Vigilada Mineducación

THE IMPACT OF THE LEGALIZATION OF MEDICAL MARIJUANA IN THE OPIOID EPIDEMIC

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Tesis de maestría

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Escuela de Economía y Finanzas

Maestría en Economía (MSc)

Medelllín

2022

The Impact of the Legalization of Medical Marijuana in the Opioid Epidemic

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November 5, 2022

Abstract

We study the effects of marijuana legalization on demand for opioids in the United states. We tackle this question using transaction level data on the purchases of opioids by all pharmacies across the US between 2006 and 2012, together with a difference-in-discontinuity research design across two pairs of states: Michigan and Indiana, and New Mexico and Texas. We show that, on average, the legalization of marijuana has lead to a reduction in the purchases of opioids. However, this negative effects is mainly driven by a reduction along the Michigan-Indiana border, while there has been an increase along the New Mexico-Texas border. This ambiguous effects, which mimics the contradictory evidence found in the literature, suggest the existence of important heterogeneous effects and the need for further investigating such differences.

JEL Codes: K23, D01, I10, I18
Keywords: Opioid, medical marijuana, cannabis,liberalization, legalization, policy

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1 Introduction

Opioids, including prescription pain killers, are widely recognized as the cause of a public health emergency in the United States (Brill et al., 2020). Over the last two decades, mortality from opioid overdoses in the United States has increased at an alarming rate (CDC, 2021). Since 1999, overdoses with prescription opioids have claimed the lives of over 400,000 Americans (CDC et al., 2019). In this same period, changes in government policy towards marijuana have resulted in 33 states having legalized medicinal marijuana and 10 of them having legalized recreational marijuana (Coit, 2018). As legalization efforts are gaining traction with time, researchers and policy makers argue about the advantages and shortcomings of legal medical and recreational marijuana for different groups of people across the country.

Considering how dangerous opioids can be and these changes towards further legalization of marijuana, it is essential to study the effects that these policy changes may have on the opioid epidemic in the US. In this paper we analyze the effect that the legalization of medical marijuana has on the purchases of opioids from pharmacies in the United States. We do so by combining transaction level data on opioid purchases by all pharmacies in the county, together with a differences-in-discontinuity research design exploiting the legalization dates of medical marijuana across state borders. We find that legalization leads to a slower growth rate of the intake of opioids by pharmacies in the US.

Opioids are highly addictive, with a rapid progression to physiological dependence with tolerance and withdrawal, even at prescribed doses and within a short period of time (Hah et al., 2017). In 2012, the national opioid dispensing rate peaked at 81.3 prescriptions per 100 persons, and even though the dispensing rate has declined since then, by 2018 there were still an average of 51.4 prescriptions per 100 persons (CDC et al., 2020).[1] In the last few years drug overdose has rapidly become the leading cause of death for Americans under 50 years old (Katz, 2017). Considering the fatal consequences that the use of (medicated or unmedicated) opioids can have in the population, it has become clear the need for alternative non-opioid treatments.

In addition, as the legalization of medical marijuana expands, questions about how these new policies affect the already existing opioid epidemic in the country arise. The effects of this relationship are ex-ante ambiguous. On one hand, cannabis could offer a new alternative for pain treatment, thus reducing opioid consumption and overdoses. On the other hand, medical marijuana can become the gateway drug to more potent and dangerous substances in the long run (Burakoff, 2022).

Based on economic theory, two normal goods can act either as substitutes or complements. Policies supporting the liberalization of medical marijuana, will undeniably shift the availability and consumption of this substance in the market. Meaning that the supply of the medical marijuana

[1] Opioid dispensing rate corresponds to the amount of opioids that pharmacies dispensed in a period of time.

will significantly expand after its legalization. This could potentially increase or decrease the the consumption of opioids in the country. Either way affecting the opioid crisis in the United States. If medical marijuana and opioid are supplements then the demand for opioids will decrease after the legalization, meanwhile if the two goods are complements we will expect a reduction in the use of opioids, meaning the demand curve for opioid would have shifted. In other words, increased access to one good (e.g., the legalization of marijuana) could either negatively or positively affect the consumption of the other good (say, opioids) (Caulkins et al., 2016). Therefore the nature of marijuana and its effects on opioid crisis is what makes this an important topic for policy makers, researches and doctors across the country.

