Declining Deadly Demand? The Impact of US Marijuana Liberalization on Violence in Mexico

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Abstract

Marijuana demand in the United States historically provided drug cartels with a thriving export market, fueling marijuana cultivation and violence in Mexico. However, the liberalization of marijuana laws in the US led to an explosion of marijuana production in the US, lowering demand for marijuana imports from Mexico, *ceteris paribus*. Using a sample of over 2,300 rural municipalities from 1996-2018, I compare the impacts of US liberalization on Mexican municipalities more suitable to marijuana cultivation relative to those less suitable. These results show US marijuana laws have led to a large and statistically significant reduction in both marijuana cultivation and gun-related homicides in Mexico as well as an increase in legal agricultural output. Through 2018, US liberalization induced a further decrease in marijuana cultivation of 27 percentage points in a municipality in the top decile of suitability compared to one of average suitability, a further decrease in gun-related homicides of 17 percentage points, and a further increase in legal agricultural output of 7 percentage points. The increase in legal agricultural output provides evidence that these poor rural municipalities look to replace the income lost to marijuana production in the US. By isolating exogenous variation in marijuana cultivation in Mexico, I show a 10% decrease in cultivation decreases gun-related homicides 1-6%. These findings directly tie US drug demand to violence in Mexico.

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1 Introduction

Prior to the liberalization of marijuana laws in the United States, "insatiable" marijuana demand in the US provided Mexican drug cartels with a thriving export market, fueling violence in Mexico.[1] According to the United Nations Office on Drugs and Crime (UNODC), the homicide rate in Mexico in 2018 was over five times the world average. However, the US-Mexico marijuana market has evolved markedly over the past few decades. While marijuana is still illegal in the US at the federal level by the 1970 Controlled Substance Act (CSA), many states have enacted medical marijuana laws (MMLs), starting with California in 1996. As opposed to marijuana decriminalization, MMLs allow for domestic production and distribution of marijuana. These state laws led to an explosion in legal domestic marijuana production in the US, particularly after the federal government began to cede marijuana enforcement to the states (Swanson, 2020). This lowers the demand for US marijuana imports from Mexico,*ceteris paribus*, impacting Mexican traffickers. The illegal US wholesale drug market is their primary market and is a market they "dominate" (Dell, 2015). Further, according to the National Institute on Drug Abuse, marijuana is the most commonly used illicit substance, making marijuana demand central to the study of violence in Mexico. Therefore, I ask how the liberalization of US marijuana laws impacts marijuana cultivation and violence in Mexico.

My empirical strategy combines temporal variation in the adoption of marijuana laws in the US with cross-sectional municipality-level variation in marijuana cultivation suitability in Mexico. The interaction of these variables produces a difference-in-differences (DD) estimator that tests whether marijuana liberalization further impacts municipalities more suitable to marijuana cultivation relative to those less suitable.[2] Since marijuana suitability measures are not available, I follow Dube et al (2015) and use historical marijuana eradication from the Mexican Secretariat of National Defense (SEDENA) as a proxy. The percentage of the US

[1] In 2009, Secretary of State Hillary Rodham Clinton said, "Our insatiable demand for illegal drugs fuels the drug trade."

[2] Other authors use similar empirical strategies. For example, Dube et al (2016) use drug suitability to examine heterogeneity in the impacts of maize price fluctuations on drug production in Mexico. Mejia and Restrepo (2013) create an cocaine suitability index to examine the impacts of cocaine demand on cocaine production and violence in Colombia.

population under a state marijuana law serves as an estimate for the reduction in US marijuana import demand due to marijuana liberalization since liberalization leads to increased legal domestic marijuana production.

The sample consists of annual observations for 2,309 rural Mexican municipalities from 1996 to 2018, which provides a large, fine-grained sample. To control for factors that affect all municipalities, such as macroeconomic shocks, I include year fixed effects. Municipality fixed effects account for time-invariant unobserved heterogeneity between muncipalities. Municipality-level linear trends account for the differential evolution of marijuana enforcement and other factors. Further, I control for the political party of the mayor (*presidente municipal*), population, real corn prices interacted with corn suitability, heroin seizures, cocaine seizures, and poppy eradication. Additional controls include unemployment and primary school incompletion.

The baseline results show that US marijuana laws have led to a large and statistically significant reduction in both marijuana cultivation and gun-related homicides in Mexico. Through 2018, US liberalization induced a further decrease in marijuana cultivation of 27 percentage points in a municipality in the top decile of suitability compared to one of average suitability and a further decrease in gun-related homicides of 17 percentage points. Using the same comparison, I also find a further *increase* in the value of legal agricultural output of 7 percentage points as marijuana producing municipalities look to replace the income lost to marijuana cultivation in the US.

To examine the relationship between illegal marijuana markets and violence in Mexico as well as to demonstrate the mechanism through which US liberalization impacts violence in Mexico, I use a two-stage least squares (2SLS) approach. Mexican marijuana cultivation captures the extent of marijuana markets in Mexico. Using the DD estimator from the baseline regressions, I instrument for Mexican marijuana cultivation to isolate plausibly exogenous variation in cultivation due to US marijuana liberalization in order to determine the causal impact of illegal marijuana markets on gun-related homicides in Mexico. To proxy for marijuana cultivation, I use contemporaneous marijuana eradication from SEDENA.[3] I find a positive and

[3]This approach follows other authors who use drug crop eradication to proxy for cultivation (Dube et al,

statistically significant impact of marijuana cultivation on gun-related homicides, consistent with the hypothesis of cartels fighting over drug rents. The instrumental variable (IV) results suggest that a 10% decrease in cultivation leads to a 1-6% decrease in gun-related homicides.

I also find that the impacts of US liberalization on gun-related homicides and marijuana cultivation are most pronounced in municipalities closest to the border, where drug rents are likely the highest. This finding further bolsters the results on illegal marijuana markets on violence, since both cultivation and violence vary by distance to the border in the same way. Further, I show that the results are not driven solely by violence during the Calderón Administration, who destabilized drug communities with an aggressive military campaign against cartels. Finally, I show my results are robust to alternative measures of homicides, data transformations, and proxies for marijuana suitability and cultivation.

This paper is central to the literature on the drivers of the Mexican drug war, by directly showing how an exogenous change in the US demand for marijuana imports affects marijuana cultivation and violence in Mexico. However, it also contributes to other strands of literature, including the literature on the impact of US marijuana liberalization on crime, which to date has not found that US marijuana liberalization affects homicides in Mexico. However, this research has focused primarily on the impacts on US crime (Dragone et al, 2019; Chu and Townsend , 2019; Hunt et al, 2018; Hughes et al, 2019; Morris et al, 2014). While Gavriola et al (2015) also focus on the impact of marijuana laws on violence in the US, they are the only authors to date that also attempt to examine the effect on violence in Mexico. They found no impact of US marijuana liberalization on violence in Mexican states adjacent to US border states with marijuana laws, but suggest this null result may be due to data quality issues or the use of state rather than municipal data. In contrast, I find the anticipated result by exploiting marijuana suitability for identification, rather than distance. Consequently, this paper is the first to my knowledge to find an impact of US marijuana liberalization on *any* outcome in Mexico.

This paper also contributes to the literature on the cultivation of illegal drugs, which

2016; UNODC, 2020; Mejia and Restrepo, 2013).

examines the role of legal alternatives and enforcement. Dube et al (2016) show that a decrease in maize price leads to an increase in marijuana and opium cultivation and violence, while Dell et al (2019) show that manufacturing job losses in Mexico increased violence and drug activity. Many studies focus on cocaine production in Colombia, where some authors find a positive relationship between plantain prices and coca production (Moreno-Sanchez et al, 2003), while others find no relationship between legal alternatives and coca production (Ibañez and Carlsson, 2010; Ibañez and Martinsson, 2013). Other research focuses on enforcement. For example, coca production and violence increased in Colombia following enforcement efforts in Peru and Bolivia (Agrist and Kugler, 2008; Meija and Restrepo, 2013). Further, Castillo et al (2020) show that supply-side shocks to Mexican cocaine trafficking increase homicides in Mexico. I complement this literature by examining the role of a change in marijuana demand resulting from a change in US enforcement.

Finally, this paper contributes to a broad body of literature on the effects of income and commodity price shocks on violence (see Dube et al, 2016, for a discussion). The literature suggests an increase in income may increase violence through predation over resources (Hirschleifer, 1991; Grossman, 1999; Mitra and Ray, 2014) or decrease it by raising the opportunity cost of fighting (Becker, 1968; Grossman, 1991. Further, the relationship between violence and income may depend on the labor intensity of a sector (Dal Bó and Dal Bó, 2011; Dube and Vargas, 2013), institutional strength (Draca and Machin, 2015; Dell et al, 2019), or whether the commodity is legal or illegal (Chimeli and Soares, 2017). Importantly, recent literature finds a positive relationship between drug rents and violence. For example, Dube et al (2016) suggests that drug rents increase when maize prices decline, as cartels exploit a declining outside option for farmers. Castillo et al (2020) show cocaine trafficking violence increases as drug rents increase due to cocaine supply shocks. This paper contributes to this literature by showing a reduction in US marijuana import demand reduces violence, which is consistent with the idea that the incentives to fight to control and extract drug rents falls with declining rents.

The following section reviews the relevant backgrounds of the Mexican drug war and the

US marijuana market. Section 3 covers the conceptual framework. Sections 4 and 5 discuss the data and methods. Section 6 presents the main results, while section 7 adds extensions and robustness specifications. Finally, section 8 concludes.

2 Background

2.1 The Mexican Drug War

Over the past few decades, illegal drug trafficking has grown into a major industry in Mexico. The US State Department (2009) estimates Mexican cartels earn an estimated $14-48 billion annually in the illegal drug wholesale market. *The 2020 World Drug Report* suggests that from 2010-2018 Mexico cultivated the most marijuana in the world. The drug trade grew in the 1960s with increasing US marijuana demand (Astorga, 2005; Toro 1995). As Figure 1 shows, marijuana cultivation continued to rise in the 1990s and into the 2000s before finally starting to decline.

