generation Jalisco Cartel optimal routes. In other words, this diluted version of the MWD-treated group contains municipalities also affected by fentanyl trafficking. Table 2, columns 3 and 4, present the estimations. All the contrasts produce sizeable and significant results.

Finally, columns 5 and 6 in table 2 present the estimations of model (1) for an extremely reduced sample composed of only three North-East bordering Mexican states: Tamaulipas, Nuevo Leon, and Coahuila (the setting depicted in Figure 5). This exercise aims to zoom into a small region containing the New Generation Jalisco Cartel's routes and allegedly obsolete poppy routes and check if, even in this restricted area, we could detect the effect of fentanyl on local homicide rates. Although the sample size reduction increases the standard errors beyond standard limits, we still capture a positive and large effect of fentanyl on homicide rates.

Tables 1 and 2 provide empirical support to our argument that the opioid crisis was a significant source of violence comparable if not surpassing that of the 2007 MWD.

Table 2: Effect of fentanyl on homicide rates (alternative specifications)

	All international ports		All poppy crops		North Mexico	
	(1)	(2)	(3)	(4)	(5)	(6)
FENT (int.)	14.994**					
	(5.861)					
Cohort = 2007		10.274***		11.073***		
		(2.139)		(2.052)		
Cohort = 2013		13.917***		11.488***		
		(2.274)		(2.090)		
FENT (int. & pop.)			15.781***			
			(5.867)			
FENT (north)					9.630	10.498
					(11.491)	(11.999)
Num.Obs.	7100	11360	8020	12320	814	814
R2	0.198	0.076	0.216	0.074	0.197	0.202
FE: idmun	X		X		X	X
FE: year	X		X		X	X
FE..first.treat		X		X		
FE..year		X		X		
SE. type	Conley	Conley	Conley	Conley	Conley	Conley
Coefficients	YES	YES	YES	YES	NO	YES

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: This table presents the estimation results of model (2) in columns 2 and 4, and the estimation results of model (1) elsewhere, with the dependent variable being the homicide rate per 100,000 inhabitants. Each column displays the estimates concerned with separate regressions of the dependent variable on a set of distinct independent variables. The table shows the inclusion of fixed effects, socioeconomic controls, and the employment of distinct standard errors. When we do not use Conley (1999) standard errors, we use robust standard errors clustered at the level indicated in the table. The socioeconomic controls are females' deaths per capita from any cause linked to or aggravated by pregnancy or its handling, marriage rates, and divorce rates. Significance values: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

6. Robustness Checks

This section presents additional validation tests. First, we conduct a randomized spatial placebo test on the New Generation Jalisco Cartel's routes. Second, we resort to Rambachan and Roth's (2022) sensitivity test to reinforce the parallel trends assumption's veracity in our setting. Third, we explore alternative areas prone to suffer the fentanyl effect on violence.

6.1 Spatially randomized placebo test

A key element in our explanation is that the New Generation Jalisco Cartel's routes are significant sources of conflict and violence. A potential concern is that the observed association between the transportation network location and increased violence might be due to random chance. To address such a concern, we performed a spatial placebo test following the approach outlined in Benshaul-Tolonen (2019), Depetris-Chauvin and Özak (2020), Guimbeau et al. (2021), and López Cruz and Torrens (2023). First, in one thousand iterations, we randomly assigned the fentanyl treatment status to units within a 50 km buffer around the New Generation Jalisco Cartel's routes. Second, we re-estimated our differences-in-differences regressions as specified in equations (1) and (2) and recorded the estimated coefficient of interest and its p-value each time. Third, we plotted the corresponding distributions.

Figure 6, panels B and C, presents the outcome of the analysis. The dashed lines represent the empirical 95% confidence intervals. As observed, coefficients do not significantly deviate from zero, suggesting that our models are not fundamentally misspecified. These results strengthen the notion that the fentanyl treatment status is a genuine source of violence.