To answer our research question, we use the Washington Post DAE pain pills dataset, which contain data on the purchases of opioids by all pharmacies across the United States between 2006 and 2012. These data also contain the exact location of each pharmacy which allow us to georeference them. Using these data, we explore two events across two different state-borders: the legalization of medical marijuana in Michigan in 2007 and New Mexico in 2008, compared to their respective neighbouring states Indiana and Texas, which have not yet legalized medical marijuana. Using such legalization dates, we perform a difference-in-discontinuity research design. This design allows us to obtain a causal effect under the assumptions that the population, pharmacies and consumption patterns in nearby locations along the border are quite similar (in levels and trends) before the legalization of medical marijuana.

Using this identification strategy, we find the the legalization of medical marijuana has significant effect of -4.7% on the purchase of opioid by pharmacies. However the results were contradictory when the estimation was done for each specific pair of states separately. While in Michigan the legalization had a negative effect, we found a positive relationship between the two goods in New Mexico. This conflicting results implies an important heterogeneous effect of marijuana legalization on opioid consumption and the need for further research studying its determinants.

This paper is related to the literature studying the different effects of marijuana legalization and the determinants and effects on the opioid epidemic. For instance, research has shown that in states with medical cannabis laws, opioid overdose deaths have risen more slowly than in states where cannabis is not legal (Bachhuber et al., 2014). In the same line, Chihuri and Li (2019) argue that legalizing marijuana could lead to a modest reduction in opioid prescriptions, but describe the scientific evidence as inconsistent and inconclusive. Moreover, Wen and Hockenberry (2018) show that a state implementation of medical marijuana laws is associated with a 5.88% lower rate of opioid prescriptions. In addition, the implementation of adult-use (recreational) marijuana laws, which all occurred in states with existing medical marijuana laws, was associated with a 6.38% lower rate of opioid prescriptions. Hsu and Kovács (2021) suggests that counties withe more cannabis

dispensaries saw fewer opioid related deaths.

Additionally, the venues in which consumers can legally purchase marijuana (dispensaries), appear to be particularly important in the relationship between marijuana and opioids. Powell et al. (2018) show that the opening of legal medical marijuana dispensaries reduces opioid overdoses by 15 percent. This result was shared by Hsu and Kovács (2021) who concluded that counties with more cannabis dispensaries experience fewer deaths within the county.

Our research contributes to the academic and political discussion of these issues by providing another angle in the relationship between the legalization of medical marijuana and the opioid epidemic, using purchases of pain pills by pharmacies across neighboring states in the US. To the best of our knowledge, this measure of pain pill purchases has not been used to study the relationship between these variables before. Furthermore, we present an novel identification strategy to study this question, which has not been widely used. One important exception is Dragone et al. (2019) who uses a similar strategy and the Oregon-Washington border to study the effects of marijuana legalization on crime.

According to medical marijuana patient registry statistics, most medical marijuana patients cite severe or chronic pain as a reason for seeking treatment (Smith, 2020). Therefore, if marijuana is a substitute for painkillers, regardless of the medical legitimacy, then the increased access to marijuana should decrease opioid use and reduce the amount of opioids prescribed to the citizens in the United States, and in consequence help alleviate this epidemic in the country.

The remainder of the paper consists of the following. In Section 2, we briefly talk about the origins of the opioid epidemic, the legalization of marijuana and some of its effects found in the literature. In Section 3, we describe the data, some summary statistics and we present our identification strategy. Section 4 presents the main results of the paper. Section 5 concludes.

2 Background

In this section we contextualize the opioid epidemic, its beginnings and consequences. Afterward, we give some context regarding the legalization of medical marijuana in the United States, as well as some of the effects of this legalization process identified in the literature.

2.1 Origins and some effects of the opioid epidemic

Between 1999 and 2019, deaths by opioid related reasons have risen enormously. To the point that nearly 500.000 people have died from an overdose involving some kind of opioid, either prescription as well as illicit opioids (CDC, 2021). From 2018 to 2019, the amount of drug overdoses in the

country increased by 5% and has quadrupled since 1999.