This paper shows that US marijuana import demand impacts violence in Mexico, however, many other factors also play a role. Until the late 1980s, drug violence was relatively restrained in Mexico due to the hegemony of the Institutional Revolutionary Party (PRI), which resulted in collusion with drug cartels that operated with relative impunity (O'Neil, 2009; Dube and García-Ponce, 2013). However, electoral competition in Mexico grew during the 1990s, making collusive agreements more difficult. Coupled with access to US guns, municipalities destabilized by electoral competition saw increased violence (Dube and García-Ponce, 2013). During the Calderón Administration (2006-2012), Mexico waged war against the drug cartels, deploying over 45,000 troops, leading to an unprecedented spike in violence (Dell, 2015). Dell shows that after close victories by the conservative National Action Party (PAN) violence increases due to a weakening of incumbent cartels and rival attempts to usurp territorial control. Further, cartel leadership was targeted during this time leading to cartel fragmentation, and aggressive territorial expansion by rival cartels (Dell, 2015; Golz and D'Amico, 2018). Central to this

paper, many scholars cite fighting for territorial control of cultivation areas and trafficking routes (Astorga, 2007; Osorio, 2012; Ravelo, 2008; Maldonado Aranda, 2012).

Figure 2 shows gun-related homicides and homicides that are not gun-related over the sample period for rural municipalities. As will be argued below, gun-violence is more closely associated with drug violence. Therefore, this figure shows that gun-related homicides, and thus drug violence, are driving the change in overall homicides. While homicides initially fell after Calderón left office, as of 2018, they were at their highest recorded levels.

2.2 US Marijuana Market

US marijuana law has evolved over time, particularly over the last two decades. Marijuana was essentially banned at the federal level by the Marijuana Tax Act of 1937, until the act was overturned by *Leary v. United States*, and quickly replaced by the CSA. In 1970, marijuana was temporarily listed as a Schedule I drug in the CSA pending the findings of a Congressional commission. However, President Nixon did not follow the commission's recommendation that marijuana be decriminalized, where marijuana is treated as a civil infraction rather than a criminal offense. In response, some states decriminalized marijuana, starting with Oregon in 1973. However, decriminalization does not allow for the production and distribution of marijuana. During the AIDS epidemic, marijuana, known for its palliative and antiemetic qualities, was seen as a treatment for AIDS patients. This led California to be the first US state to adopt an MML in 1996. Importantly, MMLs provide for the legal domestic production and distribution of marijuana for medical use.

Despite twelve more states passing MMLs prior to 2010, federal raids on state-sanctioned dispensaries were common during this time (Johnston and Lewis, 2009). However, starting with the October-2009 Ogden Memo the federal government began to cede enforcement of marijuana laws to the states with a series of Obama-era DOJ guidelines issued to federal prosecutors (see Swanson, 2020, for a summary). Figure 3 shows the number of states and percentage of the US population under an MML over time. Swanson (2020) shows that the number of

marijuana cardholders within marijuana states has also risen dramatically, which shows that not only the adoption but uptake of medical marijuana increased over time. Currently, 33 states, over 65% of the US population, have MMLs, while 11 of these states additionally allow for the recreational use of marijuana. In short, both the adoption and relevance of MMLs has increased, which suggest an increase in US marijuana production.

3 Conceptual Framework

MMLs theoretically affect both the US domestic demand and supply of marijuana, which together determine the US demand for marijuana imports. In their working paper, Pacula et al (2013) suggest that MMLs increase marijuana demand as the drug is normalized, and perceived harm and legal risk decline. An increase in domestic demand would increase US imports, *ceteris paribus*. However, MMLs also increase domestic supply, which reduces imports while growing the domestic market. While there are no official estimates of US marijuana production, there is evidence of a dramatic increase. The DOJ noted concern in their guidelines over the scope of "industrial" marijuana cultivation under the Ogden Memo (Cole, 2011). *The Cannabis Industry Annual Report* estimates legal US marijuana revenues at $8 billion in 2017, and over $16 billion in 2020 (Frontier Financial Group, Inc, 2017). Further, there is evidence of inter-state diversion of legal marijuana (Hansen, 2017), which implies MMLs affect not only the legal markets in which they operate, but also illegal markets in other states. In sum, the increase in domestic supply and demand should increase the size of the US marijuana market, but the impact on imports is *a priori* ambiguous depending on the relative shifts in US domestic supply and demand.

The net impact of the MML induced changes on the US demand for marijuana imports can be seen in the proxies for marijuana cultivation in Mexico. Figure 1 shows kilograms of marijuana seized at the US border by the CBP as well as kilograms of marijuana seized and hectares of marijuana eradicated by the Mexican government (SEDENA). The SEDENA data suggests the apex of Mexican marijuana production was between 2003-2007, while the

CBP data suggests it was around 2009. As I will discuss, the Calderón Administration (2006-2012) redirected resources from drug enforcement to a military campaign against drug cartels leaders (Dell, 2015). This could help explain why the CBP and SEDENA peak at different times. Mexico also suffers from significant corruption which could also impact the accuracy of these SEDENA data. Regardless, each of these proxies of cultivation suggests that marijuana cultivation in Mexico has declined since 2009 and is at its lowest level since at least 1996. Further, the United Nations Office on Drugs and Crime (UNODC, 2020) suggests that seizures, which it uses as a proxy for cultivation, are "strongly affected by the liberalization of cannabis markets in North America."

4 Data

4.1 Gun-Related Homicides

Data for homicides come from Mexico's National Institute of Statistics and Geography (INEGI) and include International Statistical Classification of Diseases and Related Health Problems codes (ICD), which allows for the identification of gun-related homicides, the primary outcome of interest. Gun-related homicides, which constitute nearly 64% of all rural homicides in Mexico between 1997 and 2018, are likely closely tied to cartels and illegal drugs. While firearms are not technically illegal in Mexico, firearms laws are very strict, and purchasing a firearm legally from the lone gun store in Mexico takes several months (Linthicum, 2018). Further, 90% of recovered firearms in Mexico originate from the US (US GAO, 2009). Together these facts suggest guns in Mexico are often acquired illegally, which likely links them to criminals, particularly, well-funded criminal groups, such as drug cartels. Therefore, the principal outcome variable will be gun-related homicides, though the results using total homicides are qualitatively similar and reported in the appendix, Table A2.

4.2 Marijuana Cultivation and Suitability

Since there is no existing marijuana cultivation and suitability data, municipality-level hectares of marijuana eradication will serve as a proxy. Contemporaneous marijuana eradication will proxy for marijuana cultivation, while average historical marijuana eradication for the period just prior to the sample (1990-1995) will proxy for suitability. Averaging historical marijuana eradication over a period of 6 years addresses the potential for measurement error due to imperfect enforcement. Further, while historical marijuana cultivation is not a true measure of marijuana suitability, it will also capture the impacts of fixed costs invested by cartels to establish their operations. The use of these proxies follows Dube et al (2016) who also use marijuana eradication and historical eradication to proxy for cultivation and suitability, respectively. Government officials estimate about 75% of Mexico's drug production is eradicated annually (Humphrey, 2003), which suggests eradication may be a good measure of cultivation. As a robustness check, kilograms of marijuana seizures from SEDENA will be used in place of eradication to proxy for marijuana cultivation and suitability since enforcement issues may affect seizure and eradication data differently.

It is important to show that the marijuana cultivation proxies measure changes in cultivation, not just enforcement. The net amount of marijuana available to export to the US is equal to the amount cultivated less the amount seized or eradicated. If changes in marijuana seizures or eradication are a result of enforcement alone, then an increase in seizures or eradication will be accompanied by a reduction in the flow of marijuana to the US. Therefore, if an increase in eradication or seizures is associated with an increase in the flow of marijuana to the US, then cultivation necessarily increased. To measure marijuana flows to the US I use kilograms of marijuana seized by the CBP at the US-Mexico border, controlling for enforcement at the border. Specifically, I regress (log) CBP seizures on (log) marijuana seizures and eradication from SEDENA, respectively, controlling for CBP staffing.

Table 1 reports two columns for each of the cultivation proxies, without and with linear trends, respectively. The regression coefficients are all positive and significant, which implies

there is evidence of more marijuana crossing into the US when the proxies for marijuana cultivation in Mexico increase. Since the regressions are log-log specifications the coefficients are elasticities. If a constant percentage of marijuana is eradicated or seized each year, and CBP seizures were a perfect measure of Mexican marijuana smuggled into the US, these coefficients would be 1. These regressions provide strong evidence that the cultivation proxies are indeed capturing changes in cultivation as opposed to enforcement. Having established marijuana seizures and eradication as relevant proxies, I will refer to them as marijuana cultivation, making the distinction between the various proxies only as necessary.

Figure 4 shows that marijuana cultivation over the sample period occurs in municipalities I identify as suitable to marijuana cultivation and not in others. Municipalities with historical (1990-1995) marijuana cultivation are identified as suitable, while those without are identified as unsuitable. Since this figure clearly shows that historical marijuana eradication identifies areas of future marijuana cultivation, I will refer to it as marijuana suitability.[4] Further, while my identification strategy also exploits the intensive margin of suitability, this figure is also suggestive of treatment and control groups.

It would seem natural that the areas identified as more suitable to marijuana cultivation should show signs of increased cartel activity. To investigate this relationship, I link marijuana suitability to Mexican victimization data. The National Survey of Victimization and Perception on Public Safety (ENVIPE) began in Mexico in 2011 and does not tend to repeatedly sample the same municipalities over time, therefore the sample is much smaller than that of the baseline regressions. Nonetheless, this data provides additional evidence that the municipalities identified as more suitable to marijuana cultivation show more signs of narcotrafficking activity than those that are less suitable. The survey asks two questions directly about narcotrafficking: whether the survey participant considers narcotrafficking as one of their top three public safety concerns, and whether the participant is aware of narcotrafficking combat op-

[4]The two figures exclude two municipalities that did not have historical cultivation, which I use to measure suitability, but had an explosion of cultivation over the sample period. Including these two municipalities obfuscates the fact that, out of a sample of 2,309 municipalities over 23 years, the identification strategy identifies areas of marijuana cultivation almost perfectly. Figures including the two excluded municipalities nonetheless suggest the proxies are identifying areas of marijuana cultivation and are found in the appendix.

erations in their municipality. In addition, the survey asks whether the survey participant is aware of drug consumption, drug sales, shots being fired, or homicides in the vicinity of their homes.