6.2 Parallel trends

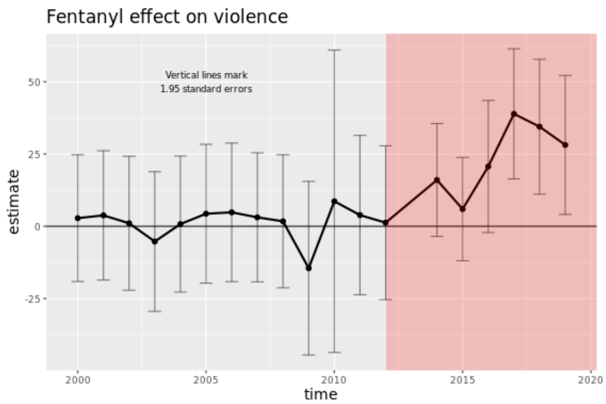
The parallel trends assumption lies at the core of our difference-in-differences approach. To reinforce the credibility of this assumption, we use Rambachan and Roth's (2022) sensitivity test based on smoothness restrictions. Briefly, the method extrapolates distorted (non-linear) versions of the estimated linear trend emerging from the pre-treatment data to the subsequent years. In other words, we allow the treatment versus control difference in trends to evolve with growing deviations. Then, the method reports the degree of disturbances until the treatment effects cease to be significant. Rambachan and Roth (2022) argue that their method is more transparent than the usual technique that adds treatment-group-specific linear trends to the regression equations to test for violations of parallel trends. This is so because adding smoothness restrictions goes beyond simply extrapolating the pre-treatment linear trend, and, additionally, it pins down the resistance threshold for the treatment effect's significance.

Figure 6, panel D, presents the results of Rambachan and Roth's (2022) sensitivity test. M in panel D indicates the upper limit on how much the slope of the difference in trends can change from one period to the next. The critical threshold for a significant effect occurs when M is around 0.5, implying that we can discard a null effect unless we accept that the linear extrapolation between consecutive periods could deviate by more than 0.5 percentage points. Thus, we consider the results in Figure 7 reassuring.

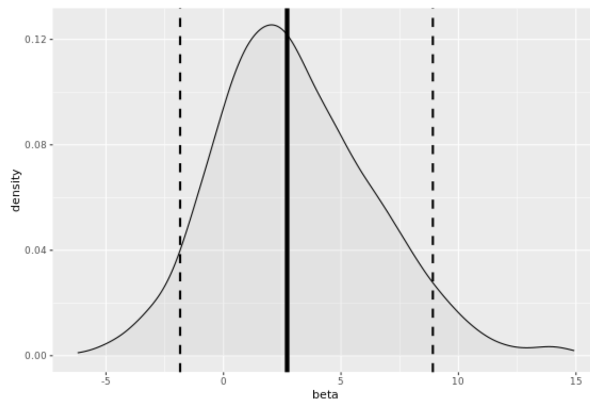
6.3 Further validations

This section considers two additional validation tests. First, we look for evidence of increased violence related to the opioid crisis that cannot be attributed to the New Generation Jalisco Cartel's trafficking routes. Second, we check if ports controlled by the New Generation Jalisco Cartel but closed to international flows initiate US-headed routes that generate violence similar to those routes with initial points at ports open to international flows.

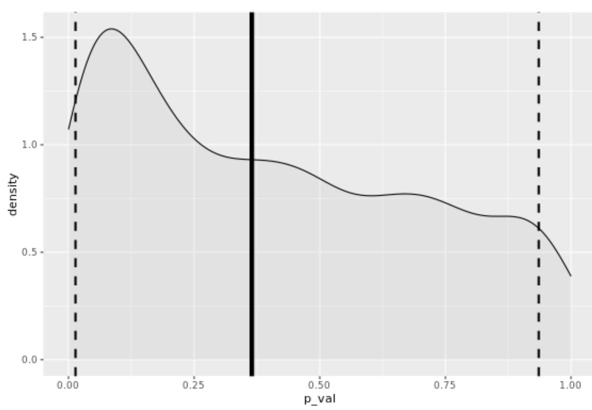
Sinaloa-related fentanyl effect: From Gonzalez's (2020) work, it follows that a few ports on the Pacific Coast inside Sinaloa Cartel-controlled territories, regularly receive fentanyl shipments. Thus, in principle, by replicating the same methodology we applied for the