This problem in United States began with a combination of well-intentioned efforts to improve pain management by doctors in the country and audacious and competitive marketing campaigns by pharmaceutical manufacturers (Morin et al., 2017). The groundwork for the crisis began in the 1980s, when pain was finally seen as a problem that needed treatment and therefore the United States began to pass multiple intractable pain treatment acts, which stop the prosecution of doctors who treated pain with controlled substances (Vadivelu et al., 2018).

As this new conditions began to spread across the country, the idea that opioids might be safer and less addictive than was previously thought began to take root. Multiple studies at the time started to support this theory and concluded that opioids where only addictive when used recreationally and not when used to treat pain. Due to this environment the prescription for opioids increased between the 1980s and the early 1990s. In the mid-1990s with the introduction of new opioid-based products and the re-branding of Oxycodone by pharmaceutical companies started to establish opioid as the preferred method to treat chronic pain (DeWeerdt, 2019).

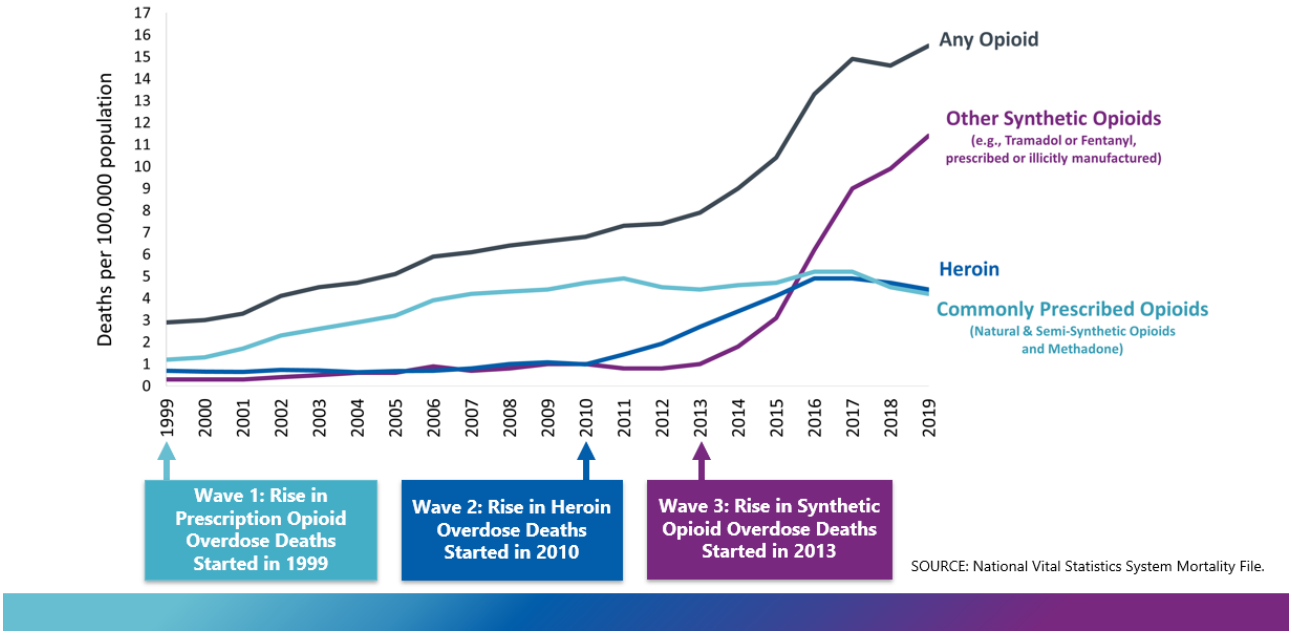
During this time pharmaceutical companies promoted, sponsored doctors and lobbied lawmakers introducing new opioid-based products. In particular a sustained re-release formulation of Oxycodone, named OxyContin, manufactured by Purdue Pharma. This company, among others, promoted their opioid products heavily and sponsored continuing medical-education courses, funded professional and patient organizations and sent representatives to visit individual doctors. All throughout that process claiming and emphasizing the efficacy and low potential for addiction of prescription opioids. Which research has shown in not true because opioids are highly addictive (CDC, 2021) and their potential for long-term pain treatment is minimized by the tolerance that people can develop, and there are reports that explain that people can become more sensitive to pain with constant and long term opioid consumption (DeWeerdt, 2019).