Table 2 shows that, at the municipality level, there is a strong positive relationship between these signs of cartel activity and marijuana suitability, where each cell reports the coefficient of a simple bivariate regression. I regress each of the measures from the ENVIPE survey on various measures of marijuana suitability, in turn. Each column of the table is a different outcome variable from the ENVIPE survey, and each row is a different measure of suitability. The suitability measures are split into two panels. Panel A uses the continuous proxy of marijuana suitability, where the resulting coefficients from these log-log specification are elasticities. For example, a 10% increase in suitability is associated with 1.7% increase in the perception of narcotrafficking combat operations. Panel B uses a simple binary indicator of suitability, which is coded 1 for a municipality that has suitability, and 0 otherwise. This log-level specification suggests that municipalities that are suitable to marijuana cultivation perceive 38% more narcotrafficking combat operations than those that are not suitable. As a whole this table provides additional indirect evidence that the marijuana suitability measures capture differences in suitability.

4.3 Controls

The controls for this research come from several different sources. US population data from the US Bureau of the Census were downloaded from the RAND Corporation. Municipality-level population data come from the Mexican census. Data on unemployment and the number of individuals age 5 or older who did not complete primary school are from the National Employment Survey (ENE) from 1998 to 2004, and later from the National Survey of Occupation and Employment (ENOE); these data are only available at the federal entity (state) level. Federal-entity-level agricultural data, including price and production, are from the Agri-Food and Fisheries Information Service (SIAP). Municipality information, such as surface area

and the political party of mayors, come from the National Institute for Federalism and Municipal Development (INAFED). Additional municipality-level data from SEDENA include cocaine and heroin seizures as well as poppy eradication. Customs and Border Patrol marijuana seizures were procured by the author through a Freedom of Information Act (FOIA) request (CBP-2019-029124). Finally, US marijuana law information is from Pro.Con.org, a non-partisan, non-profit organization devoted to public policy.

4.4 Descriptive Statistics

Table 3 shows the descriptive statistics for the sample of rural municipalities from 1996-2018. To accommodate 0 values, I add 1 before taking logs of gun-related homicides, marijuana seizures, marijuana eradication, poppy eradication, heroin seizures, and cocaine seizures.[5] The municipalities with marijuana eradication variable is a binary indicator and identifies whether a municipality has any marijuana eradication in a given year. The municipalities with marijuana seizures is analogously defined. In the proceeding analysis, I also create marijuana suitability dummies that indicate whether a municipality has any suitability, defined as historical cultivation from 1990-1995.

4.5 Sample

The sample consists of annual observations for 2,309 rural Mexican municipalities from 1996 to 2018, providing a large, fine-grained sample. Only municipalities that existed as of the 1995 census are included to ensure all municipalities existed for the entire sample period. Since marijuana cultivation is inherently a rural phenomenon, only rural municipalities are included in the sample, with rural municipalities defined as municipalities without cities of 100,000 inhabitants or more. Urban municipalities may experience violence, even drug violence, for different reasons than rural areas. Therefore, the sample of rural municipalities identifies a

[5]These variables contain many zeros. For example, over 80% of the municipality-year observations for the cultivation proxies are 0. Similarly, over 50% of gun-related homicide observations are 0. In the appendix, I examine the robustness to alternative approaches to the log plus one transformation. The results are qualitatively similar using the inverse hyperbolic sine transformation as well as count model specifications.

particular form of violence associated with marijuana cultivation and serves as a lower bound for the change in all violence due to marijuana liberalization in the US.

5 Identification

To test the impacts of US marijuana laws on violence in Mexico, the identification strategy exploits the assumption that US marijuana liberalization should affect violence in areas that are more suitable to marijuana cultivation more than those areas that are less suitable. My empirical strategy combines temporal variation in the adoption of marijuana laws in the US with cross-sectional municipality variation in marijuana cultivation suitability in Mexico. The interaction of these variables produces a difference-in-differences (DD) estimator that tests whether marijuana liberalization differentially impacts more suitable municipalities. The percentage of the US population under a state marijuana law measures the prevalence of marijuana liberalization in the US. This gives rise to the following specification:

$$\text{Hom}_{jt} = \beta_1 \text{MJ Suit}_j \text{ x MML shr}_t + \mathbf{X}'_{jt}\boldsymbol{\delta}_1 + \alpha_{1t} + \lambda_{1j} + \mu_{1j}t + \epsilon_{1jt} \tag{1}$$

The dependent variable Hom_{jt} is gun-related homicides in municipality j at time t; λ_{1j} are municipality fixed effects, which account for non-time varying heterogeneity between municipalities such as fixed geographical traits or the strategic value of a municipality's location, such as its proximity to the US border; α_{1t} are year fixed effects to address time-varying heterogeneity that affects all municipalities equally, such as national economic shocks; $\mu_{1j}t$ are municipality-specific trends, which allow for the municipality-specific time-varying unobservables, such as the municipality-specific evolution of enforcement; $\mathbf{X}'_{jt}$ are time varying municipality and state-level controls.

Several controls are used in identification. Time-varying controls include the political party of the mayor, (log) population, real corn price interacted with corn suitability, (log) unemployment, (log) primary school incompletion, and measures of other drug activity. Dell (2015)

shows the political party of the mayor affects violence. Therefore to control for enforcement, I include 5 dummies representing the party of the mayor, including National Action Party (PAN), Party of the Democratic Revolution (PRD), Institutional Revolutionary Party (PRI), Coalition Party (COAL), customs and traditions (UYC), and "other" being the omitted category.[6] Dube et al (2016) show maize prices affect drug cultivation in Mexico. Therefore, I include municipality-level average rural (real) corn price interacted with corn suitability, since the price of corn will impact the areas most suitable to corn disproportionately. Since unemployment and education affect violence, I also include controls for unemployment and education, specifically the (log) number of people unemployed and (log) number of people age 5 and older who did not complete primary school. Finally, I control for measures of other drug activity include poppy eradication, heroin seizures, and cocaine seizures.

In order to demonstrate the mechanism through which marijuana liberalization impacts violence as well as determine the causal impact of illegal marijuana markets on violence, I use a two-stage least squares (2SLS) approach. In order to identify the causal impact of illegal marijuana markets on violence, it is important to use an exogenous source of variation since the OLS results likely suffer from several forms of endogeneity. First, time-varying omitted variables, such as enforcement or cultural norms and attitudes, can correlate with violence as well as cultivation and bias results. Second, there is likely a severe form of measurement error present since eradication is plausibly a noisy measure of cultivation, and further, there is likely a strong negative correlation between the error with which cultivation is measured and the amount of actual cultivation.[7] Further, there is the possibility of reverse causality, where violence leads to cultivation by undermining legal opportunities and policing. Therefore, I instrument for marijuana cultivation by interacting marijuana suitability with the change in US marijuana import demand due to US marijuana liberalization, the same instrument from the preceding reduced form specifications. US marijuana liberalization is used as an exogenous shift in US marijuana import demand. The corresponding reduced form, first stage, second

[6]UYC, which is a form of indigenous self-governance, is treated as a political party.

[7]The measurement error issue is discussed further in the appendix.

stage, and OLS specifications are shown in equations (2)-(5):

Reduced form:

$$\text{Hom}_{jt} = \beta_1 \text{MJ Suit}_j \text{x MML shr}_t + \mathbf{X}'_{jt}\boldsymbol{\delta}_1 + \alpha_{1t} + \lambda_{1j} + \mu_{1j}t + \epsilon_{1jt} \tag{2}$$

First stage:

$$\text{MJ Cult}_{jt} = \beta_2 \text{MJ Suit}_j \text{x MML shr}_t + \mathbf{X}'_{jt}\boldsymbol{\delta}_2 + \alpha_{2t} + \lambda_{2j} + \mu_{2j}t + \epsilon_{2jt} \tag{3}$$

Second stage:

$$\text{Hom}_{jt} = \beta_3 \widehat{\text{MJ Cult}}_{jt} + \mathbf{X}'_{jt}\boldsymbol{\delta}_3 + \alpha_{3t} + \lambda_{3j} + \mu_{3j}t + \epsilon_{3jt} \tag{4}$$

OLS:

$$\text{Hom}_{jt} = \beta_4 \text{MJ Cult}_{jt} + \mathbf{X}'_{jt}\boldsymbol{\delta}_4 + \alpha_{4t} + \lambda_{4j} + \mu_{4j}t + \epsilon_{4jt} \tag{5}$$

The variables for these specifications are analogously defined to the reduced form specification previously introduced, except for MJ Cult_{jt}, which is marijuana cultivation in municipality j at time t. These regressions are otherwise identical to those in the preceding specification and contain the same controls, year fixed effects, municipality fixed effects, and municipality-level linear trends.

For the interaction term to serve as a valid instrument it must satisfy both the exclusion restriction and relevance requirements. The relevance condition requires that the interaction of marijuana suitability and changing import demand correlate to current cultivation. This is demonstrated by the large F-stat on the excluded instruments in each of the specifications. In order to properly address the measurement error issue, the exclusion restriction requires the instrument be uncorrelated with the measurement error believed to be a result of contemporaneous enforcement, which seems plausible. Further, the exclusion restriction requires that after controls the only way the instrument affects violence in Mexico is through its impact on marijuana cultivation. That is, the instrument must be as good as randomly assigned after controls for the IV and reduced form regressions to be causally interpreted. Recall, these

instruments are derived from the interaction of suitability, a fixed trait, and US marijuana laws that are exogenous to Mexican outcomes except through their impact on the Mexican marijuana market. Therefore, there is a strong case for a causal interpretation.