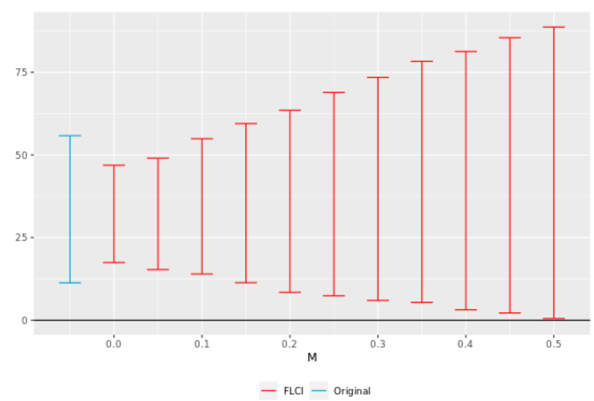
(A) Event Study Regression



(B) Spatial placebo test: fentanyl effect coefficients



(C) Spatial placebo test: fentanyl effect p-values



(D) Honest DID technique

Figure 6. Validation tests. *Note*: Panel A shows the coefficient values from our event study regression. Panel B shows the output of Rambachan and Roth's (2022) smoothness restrictions procedure that allows the pre-2013 treatment versus control difference in trends to evolve with growing deviations. The confidence intervals are set at a 95 percent confidence level. Panel C displays our spatial placebo effect's estimate of fentanyl on violence from one thousand regressions. The vertical lines represent the 95 percent empirical interval. Panel D shows the p-values distribution from Panel C's test. *Sources*: (2022), INEGI (2014), INEGI (2016), Signoret et al. (2021)

New Generation Jalisco Cartel, we should obtain evidence of violence upticks caused by fentanyl trafficking. Indeed, Table A.1, columns 1 and 2, in the Appendix shows the results of re-estimating model (1), this time taking the 2013 Sinaloa Cartel-controlled international ports and the municipalities traversed by the associated cheapest routes to the US as treated units. The control group continues to be Sinaloa Cartel's poppy-related routes used in Table 1's estimations. As can be observed in Table A.1, columns 1 and 2, the estimated effect of fentanyl is 20 additional homicides per 100,000 inhabitants. Moreover, when we add a treatment status variable for the hydrocarbon network, the fentanyl effect remains large and significant. These results reinforce the idea that fentanyl was the key force driving the second wave of violence nationwide.[25]

Fentanyl effects through domestic ports: Table A.1, columns 3 and 4, display the results of estimating model (1) but confining the New Generation Jalisco Cartel's fentanyl-exposed ports to those on the Pacific Coast limited to domestic transactions (González 2020). The expectation is to find lower effects than those reported in table 1. This is so because, as section 3 explains, all the fentanyl precursors enter Mexico from abroad and, thus, are more likely to reach the Pacific Coast via ports open to international flows. Table A.1 shows mixed results. On the one hand, column 3 suggests a fentanyl effect as sizable as before. However, column 4 reveals that such an effect vanishes when we incorporate the hydrocarbon theft competing hypothesis. Overall, we read these results as suggestive evidence that being open to international trade is a prerequisite that ports must fulfill to generate fentanyl-affected routes.

[25] In this exercise, we could not include a treatment status variable comprising the local drug-production centers because the entire set of on-route municipalities are also drug-valuable. Similarly, due to a lack of horizontal segments in the corresponding networks, we could not re-estimate model (2).

7. Conclusions

The paper has established a link between the fentanyl opioid crisis in the US and a second wave of drug-related violence in Mexico. We have argued that trafficking fentanyl to the US was a substantial business opportunity for some Mexican DTOs who reorganized their trafficking routes to seize it. These developments led to new clashes and violence in municipalities traversed by these new fentanyl routes, often bringing violence to locations that have not been affected by the MWD or triggering a new wave of violence in areas where the MWD's violence wave was fading. Moreover, the violence caused by fentanyl was large enough to significantly raise homicide rates nationwide, reversing the declining trend after the Mexican War on Drugs high point around 2011.

The findings in this paper suggest important implications for understanding violence dynamics associated with organized crime. First, sizeable shocks to organized crime (either government clampdowns such us the MWD or demand shocks such as fentanyl) triggered changes in the logistic networks, clashes among criminal organizations, and violence until the contestants settled their disputes. From this perspective, the MWD and the emergence of fentanyl look very similar. Regardless of the reason propelling criminal organizations into reoptimizing their logistic networks, a burst of clashes and violence ensues. Therefore, curbing violence requires limiting the contestants' incentives to reoptimize or punish organizations challenging their rivals' territories and logistics. In the case of Mexico, this might explain why the PRI regime successfully controlled drug trafficking-related violence.