Additionally, DeWeerdt (2019) explains how the structure of the health-care system in the United States also contributed to the over prescription of opioids. Many medical professionals work in private practices, where they can increase their income by seeing more patients and ensuring positive and high patient satisfaction rates. Which can insentience the over prescription of all types medication, especially pain management medication. Moreover, health insurance companies often offer plans that cover pain medication but not pain-management approaches, such as physical therapy, due to opioids being a fast and cheap alternative in short run.

To better understand the origins of the opioid crisis in the United States, the CDC (2021) describes the epidemic in three specific waves. The first one in the 1990s when the increase of prescribed opioids began and there was an increase of deaths in the country by these types of opioids. This

involved mainly natural or semi-synthetic opioids. In 1999, by the end of the decade, the increase of deaths involving opioids was accelerated and started to move from predominantly rural areas to urban areas. Additionally, the use of opioids transition from natural and semi-synthetic opioids to other synthetics opioids that have been proven more dangerous (Miloucheva, 2021). The second wave began in 2010 when the rates of overdose by Heroin increased rapidly. The third and (hopefully) final wave started in 2013. In this year deaths by overdose using synthetic, illicitly manufactured opioids increased significantly. These three waves are shown in Figure 1.

Figure 1: Three waves of the rise of the opioid epidemic



Note: In this figure we show the graphic representation of the 3 moments in which the opioid epidemic has expanded, constructed by CDC (2021)

This epidemic has had devastating consequences in public health and the socioeconomics tendencies within the country. In Klobucista (2022) they specify that the opioid crisis is causing high rates of hepatitis C, HIV, and other diseases, mainly due to shared syringes. Mothers can pass an opioid dependency on to their children if they use opioids while pregnant causing neonatal abstinence syndrome, or withdrawal symptoms to newborns. Additionally the rate of children in foster care has strongly increased due to the amount of parent who are addicted to opioids.

The CDC (2021) calculated the opioid crisis costs the United States $78 billion per year, this accounting from health care, lost productivity, treatment programs, and legal expenses. In 2017 Treasury Secretary Janet Yellen, expressed the link between the opioid epidemic and declining labor-force participation among "prime-age workers". This was later confirmed by Krueger (2017) and Lelling (2018) who explain the 20% and 25% of the decline in participation among men and

women respectively from 1999 to 2015 was due to the increase of the opioid epidemic in the country.

2.2 Legalization of medical cannabis

The state level marijuana liberalization policies have been changing, progressing and evolving for the past five decades. In the United States 37 of its states, four permanently inhabited U.S territories and the District of Columbia have legalized the use of cannabis for medical purposes (Garcia and Hanson, 2022). Even with this, the medical marijuana laws variate significantly from state to state changing in basic parameters as how it is produced and distributed within the state, how can it be consumed , limiting the THC content [2] and what medical condition can be used for.

The first state to legalize medical cannabis was California in 1996 with the Proposition 215, after this initial shock several other states, like Alaska, Nevada, Oregon and Washington followed with successful ballots for the legalization of medical marijuana in 1998. Next in 2000 Hawaii became the first state to legalized medical cannabis by an act of state legislature. By 2016 the legalization of medical marijuana became widespread across the country, with the majority of states adopting some kind of law for cannabis liberalization (Garcia and Hanson, 2022).

In the map bellow figure 2 we can see the year of legalization of medical marijuana of all the states in the United States, in the map in white we have all the states that have not yet legalized medical marijuana like Idaho, North Carolina, Nebraska, Indiana, Texas, among others. And in a blue gradient we have all the states that have legalized medical cannabis, in the lightest blue we have the states that legalized it first and as the color grows darker the year of legalization is more recent, which is the case for Alabama and Mississippi, the last 2 states in legalized medical marijuana in 2021.