However, there is a possible violation of the exclusion restriction, since a reduction in marijuana import demand from the US can affect the Mexican marijuana market through both price and quantity effects. Unfortunately, no reliable marijuana price data exists, so only the proxy for marijuana cultivation is included. However, if Mexican marijuana is a fairly homogeneous product with many small producers such that there is a single market price, then any price effects are subsumed by the time fixed effects. This is likely true, since marijuana grown outdoors is generally of lower quality. Further, if the price is a linear function of quantity then these two effects are not individually identified. If none of the above applies, then the municipality-specific trends may help address this potential violation of the exclusion restriction. Another concern is that cartels substitute production of other drug in response to US marijuana liberalization, which in turn affects violence. Therefore, I control for poppy eradication as well as cocaine and heroin seizures.

6 Results

6.1 Marijuana Cultivation and Gun-related homicides

In the following reduced form analysis, the independent variable of interest is the interaction of temporal variation in the adoption of marijuana laws in the US with cross-sectional municipality variation in marijuana cultivation suitability in Mexico, which identifies whether marijuana liberalization differentially impacts municipalities more suitable to marijuana cultivation. Following Dube et al (2016), I take logs of the dependent variables as well as the marijuana suitability and cultivation after adding 1. Since many municipalities have no marijuana cultivation in a year or no suitability, adding 1 prior to taking logs ensures the logs are defined for zero values and not dropped from the sample. In the appendix, I check this

transformation by repeating the analysis using the inverse hyperbolic sine transformation as well as count regressions, using poisson pseudo maximum likelihood estimation (PPML). All approaches yield similar results.

Table 4 examines whether US marijuana liberalization led to a differential change in marijuana cultivation. Each column progressively adds controls. Column (1) reports the results with only state and year fixed effects; column (2) adds controls for the political party of the mayor, (log) population, corn suitability x real corn price, (log) poppy eradication, (log) heroin seizures, and (log) cocaine seizures; column (3) additionally controls for (log) unemployment and (log) primary school incompletion.[8]; column (4) adds municipality-specific linear trends. Standard errors are clustered by municipality. Each specification reports a negative and significant interaction term, meaning that there is a further decrease in marijuana cultivation in municipalities more suitable to marijuana cultivation relative to those less suitable. The results, while attenuated, survive the inclusion of municipality-specific linear trends. To interpret the coefficient in column (4), I examine the change due to US marijuana liberalization through 2018 by comparing a municipality in the top decile of suitability (historical eradication = 1.26) to one of average suitability (historical eradication = 0.36). These results suggest US marijuana liberalization through 2018 would induce a decrease in marijuana cultivation of 14% in a municipalities with average suitability, but induce a decrease of 41% in a municipality in the top decile of suitability (henceforth referred to as high suitability), a further decline of 27 percentage points. This suggests that there is a change in marijuana cultivation in response to US marijuana liberalization, and that this change is indeed realized in the municipalities identified as more suitable to marijuana cultivation.

Given marijuana cultivation in Mexico responds to US marijuana liberalization, Tables 5-7 examine whether liberalization in turn impacts drug violence in Mexico. These tables share the same layout as Table 4, where each column progressively adds controls. Standard errors are clustered by municipality. In each specification of Table 5, I find a negative and statistically

[8]The additional controls in column (3) are not readily available for 1996 and 1997, and therefore including these variables drops these years from the sample.

significant interaction term, meaning that there is a further decrease in gun-related homicides in municipalities more suitable to marijuana cultivation relative to those less suitable. Using the same comparison as in the previous table, US marijuana liberalization would induce a decrease of only 7% in gun-related homicides in a municipality of average marijuana cultivation suitability, while inducing a decrease of 24% in highly suitability municipality, a further decline of 17 percentage points.

To examine whether the baseline results are simply driven by differences between municipalities with or without marijuana cultivation suitability, or whether the degree of suitability is important, I repeat the analysis two additional ways. First, in Table 6, I use a binary measure of marijuana suitability, coded 1 if a municipality has suitability (historical eradication>0) and 0 otherwise. Table 7 repeats the analysis from Table 5 but limits the sample to municipalities with marijuana suitability. Standard errors are clustered by municipality throughout. The specifications using a binary suitability indicator in Table 6 do not identify any effects without controlling for municipality-specific linear trends. After controlling for trends, I once again find negative and significant impacts of liberalization on gun-related homicides. Table 7 shows limiting the sample to only marijuana suitable municipalities produces slightly larger effects. Overall, Tables 6 and 7 suggest that US marijuana liberalization affects municipalities with and without marijuana cultivation suitability differently, but that the intensive margin of suitability is important.

6.2 Agricultural Output

Declining US demand for marijuana imports will impact production decisions of rural farmers through income and substitution effects. Assuming leisure is a normal good, a decline in the marijuana prices, all else equal, will leave farmers poorer, leading them to consume less leisure and work more. Further, the value of marijuana cultivation is now relatively lower than other crops, leading farmers to substitute other crops in its place, *ceteris paribus*. However, the canonical labor-leisure model also suggests that a decline in wages should increase leisure,

since it would be relatively cheaper, given foregone wages are the price of leisure. While this discussion suggests some theoretical ambiguity, given many rural farmers live at or near subsistence levels, survival likely dictates that working less is not a viable option. Therefore, in the context of rural Mexico, *prima facie* legal alternatives should increase in response to a decrease in the demand for illegal cultivation.

In Table 8, I ask if there is a corresponding compensation in legal agricultural output when the marijuana market declines. This is essentially the reverse of Dube et al's (2016) finding that drug cultivation increases as maize prices decline. Table 8 is identical to Table 5 except for the outcome variable is the (log) real value of agricultural production measured in 2015 pesos. The results show that US marijuana laws increase agricultural production, where the (log) real value of agricultural output increases in municipalities more suitable to marijuana cultivation relative to those less suitable. The coefficient in column (4) implies a highly suitable municipality would see an increase of almost 10% in the value of legal cultivation due to US marijuana liberalization, while a municipality with average marijuana suitability would only see an increase in agricultural production of 3%, a further increase of 7 percentage points in a highly suitable municipality. This finding provides strong indirect evidence of a decline in marijuana cultivation, which is not subject to drug enforcement concerns. Further, the impacts on legal agricultural output are themselves of great interest. Given many Mexican agricultural products are exported to US markets, this could potentially put downward pressure on food prices in both countries. According to the International Trade Administration (ITA), Mexico exported nearly $26B in agricultural goods to the US in 2018, making it Mexico's principal agricultural trading partner (ITA, 2019).

6.3 The Impact of Illegal Marijuana Markets on Violence

It is important to demonstrate the mechanism through which marijuana liberalization impacts violence. Further, the causal impact of illegal drug markets on violence is of important interest. Table 9, therefore, combines the results from Tables 4 and 5 into a 2SLS specification.

The interaction of marijuana cultivation suitability and the percentage of US population under a marijuana law, which serves as the DD estimator in Tables 4 and 5, now serves to identify plausibly exogenous variation in marijuana cultivation in Mexico. It is helpful to remember that I proxy for marijuana suitability with historical marijuana cultivation in the period just prior to the sample (1990-1995). Therefore, I instrument for contemporaneous marijuana cultivation with historical marijuana cultivation interacted with the percentage of US population under a marijuana law.

Table 9 is divided into four pairs of columns, one pair each for the OLS, IV, reduced form, and first stage regressions. Each pair of columns reports the results with and without municipality trends. Standard errors are clustered by municipality. The first stage regressions reported in columns (7) and (8) correspond to Table 4 and show that the instrument has a strong relationship with marijuana cultivation. The large F-stat on the excluded instrument suggests the instrument is indeed relevant. The reduced form regressions reported in columns (5) and (6) correspond to Table 5 and show the DD estimates of the impact of marijuana liberalization on gun-related homicides in Mexico. Combining the results of columns (5) - (8) produces the 2SLS estimates in columns (3) and (4). These IV regressions examine the causal impact of illegal marijuana markets on gun-related violence in Mexico. If there was no clear impact of US marijuana import demand on Mexican marijuana cultivation (first stage), and further if marijuana cultivation in Mexico did not affect violence (IV), then it would call into question the mechanism through which a reduction in US marijuana import demand affects drug violence in Mexico (reduced form). Since gun-related homicides and marijuana cultivation are both measured in logs, the resulting coefficients in the OLS and IV regressions are elasticities. In contrast to the IV specifications, the OLS estimates in columns (1) and (2) are null, likely due to the endogeneity concerns previously discussed biasing the results downward. The IV results suggest that a 10% increase in cultivation leads to a 1-6% increase in gun-related homicides.

The strong relationship between cultivation and violence is consistent with other studies that find a positive relationship between drug cultivation and violence (Agrist and Kugler,

2008; Meija and Restrepo, 2013; Dube et al, 2016). While the policy relevance of these magnitudes outside of marijuana production in Mexico is unclear, the direction of this effect is itself relevant since it is theoretically ambiguous. One narrative suggests that there will be more violence as cartels fight over resources, such as land, used in marijuana cultivation, while the other narrative suggests that violence should decrease as the opportunity cost of violence (productive labor) increases. The positive relationship between cultivation and violence is consistent with the notion that cartels contest drug rents through violence in the absence of property rights and enforceable contracts.

7 Extensions and Robustness

7.1 Heterogeneity

The baseline regressions identify whether US marijuana liberalization further impacts Mexican municipalities more suitable to marijuana cultivation relative to those less suitable. In Table 10 I examine whether this differential change varies by distance to the US-Mexico border for both marijuana cultivation and gun-related homicides. Therefore, Table 10 repeats the baseline regression including all controls and municipality-level linear trends, but splits the sample into municipalities above and below the mean distance to the border. The first two columns examine the heterogeneity in violence with column (1) reporting the results for municipalities closer to the border and column (2) the results for those further away. Columns (3) and (4) report the analogous results for marijuana cultivation.

Table 10 shows the impact of marijuana liberalization on marijuana cultivation in municipalities closer to the border is greater than those further away, while the impact on gun-related homicides shows a correspondingly greater impact in municipalities closer to the border. The consistency between the cultivation and homicide results further bolsters the results on illegal marijuana markets on violence, since both cultivation and violence vary by distance to the border in the same way. Further, the larger impacts in municipalities closer to the border is

consistent with the idea that these municipalities are more valuable and yield larger rents to cartels. This interpretation is consistent with Castillo et al (2020) who find that cocaine supply shocks impact municipalities closer to the border, since these municipalities are strategically more valuable and produce higher drug rents. This also agrees with Dell (2015) who finds that cartels appear to traffic drugs using the most direct route to the border possible while avoiding enforcement, since longer routes expose drug shipments to greater risk of interdiction. This implies that the territories closest to the border are in fact the most valuable and produce the highest drug rents, which is consistent with these heterogeneity results.