Second, different shocks to organized crime affect criminal organizations' logistic networks in different geographic points. For example, most initial clashes and violence associated with the MWD occurred in Northern Mexico. From this perspective, the MWD and the emergence of fentanyl produced a very different spatial distribution of violence. Indeed, many municipalities traversed by the new fentanyl routes did not experience any severe rise in violence immediately after the MWD. In other words, overall, a similar violence dynamic nationwide between the MWD and fentanyl hides very dissimilar regional patterns.

Third, our findings also suggest the possibility of an interaction effect between MWD and fentanyl as the doubly treated versus MWD treated contrast produces a higher estimation of the effect of fentanyl on homicides than the MWD versus FENT contrast. If this is indeed the case, it would be interesting to identify the exact mechanism through which municipalities that experienced the first wave of violence are more prone to generate violence when exposed to the fentanyl shock.

Finally, the spatial and temporal differences in exposure to organized crime-related violence might be useful to investigate the long run effects of this form of violence on socioeconomic variables, such as educational attainment, labor market outcomes, and domestic violence.

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Appendix

A. Additional Figures and Tables

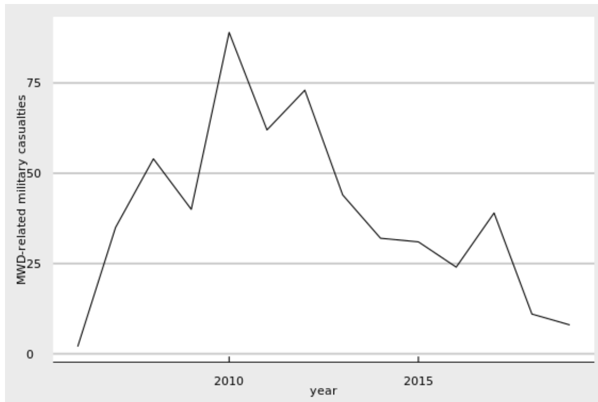
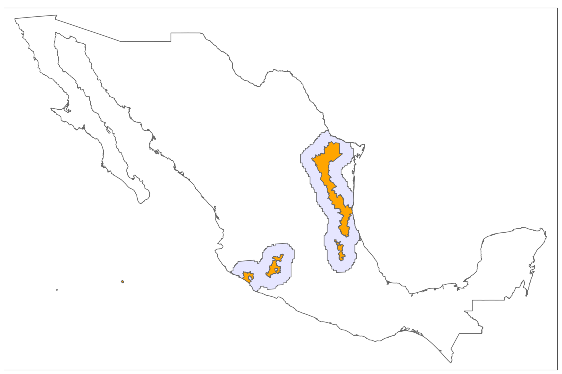


Figure A.1. Military casualties in anti-drug trafficking operations, 2006-2019. *Note*: This figure plots the number of military casualties in Mexico in the context of oparations against drug trafficking activities as reported by the Drug Policy Program at the Center for Research and Teaching in Economics (CIDE). *Sources*: CIDE (2020)

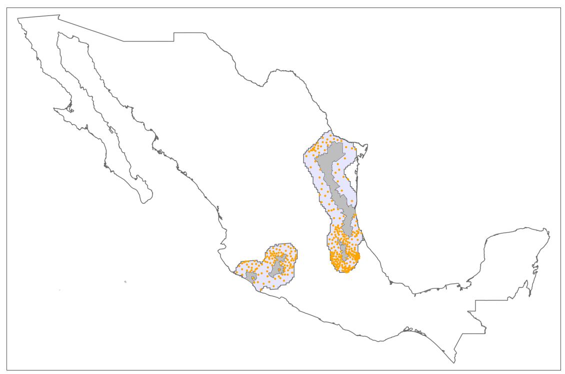
(A) US-Mexico crossings

(B) Locations with poppy crops

(C) Fentanyl-receiving ports on the Pacific Coast



(D) 50-km Buffer around treated municipalities



(E) Placebo treatment candidates (municipalities centroids).