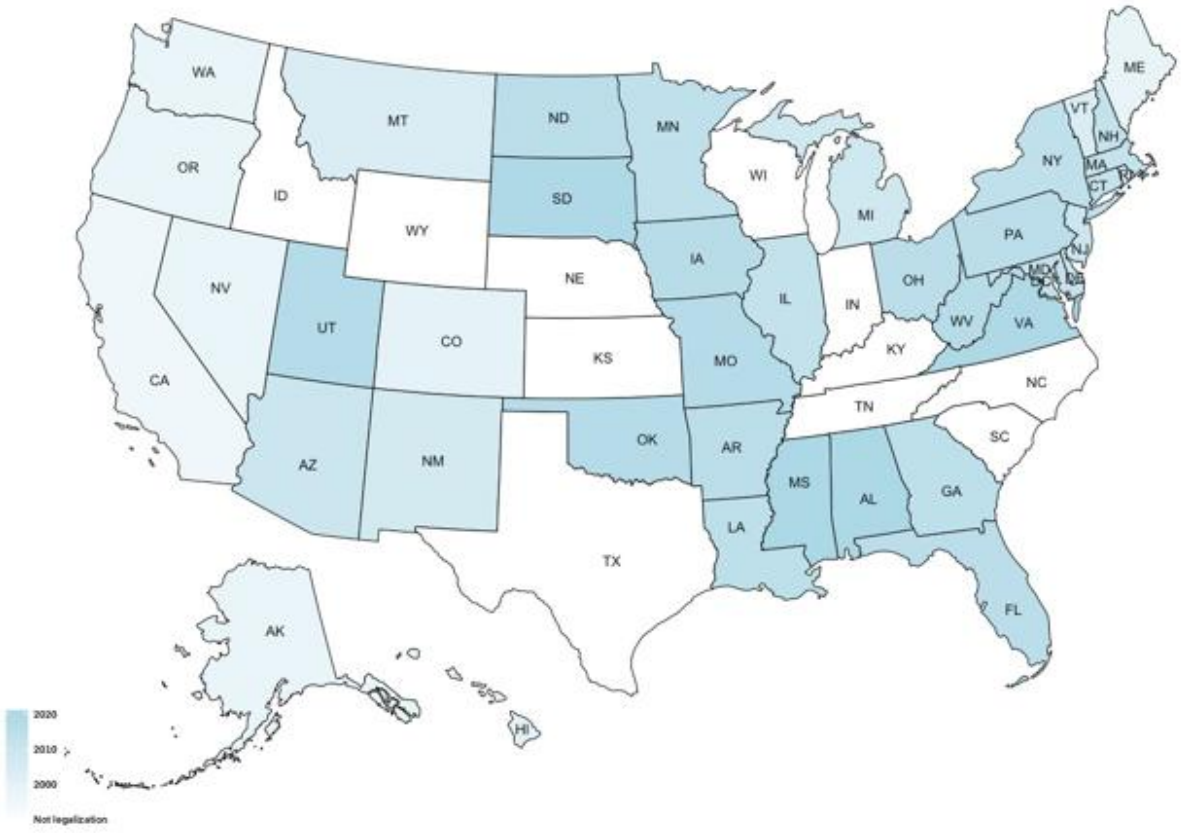
Despite the different types of cannabis legalization at state level in the country[3], federal law has prohibited the use and distribution of marijuana in the United States since 1937 (Pacula and Smart, 2017). This environment has resulted in vast spectrum of marijuana legalization policies across the United States, giving researches and academics the opportunity to quantitatively evaluate and estimate how marijuana legalization policies affect multiple health and socioeconomic outcomes. Nevertheless, this is not the case, and the literature on the subject is not as vast as it could be and what it exists has often conflicting and somewhat inconsequential findings.