7.2 The Calderón Administration

Table 11 addresses the concern that the increase in violence may be driven solely by the aggressive military campaign that the Calderón Administration waged against drug cartels. During this time over 45,000 troops were deployed and resources were redirected from drug crop eradication to direct military engagement with cartels (Dell, 2015). To examine this concern, I exclude 2007-2012 from my sample since Calderón was in office from December 2006 through November 2012. Table 11 reports the results from Table 9 in Panel A, and then repeats the analysis removing the years of the Calderón Administration in Panel B. The impact on marijuana liberalization on gun-related violence excluding the years of the Calderón Administration is qualitatively similar to baseline; even the magnitude is quite similar in the specification without linear trends. However, the impact of US liberalization on marijuana cultivation and the corresponding 2SLS results, which examine the relationship between cultivation and violence, are sensitive to the inclusion of municipality trends. This null result could be due to the Calderón Administration redirecting resources away from drug crop eradication as suggested by Dell (2015). However, the reduction in violence in response to US liberalization provides indirect evidence that the lack of response in eradication was not the result of a lack of change in cultivation.

7.3 Robustness

Tables 12 and 13 show the results are robust to alternative proxies for marijuana suitability and cultivation despite these proxies potentially being subject to different biases. These tables repeat the analysis from Tables 4 and 5, but use marijuana seizures rather than eradication to proxy for cultivation and suitability. While marijuana seizures and eradication are highly correlated (corr = 0.78), these two proxies for marijuana cultivation and suitability still may differ in important ways. The eradication of drug crops is a very targeted and high-level form of enforcement involving the physical destruction of crops after surveillance efforts, such as satellite imaging. Marijuana seizures, on the other hand, provide a potentially less targeted and lower-level measure of marijuana enforcement, as routine patrols can result in seizures. Given the prevalence of corruption at all levels of government in Mexico it is possible that seizures and eradication are prone to different biases in enforcement.[9] The drawback to using seizures as a proxy for marijuana cultivation, however, is that marijuana may not be seized in the municipality in which it was produced. The results using marijuana seizures as a proxy for marijuana cultivation and suitability are qualitatively similar to the results which use eradication.

Several robustness checks are also found in the appendix. Table A2 shows the results are robust to examining all homicides rather than only gun-related homicides. This is unsurprising since gun-related homicides constitute nearly 64% of all homicides in the sample. Table A3 examines the robustness to alternative data transformations. Panel A reports the results from Table 9, where I add 1 prior to taking logs, while Panel B reports the results using the inverse hyperbolic sine transformation, which is an approximation of the log function that is defined for 0 values (Johnson, 1949; Bellemare and Wichman, 2020). The results in Panel A and B are nearly identical. Table A4 is the final robustness table in the appendix. This table repeats the analysis using a poisson pseudo maximum likelihood (PPML) count model. The resulting

[9]US ambassador to Mexico Roberta Jacobson admitted both Mexico and the US knew that Calderón's secretary of public security, Genaro García Luna, was working with the Sinaloa Cartel (Hackbarth, 2020). Mexican Attorney General Jesus Murillo said Iguala Mayor Jose Luis Abarca and wife Maria de los Angeles Pineda were the "probable masterminds" in the 2014 disappearance of 43 student protesters (Rhodan, 2014).

coefficients are comparable to the main results.

8 Conclusion

Drug violence in Mexico is fueled by strong demand for illegal drugs in the US. However, US marijuana liberalization has led to an explosion of domestic marijuana production in the US, lowering the demand for US marijuana imports from Mexico, *ceteris paribus*. Using a sample of over 2,300 rural municipalities from 1996-2018, I show that US marijuana laws have led to a large and statistically significant reduction in both marijuana cultivation and gun-related homicides in Mexico as well as an increase in legal agricultural output. The increase in legal agricultural output provides strong indirect evidence of a change in marijuana cultivation, as these poor rural municipalities look to replace the income lost to marijuana production in the US. Using US marijuana liberalization as an exogenous source of variation in marijuana cultivation in Mexico, I find a 10% change in cultivation increases gun-related homicides 1-6%. While US marijuana liberalization ultimately lowers violence in Mexico, it underscores the role that US drug demand plays in the violent drug war there.

Future research should examine the impacts of marijuana liberalization in the US on other outcomes in Mexico, such as labor market outcomes, poverty, education, migration, and inequality. This research should examine whether these outcomes are rendered solely through their impact on violence or through other channels. This would complement the literature on the impact of violence on these outcomes by examining plausibly exogenous variation in violence.

More broadly, this paper illustrates that there are foreign externalities related to domestic policy decisions. International drug trafficking is indeed an *international* problem, which requires a coordinated solution. Further, policies of interdiction have been costly and largely ineffective, and in some cases have increased drug rents, inciting even more violence. This paper contributes to a growing literature that suggests economic solutions are a viable alternative by providing legal alternatives to drug production or legalizing markets to reduce drug rents

and therefore violence.

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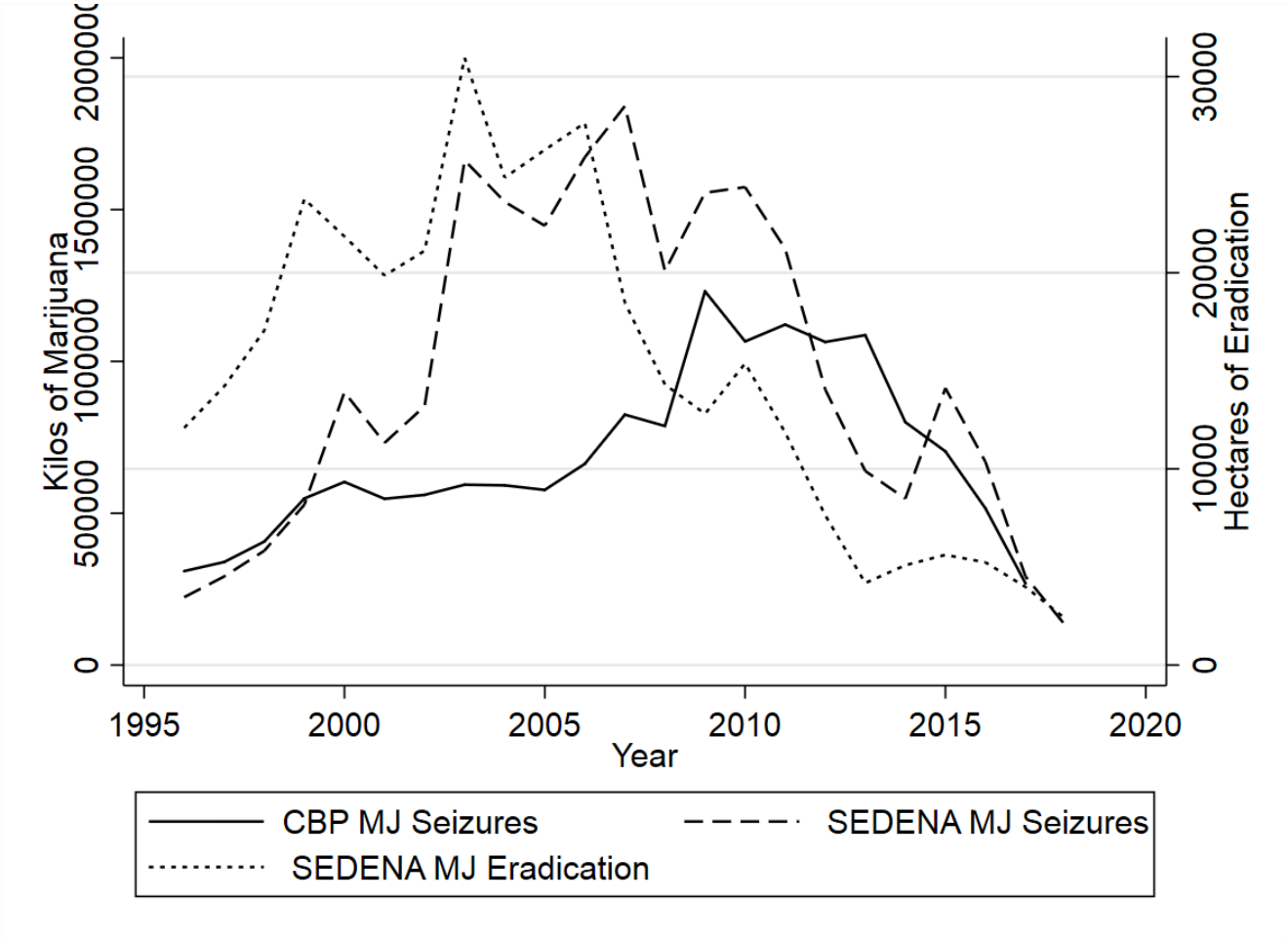
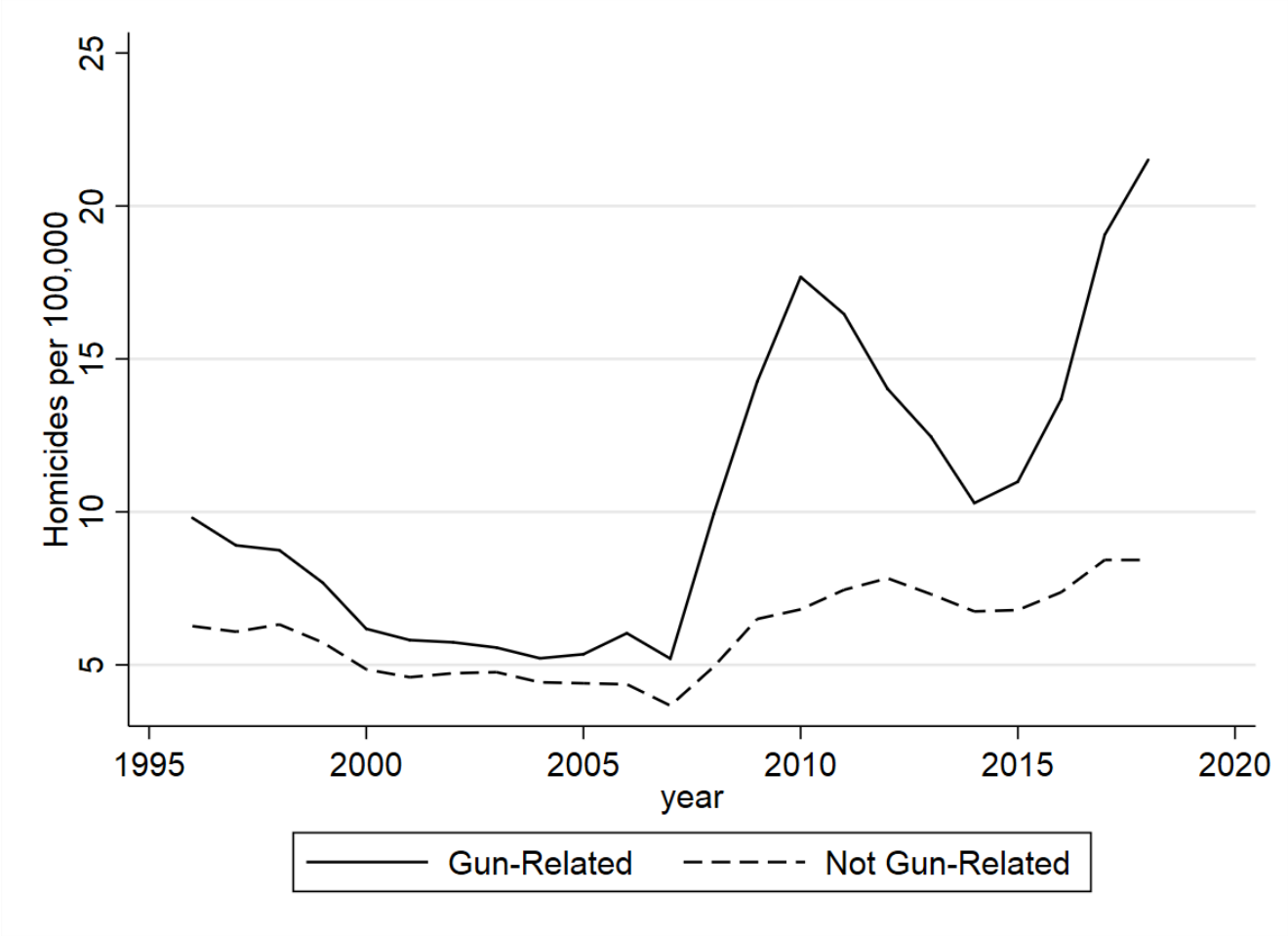
Figure 1 - Proxies for Marijuana Cultivation in Mexico