Figure A2. Regions of interest. *Note*: *Panel A*. The dots on the map represent the location of the US-Mexico crossings in the top 15 per cent of all crossings according to truck traffic. *Panel B*. This map shows the cells' centroids of a raster covering municipalities with detected poppy crops (see Section C). T*Panel C*. The map reflects the location of all the Mexican ports receiving fentanyl according to XX. *Panel D*. The map depicts a 50-km buffer around the municipalities along the 2013 CJNG route. *Panel E* The map displays the centroids of those municipalities enclosed within panel D's buffer. extitSources: INEGI (2014), BTS (2023), Resa (2016), González (2020)

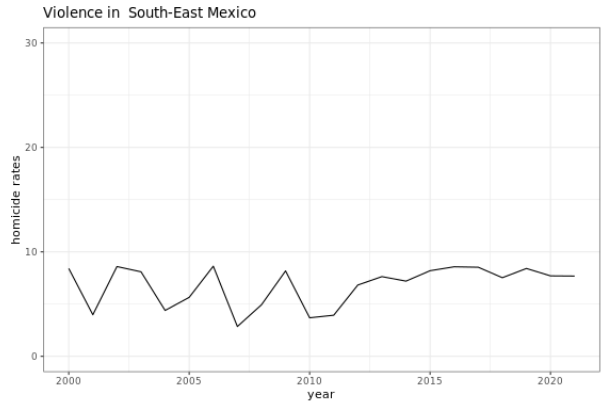


Figure A.3. Violence in south Mexico, 2006-2019. *Note*: This figure plots the the homicide rates conerning the three southrenmost Mexican states: Chiapas, Yucatán and Campeche. *Sources*: INEGI (2016)

Table A.1: Effect of fentanyl on homicide rates (Robustness)

	(1)	(2)	(3)	(4)
FENT	19.965**	15.416***	20.970*	6.714
	(8.612)	(5.720)	(11.236)	(4.858)
FENT (b.line) x hpn		7.011		19.003*
		(9.943)		(11.507)
Num.Obs.	580	580	780	780
R2	0.349	0.349	0.416	0.423
FE: idmun	X	X	X	X
FE: year	X	X	X	X
SE. type	Conley	Conley	Conley	Conley
Coefficients	YES	YES	YES	YES

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: This table presents the estimation results of model (1), with the dependent variable being the homicide rate per 100,000 inhabitants. Each column displays the estimates concerned with separate regressions of the dependent variable on a set of distinct independent variables. The table shows the inclusion of fixed effects, socioeconomic controls, and the employment of distinct standard errors. When we do not use Conley (1999) standard errors, we use robust standard errors clustered at the level indicated in the table. The socioeconomic controls are females' deaths per capita from any cause linked to or aggravated by pregnancy or its handling, marriage rates, and divorce rates. Significance values: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A.2: Variables, availability, and data sources

Variable	Availability	Linear Interpolation	Source
All homicide variables	2000-2020	No	INEGI (2021)
Population	2000-2020	The values for the 5 years gaps between 95-2020, come from linear interpolations.	INEGI (2023)
Marriage & Divorce Rate	94-13, 15-19	2014	INEGI (2023)
Pregnancy-related death rates	2000-2019	No	INEGI (2021)
Hydrocarbon pipelines indicator	2019	No	López Cruz and Torrens (2023)
Municipal drug production index	2000-2010	No	Osorio (2015)
Mexican highways network	2014	No	INEGI (2014)
DTOS's presence	2007-2015	No	Signoret et al. (2021)
Ports Classification	2021	No	Juárez (2021)
Poppy erradication data	2007-2015	No	Resa (2016)
Fentanyl-importing ports	2017-2019	No	González (2020)

Table A.3: Summary statistics

Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
Homicide rate	41724	187	277	0	29	228	4665
Divorce rate	41724	32	87	0	0	30	4311
Marriage rate	41724	511	494	0	282	665	12683
Pregnancy-related deaths rate	41724	0.62	3.5	0	0	0	354
Total population	41724	49908	140210	82	4875	35709	1886239
Military casualties (fireguns)	41705	0.043	0.86	0	0	0	94