The shifts in policy seen over the past few decades have been influenced by a variety of different situations, in Raphael and Stoll (2009) and Reuter et al. (2001) the authors explain how the

[2] Tetrahydrocannabinol - the major psychoactive component of cannabis (Gupta, 2021)

[3] All states can be at a different point in the legalization time line, the states can have decriminalization only, cannabidiol (CBD) only, medical marijuana law only, decriminalization and CBD law, decriminalization and medical marijuana law and decriminalization, medical marijuana law and legalization

Figure 2: Years of Medical Marijuana Legalization in the US



Note: In this figure we show the graphic representation of the year of legalization of medical marijuana for all states in the US, the states in white are the ones that have not legalized medical marijuana, all the states in blue have legalized medical marijuana, the gradient goes from 1996 in the lightest blue to 2021 in the darker blue.

increasing expenses to the state budget of arresting and imprisoning nonviolent drug offenders can influence the process of cannabis legalization within the state. Furthermore, Hill (2015) and Koppel et al. (2014) analyze the involvement of the increasing scientific evidence that the marijuana plant has therapeutic benefits, on the legalization of cannabis. Additionally, Caulkins et al. (2015) and Kilmer et al. (2010) explore the possibility of using the legalization of cannabis as an additional source of tax revenue as a result of pressured state budgets.

As more and more states are moving towards the legalization of cannabis–whether medicinal, recreational or both–and the legal reforms of this states are changing and evolving, a new industry of legal cannabis business is growing and expanding in the country. This includes research and development of new cannabis-based products, the production and grow of the marijuana plant, the distribution, among others. The effects in the overall economy of this new industry could have a significant impact in the tax revenue of the country, as seen in Washington and Colorado, where

the legal cannabis tax revenue could increase up to 10% after the legalization has been establish (Krishna, 2022). Additionally, with a new industry the potential for new jobs increases and a boost in the overall economic activity in the cannabis industry in these areas. This is the case for states like Colorado and Nevada, where after the infrastructure for legal marijuana business was complete the job market opened up to 41.000 and 81.000 job respectively (Johnston, 2016; Rindels, 2018).

In prior studies, researchers have focused on the relationship between alcohol and marijuana consummation, and how depending on their type of relation, the legalization of marijuana can potentially increase or decrease the alcohol consumption in the country. This has mainly been done using policies that affect the availability of alcohol, like an increase in the minimum drinking age in the state (Good and Evans, 2015). Most literature on the subject suggests that marijuana consumption in young adults increases after the alcohol availability is lowered, hinting that marijuana and alcohol are substitutes, this is the case for studies like DiNardo and Lemieux (1992), Chaloupka IV and Laixuthai (1994) and Crost and Guerrero (2012). The contrary has been argue by Pacula (1998), who shows that even if the availability of alcohol is limited by a policy, the early use of alcohol by young adults encourages them to experiment with other substances being the most common one marijuana.

Another important impact that the legalization marijuana brought is an increase in the overall rate of car crashes with injuries and the rate of fatal crashes. Farmer et al. (2022) finds that states where marijuana was legal for people who are 21 and older the car crashes with injuries rate rose 6% and the rate for fatal crashes increase by 4%. They demonstrated that marijuana consumption slows reaction time, inhibits road tracking and lane keeping, and impairs one's ability to maintain attention, which are abilities necessary for safe driving.

In the past few years a lot of studies have repeatedly tried to identify the relationship between the legalization of marijuana and crime. Using county-level data for California, Hunt et al. (2018) show that there is no apparent relationship between the laws that legally permit dispensaries and the violent crimes that were reported. Additionally, they found a negative and significant relationship between dispensaries within a county and the property crime rates in the same county. However, Lu et al. (2021) finds that the legalization of marijuana in Colorado had little to no effect on the rates of property or violent crime. Nevertheless, a policy changes inside the state seems to be associated with a long-term decline in burglaries in the state. Contrary to those findings, Wu et al. (2020) studying how the legalization of marijuana in Colorado and Washington state can affected crime rates in neighboring states, determined that cannabis laws could have a negative impact in certain mayor crimes in nearby jurisdictions. Additionally, Dragone et al. (2019) compares Oregon (legalized in 2014) and Washington (legalized in 2012), and finds that after the legalization of marijuana, crime dropped between 15% and 30% in Washington the two years after the legalization.