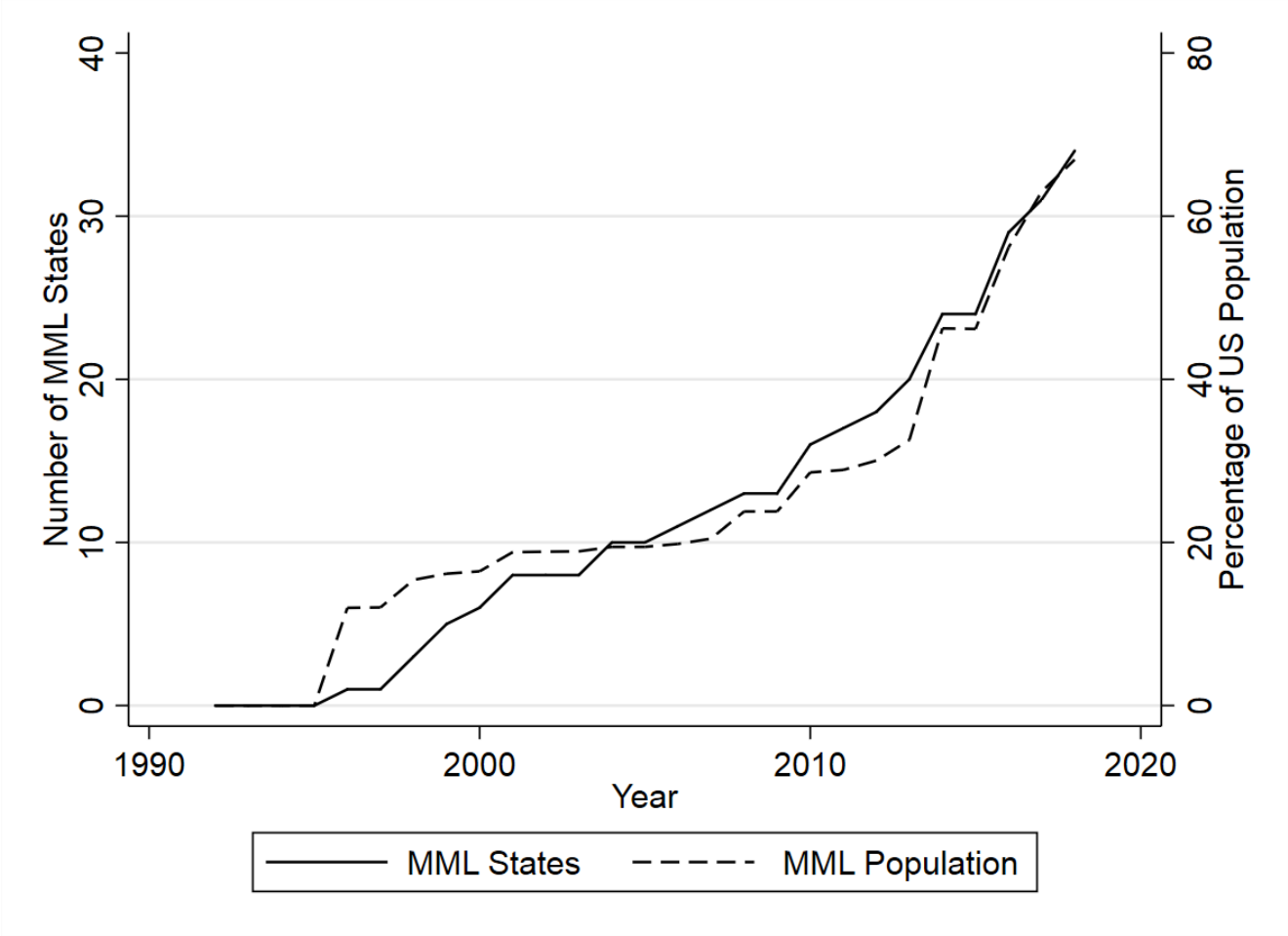
Note: This figure shows marijuana eradication in hectares and seizures in kilograms by the Mexican military throughout Mexico reported by SEDENA from 1997-2018. The figure also shows marijuana seizures in kilograms by the CBP at the US-Mexican border from 1996-2017.

Figure 2 - Number of Homicides Per 100,000 Population



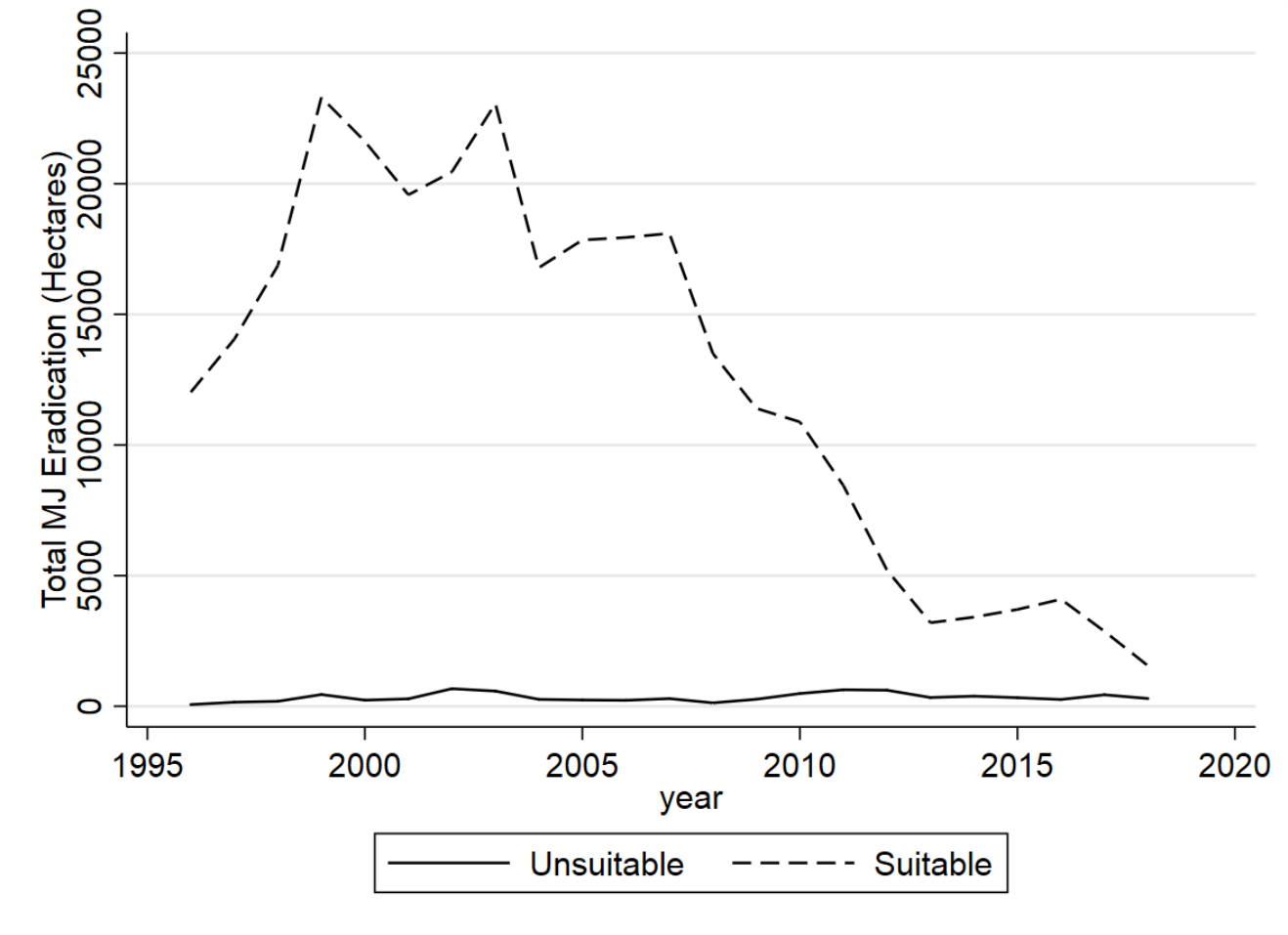
Note: Homicides in rural municipalities (excluding municipalities with cities of 100,000 population or more) from 1996-2018.