With the increase in popularity of cannabis and most states adopting some type of marijuana liberalization policy. The use of cannabis as medicine both prescribed and non-prescribed has expand across the country. Researchers wonder about how this new environment is interacting with already big crisis regarding opioids in United States. Although there is research and evidence that suggest that states with medicinal marijuana laws see a decline in the usage of opioids and opioid-related deaths (Chihuri and Li, 2019); there is contradictory literature that proofs the opposite and shows that over a long period of time marijuana legalization is not associated with a decrease in opioid-related deaths (Burakoff, 2022). Despite the conflicting arguments (Kvamme et al., 2021) proposed marijuana as an effective intervention technique to address the ongoing opioid epidemic in the USA.

3 Data

In this section we describe the main sources of the data that we use to study the relation between the legalization of medical cannabis and the opioid crises in the United States. After presenting some summary statistics, we present our identification strategy, which consists on a spatial differences-in-discontinuity model.

3.1 Data description

In this paper we use the database from The Washington Post in which they track the path of every opioid pill from the manufacturer to end pharmacy in the United States from 2006 to 2012.[4] This database is at the transaction level, that is, it has all the individual transactions made by all the pharmacies in the United States in order to acquire opioid pills. Each row of the database represents a sale from a supplier to a pharmacy. In the data we can identify each transaction, its date, the amount, the supplier, the pharmacy, its location, among other variables. These data are also used in other academic articles such as Miloucheva (2021) and Stirling et al. (2019)

Even though there is multiple types of opioids in the market and the different data on those, the data only contains information in two types of opioids, Oxycodone and Hydrocodone. This is because the 2 combine represent the 75% of the market share of opioids sold in the United States (CDC, 2021). Additionally, Rich et al. (2019) specify that the shipments on the other 10 types of opioids in the market were much smaller, meaning they were shipped in much lower quantities and were diverted –when pills do not go directly to a patient and end up at another source like the black market– at far lower rates over the seven years included in the database. Data on shipments

[4]This data is available at https://www.washingtonpost.com/national/2019/07/18/how-download-use-dea-pain-pills-database/. The Washington Post has used these data for several journalistic articles and are now publicly accessible to both journalist and researchers to promote a deeper understanding of the regional and local effects of the opioid crisis in the country.

that did not end up in the hands of potential consumers was not included in this data set.[5]

We have also cleaned the data set to include only information on 2 pairs of states Michigan - Indiana and New Mexico - Texas. This distention was made to better understand the impact that the legalization of medical marijuana has in the intake of opioid pills by pharmacies in states that have legalized medical marijuana –Michigan (2008) and New Mexico (2007)– against their neighboring states that have not yet legalize it (Indiana and Texas respectively). This process left us with a total of 385.153 observations. We used the year of legalization of medical marijuana in each state to define the pre and post periods for each pairs of states.

In April 2007 medical marijuana was legalized under the Lynn and Erin Compassionate Use Act, into law Senate Bill 406, in New Mexico, it initially allowed the use of medical cannabis with the recommendation of a physician for the treatment of specific medical conditions such as HIV/AIDS, cancer, glaucoma, multiple sclerosis, and epilepsy. In Michigan, the use of medical marijuana was legalized on November 2008, with the passage of Proposal 1, the Michigan Compassionate Care Initiative. The new law included the legalisation of possession of medical marijuana up to 2.5 ounces or 71 grams for patients with certain medical conditions and the approval of a physician; it allowed patients or their caregivers to cultivate up to 12 cannabis plants but it did not allowed for dispensaries to operate within the state.

Furthermore, we focus only in retail and chain pharmacies in the four states and left out all types of practitioner[6] intake of opioid pills, this is because the retail and chain pharmacies represent in all four states over 99% of the transactions made, therefore the intake by practitioners can be statistically irrelevant for this study.

This data set includes information on the specific location of each individual pharmacy, it contains variables like address, county, postal code, among others. With this information we georeferenced each pharmacy location, which means we transform a specific location into coordinates (latitude and longitude). After this process we calculated the shortest distance form a particular pharmacy to the closest state line with its corresponding neighboring state using a GIS software. We aggregate these data at the quarter and pharmacy level to smooth out possible cyclical fluctuations and purchasing patterns, given that not all pharmacies purchase pills with a relatively high frequency.