Figure 3 - Number of US States and Percentage of Total Population Under an MML



Note: Medical marijuana law (MML) information from ProCon.org through 2018.

Figure 4 - Marijuana Cultivation in Municipalities with and without Marijuana Cultivation Suitability over Time



Note: The figure shows hectares of marijuana eradication in municipalities identified as suitable or unsuitable to marijuana cultivation and excludes two outlier municipalities that had an explosion of cultivation during the sample, but no suitability.

Table 1 CBP Marijuana Seizures at the US-Mexico Border and Mexican Marijuana Cultivation

	(1)	(2)	(3)	(4)
SEDENA Seizures	0.460***	0.448***		
	(0.121)	(0.118)		
SEDENA Eradication			0.590***	0.569***
			(0.146)	(0.168)
R-squared	0.81	0.83	0.80	0.80
Linear Trend	No	Yes	No	Yes
Control for CBP Staffing	Yes	Yes	Yes	Yes
N	26	26	26	26

Note: All variables are in logs. Sample period: 1992-2017. Robust standard errors in parenthesis.

Table 2 Marijuana Cultivation Suitability and Cartel Presence

	(1) Narco Concern	(2) Narco Combat	(3) Drug Consumption	(4) Drug Sales	(5) Shots Heard	(6) Homicides
Panel A: Continuous Proxy for Marijuana Suitability:						
Eradication	0.086***	0.171***	0.034**	0.047**	0.042**	0.060***
	(0.016)	(0.020)	(0.016)	(0.019)	(0.019)	(0.019)
Panel B: Binary Proxy for Marijuana Suitability:						
Mun with Erad	0.182***	0.383***	0.086**	0.121***	0.039	0.115***
	(0.036)	(0.047)	(0.038)	(0.044)	(0.046)	(0.042)
N	7,430	7,391	7,430	7,430	7,430	7,430

Note: Each cell is the coefficient of a bivariate regression of cartel presence on the corresponding measure of marijuana cultivation suitability. Panel A are log-log specifications, while Panel B are log-level. See text for full description of outcome variables. Standard errors clustered by municipality in parenthesis.

Table 3 Descriptive Statistics

	Observations	Mean	Standard deviation
Dependent Variables:			
(Log) Gun-related homicides	53,107	1.139	1.470
(Log) Real value agricultural output	53,107	23.310	0.726
Drug variables:			
Percent of US states under MJ law	23	0.284	0.158
(Log) MJ seizures	53,107	0.734	2.048
Municipality w/MJ seizures	53,107	0.160	0.367
(Log) MJ eradication	53,107	0.294	0.912
Municipality w/MJ eradication	53,107	0.185	0.388
(Log) Poppy eradication	53,107	0.172	0.764
(Log) Heroin seizures	53,107	0.005	0.112
(Log) Cocaine seizures	53,107	0.030	0.337
(Log) CBP MJ seizures	22	13.366	0.412
Political variables:			
PAN mayor	52,497	0.142	0.338
PRI mayor	52,497	0.338	0.462
PRD mayor	52,497	0.089	0.279
COAL mayor	52,497	0.069	0.244
UYC mayor	52,497	0.171	0.377
Other party mayor	52,497	0.192	0.384
Other variables:			
(Log) Population	53,107	9.197	1.375
(Log) Unemployment rate	48,489	-3.688	0.875
(Log) Primary school incompletion rate	48,489	-1.191	0.217
Real Corn Price x Corn Suitability	52,136	2.432	0.801

Note: The sample consists of rural municipalities from 1996-2018. See text for variable definitions.

Table 4 The Effect of US Marijuana Liberalization on Marijuana Cultivation in Mexico

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	-1.141***	-1.198***	-1.221***	-0.559***
	(0.059)	(0.048)	(0.049)	(0.081)
Method	OLS	OLS	OLS	OLS
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	53,107	51,566	47,041	47,041

Note: Marijuana cultivation and suitability are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table 5 The Effect of US Marijuana Liberalization on Gun-Related Homicides in Mexico
Continuous Measure of Marijuana Cultivation Suitability

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	-0.131***	-0.128***	-0.122***	-0.333***
	(0.035)	(0.034)	(0.035)	(0.061)
Method	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	53,107	51,566	47,041	47,041

Note: Homicides and marijuana suitability are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table 6 The Effect of US Marijuana Liberalization on Gun-Related Homicides in Mexico
Binary Measure of Marijuana Cultivation Suitability

	(1)	(2)	(3)	(4)
Mun w/MJ Suit x Pcnt MML	-0.021	-0.015	0.003	-0.301***
	(0.061)	(0.061)	(0.064)	(0.110)
Method	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	53,107	51,566	47,041	47,041

Note: Homicides are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Marijuana suitability is a binary indicator denoting whether a municipality is suitable to marijuana cultivation. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table 7 The Effect of US Marijuana Liberalization on Gun-Related Homicides in Mexico
Sample Limited to Municipalities with Marijuana Cultivation Suitability

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	-0.171***	-0.170***	-0.165***	-0.335***
	(0.041)	(0.040)	(0.041)	(0.071)
Method	OLS	OLS	OLS	OLS
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	19,688	19,277	17,589	17,589

Note: Homicides and marijuana suitability are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018 and limited to municipalities with marijuana suitability. Standard errors clustered by municipality in parenthesis.

Table 8 The Effect of US Marijuana Liberalization on the Real Value of Agricultural Output in Mexico

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	0.222***	0.209***	0.182***	0.118***
	(0.016)	(0.015)	(0.014)	(0.015)
Method	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	53,107	51,566	47,041	47,041

Note: (Log) Real value of agricultural output is measured in 2015 pesos. Marijuana suitability is transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table 9 The Causal Impact of Marijuana Markets on Gun-Related Homicides in Mexico

	OLS		IV		Reduced Form		First Stage	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cultivation	0.004	0.000	0.100***	0.596***				
	(0.008)	(0.008)	(0.028)	(0.138)				
MJ Suit x Pcnt MML					-0.122***	-0.333***	-1.221***	-0.559***
					(0.035)	(0.061)	(0.049)	(0.081)
F-Stat on Excl. Instr.			624.2	47.8				
Method	OLS	OLS	2SLS	2SLS	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Base Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Add'l Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mun Trends	No	Yes	No	Yes	No	Yes	No	Yes
N	47,041	47,041	47,041	47,041	47,041	47,041	47,041	47,041

Note: Homicides, marijuana suitability, and marijuana cultivation are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table 10 The Effect of US Marijuana Liberalization on Gun-Related Homicides in Mexico
Heterogeneous Effects by Distance to the US Border

	Gun-Related Homicides		Marijuana Cultivation	
	(1) < Mean	(2) > Mean	(3) < Mean	(4) > Mean
MJ Suit x Pcnt MML	-0.572***	-0.164**	-1.058***	-0.347***
	(0.091)	(0.079)	(0.120)	(0.107)
Method	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	Yes	Yes	Yes	Yes
Add'l Controls	Yes	Yes	Yes	Yes
Mun Trends	Yes	Yes	Yes	Yes
N	19,905	27,136	19,905	27,136

Note: Homicides and marijuana suitability are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018 and split by above and below the mean distance to the US-Mexico border. Standard errors clustered by municipality in parenthesis.

Table 11 The Causal Impact of Marijuana Markets on Gun-Related Homicides in Mexico
Excluding the Calderón Administration

	OLS		IV		Reduced Form		First Stage	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Entire sample period								
Cultivation	0.004	0.000	0.100***	0.596***				
	(0.008)	(0.008)	(0.028)	(0.138)				
MJ Suit x Pcnt MML					-0.122***	-0.333***	-1.221***	-0.559***
					(0.035)	(0.061)	(0.049)	(0.081)
F-Stat on Excl. Instr.			624.2	47.8				
Panel B: Excluding the years of the Calderón administration (2007-2012)								
Cultivation	0.011	-0.006	0.090***	4.582				
	(0.009)	(0.008)	(0.029)	(16.324)				
MJ Suit x Pcnt MML					-0.109***	-0.172***	-1.212***	-0.037
					(0.035)	(0.066)	(0.053)	(0.134)
F-Stat on Excl. Instr.			530.3	0.1				
Method	OLS	OLS	2SLS	2SLS	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Base Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Add'l Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mun Trends	No	Yes	No	Yes	No	Yes	No	Yes
N	33,649	33,649	33,649	33,649	33,649	33,649	33,649	33,649

Note: Homicides, marijuana suitability, and marijuana cultivation are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table 12 The Effect of US Marijuana Liberalization on Marijuana Cultivation in Mexico
Marijuana Cultivation and Suitability Proxied by Marijuana Seizures

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	-0.572***	-0.579***	-0.692***	-0.996***
	(0.057)	(0.056)	(0.058)	(0.110)
Method	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	53,107	51,566	47,041	47,041

Note: Marijuana cultivation and suitability are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table 13 The Effect of US Marijuana Liberalization on Gun-Related Homicides in Mexico
Marijuana Cultivation Suitability Proxied by Marijuana Seizures

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	-0.052***	-0.053***	-0.046**	-0.129***
	(0.018)	(0.018)	(0.018)	(0.032)
Method	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	53,107	51,566	47,041	47,041

Note: Homicides and marijuana suitability are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Appendix

A.1 Measurement Error

A key concern for the proper identification of the effects of US marijuana laws is the presence of measurement error in the proxy for marijuana cultivation, marijuana eradication. Non-classical measurement error, where the measurement error negatively correlates to the true value of the independent variable, can potentially attenuate the results much worse than classical measurement error. Table A1 shows the OLS buildup in a regression of (log) gun-related homicides on (log) cultivation. Column (1) shows the raw correlation without any controls. Marijuana cultivation results in a statistically significant increase in gun-related homicides with an elasticity of 0.268. Column (2) shows this relationship survives the inclusion of the base controls and year fixed effects. However, these results do not survive unobserved municipality-level variation, either municipality fixed effects or municipality-specific trends, Columns (3) - (6). These results are consistent with municipality-level measurement error due to enforcement issues as well as the other endogeneity concerns previously discussed.

In a simple bivariate regression where the true value of the independent variable x is correlated with the measurement error u, the attenuation factor is given by equation (6) (Pischke, 2007).

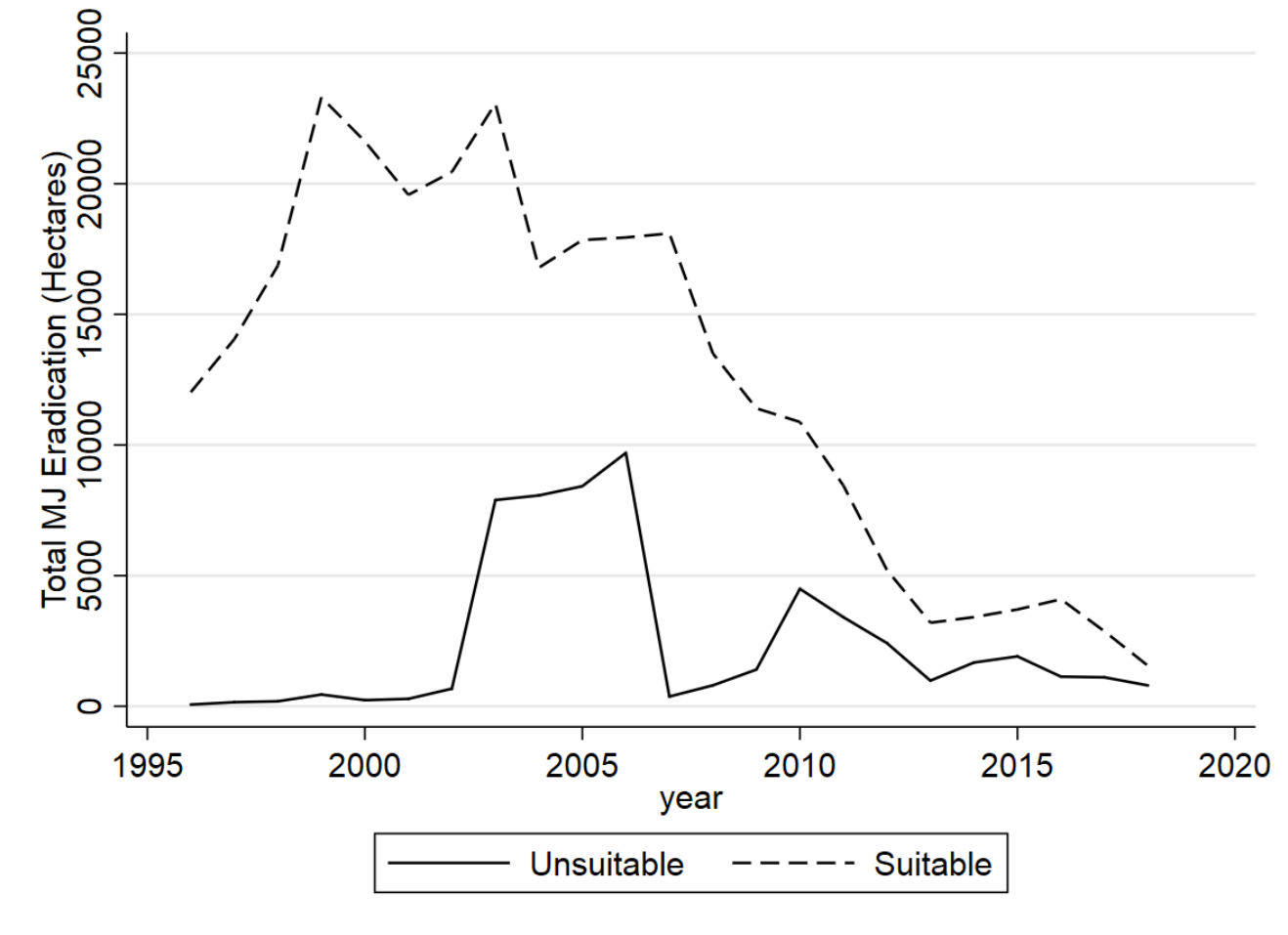
$$\lambda = \frac{\sigma_x^2 + \sigma_{xu}}{\sigma_x^2 + \sigma_u^2 + 2\sigma_{xu}} \tag{6}$$

$$\frac{\partial \lambda}{\partial \sigma_{xu}} = \frac{\sigma_u^2 - \sigma_x^2}{(\sigma_x^2 + \sigma_u^2 + 2\sigma_{xu})^2} \tag{7}$$

Differentiating the attenuation factor with respect to σ_{xu} as in (7) shows that the attenuation factor increases (bias decreases) with σ_{xu}, if the variance of the noise is greater than that of the signal. Therefore, if a noisy ($\sigma_u^2 > \sigma_x^2$) independent variable is negatively correlated with the measurement error, then the attenuation factor is smaller (more attenuated) than with classical measurement error. Further, if the negative correlation is sufficiently large in abso-

lute value, then it is even possible for the sign of coefficient to change, which is not true under classical measurement error. While untestable without further data, there is reason to believe this is precisely the severe form of measurement error present in the marijuana cultivation proxies. If the military fails to eradicate some municipalities, then those municipalities with lots of cultivation will have larger (in absolute value) negative measurement error compared to those municipalities with less cultivation. Therefore, severe attenuation bias is a serious concern, and the null or near null OLS results are consistent with the presence of non-classical measurement error.

Figure A1 - Marijuana Cultivation for Municipalities with and without Marijuana Cultivation Suitability over Time



Note: The figure shows hectares of marijuana eradication in municipalities identified as suitable or unsuitable to marijuana cultivation and includes two outlier municipalities that had an explosion of cultivation during the sample, but no suitability.

Table A1 The Relationship between Gun-Related Homicides and Marijuana Markets
OLS Buildup

	(1)	(2)	(3)	(4)	(5)	(6)
Cultivation	0.268***	0.166***	0.004	0.005	-0.004	0.000
	(0.014)	(0.012)	(0.008)	(0.008)	(0.007)	(0.008)
Mun FE	No	No	Yes	No	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes	Yes	Yes
Add'l Controls	No	No	No	No	No	Yes
Mun Trends	No	No	No	Yes	Yes	Yes
N	53,107	51,566	51,566	51,566	51,566	47,041

Note: Homicides and marijuana cultivation are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table A2 The Effect of US Marijuana Liberalization on Total Homicides in Mexico
Continuous Measure of Marijuana Cultivation Suitability

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	-0.094***	-0.090***	-0.096***	-0.342***
	(0.033)	(0.032)	(0.032)	(0.056)
Method	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
Mun Trends	No	No	No	Yes
N	53,107	51,566	47,041	47,041

Note: Homicides and marijuana suitability are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table A3 The Causal Impact of Marijuana Cultivation on Gun-Related Homicides in Mexico
Including the Inverse Hyperbolic Sine Transformation

	OLS		IV		Reduced Form		First Stage	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: log(x+1) transformation								
Cultivation	0.004	0.000	0.100***	0.596***				
	(0.008)	(0.008)	(0.028)	(0.138)				
MJ Suit x Pcnt MML					-0.122***	-0.333***	-1.221***	-0.559***
					(0.035)	(0.061)	(0.049)	(0.081)
F-Stat on Excl. Instr.			624.2	47.8				
Panel B: Inverse hyperbolic sine transformation								
Cultivation	0.005	-0.001	0.114***	0.576***				
	(0.008)	(0.008)	(0.030)	(0.135)				
MJ Suit x Pcnt MML					-0.131***	-0.320***	-1.148***	-0.556***
					(0.034)	(0.062)	(0.046)	(0.074)
F-Stat on Excl. Instr.			635.9	56.4				
Method	OLS	OLS	2SLS	2SLS	OLS	OLS	OLS	OLS
Mun FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Base Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Add'l Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mun Trends	No	Yes	No	Yes	No	Yes	No	Yes
N	47,041	47,041	47,041	47,041	47,041	47,041	47,041	47,041

Note: In Panel A, homicides, marijuana suitability, and marijuana cultivation are transformed log(var+1) to accommodate 0 values. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. In Panel B, all variables with logs in Panel A are instead transformed using the inverse hyperbolic sine transformation. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.

Table A4 The Effect of US Marijuana Liberalization on Gun-Related Homicides in Mexico
Continuous Measure of Marijuana Cultivation Suitability

	(1)	(2)	(3)	(4)
MJ Suit x Pcnt MML	-0.339***	-0.458***	-0.484***	-0.407***
	(0.108)	(0.061)	(0.068)	(0.064)
Method	PPML	PPML	PPML	PPML
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Base Controls	No	Yes	Yes	Yes
Add'l Controls	No	No	Yes	Yes
State Trends	No	No	No	Yes
N	48,300	46,905	42,279	42,279

Note: The table reports count model results using poisson pseudo maximum likelihood (PPML), where the dependent variable is the count of gun-related homicides. Base controls include: 5 indicators for political party of mayor, (log) population, corn suitability x real price, (log) poppy eradication, (log) heroin seizures, (log) cocaine seizures. Additional controls included (log) unemployment, (log) primary school incompletion. Sample: 1996-2018. Standard errors clustered by municipality in parenthesis.