3.2 Summary statistics

Table 1 reports the number of pharmacies before and after the legalization of medical marijuana in Michigan, Indiana, New Mexico and Texas, as well as the number of pharmacies within a 100

[5] Shipments from distributors to themselves or other distributors.

[6] Practitioners include simple practitioner, practitioner-DW/100, practitioner-DW/30 and practitioner-DW/275.

km of the respective state border. It also reports the average distance of a pharmacy to the state border for all the pharmacies and those located within 100km of the border.

In Figure 3, we show the average change of the intake of opioids by pharmacies in the US, comparing the time before the year of legalization of medical marijuana and the time after the policy, which was 2008 in Michigan and 2007 in New Mexico. In the maps we can see bigger, red and orange circles for pharmacies in which the intake of opioid expanded at a greater level than the smaller dots in blue and green which represent pharmacies in which the intake of opioids increased at a much slower rate.

In Figure 4a, we can clearly observe that are more of the bigger red circles in Indiana's side of the border than its counterpart Michigan where we can see more of the blue and green dots. This means that the intake of opioids by pharmacies grew more in the pharmacies around the border in Indiana than the pharmacies near the state line in Michigan. This conclusion is not as evident for the other pair of states, despite of that, in Figure 4b we still fewer red and orange circles around New Mexico's side of the border and a lot more dots of all types in Texas, the reason for this distinction may be the difference in population in both pairs of states and the number of pharmacies.

The previous statement is also visible in Table 2 in which we can see an overall increase on the average intake of opioids by pharmacies in both types of opioids (Oxycodone and Hydrocodone) in the 4 states (Michigan, Indiana, New Mexico and Texas) being studied in this paper. This tendency is due to the opioid crisis being a really in the United States and the legalization of medical marijuana being only one of the possible determinants of the epidemic. What we want to find is a smaller grow in the states where medical marijuana had been legalized (Michigan and New Mexico). Which is the case for Michigan and Indiana, where the average of the intake of opioids increased, but the expansion was much greater, in about 10%, in Indiana (41.32%) than is counterpart Michigan (31.48%), this result is replicated for both types of opioid and the overall average as well as the average calculated for pharmacies within 100km of the border, which is shown in Table 3.

Following this logic, Michigan and Indiana could be the pair of states that contribute to reinforce the idea that the legalization of medical marijuana could have an impact in the opioid crisis but this still needs to be proven formally using an empiric strategy. Nevertheless, the same behaviour is not seen in the other pair of states, New Mexico and Texas, where the increase on the average intake of opioids is much smaller in Texas (123.1%), state that did not legalized medical marijuana, than New Mexico (166.06%), the state that did. This can imply ambiguous results which could corroborate the literature that explains that the legalization of marijuana has no real effect on the opioid crisis or at least that the effects are only in the short run.

It is important to bear in mind that the increase of the intake of opioid by pharmacies in the United States cannot only be explain by the policies on marijuana in the different states. This is due to the legalization of medical marijuana, in this case, in not the only factor at play, and many other determinants can contribute to the expansion of the opioid epidemic in the country. Some of this factors could be the The Great Recession of 2008, the aggressive marketing strategies of the pharmaceutical companies, the unemployment rate, specific characteristics of the individual states, among others.

Table 1: Descriptive Statistics

	Michigan	Indiana	New Mexico	Texas
Panel A: All Pharmacies				
N pre legalization	2386	1030	285	4413
N post legalization	2569	983	345	5588
Average distance to the border	165.21	195.32	264.64	596.56
Panel B: Pharmacies within 100km of the border				
N pre legalization	237	288	52	169
N post legalization	236	268	60	206
Average distance to the border	58.2	52.17	44.40	42.42

Note: Number of pharmacies (N) in each state before and after the legalization of medical marijuana; in the whole state and within a 100km of the border, additionally this table has information on the average distance of the pharmacies to the closest state line with its neighboring state, in all four states and the average distance of pharmacies within a 100km of the border with its neighboring state.

3.3 Identification strategy

Our paper follows a differences-in-discontinuity research design at two sate borders in the United States, the MI-IN border and the NM-TX border. This type of design will allow us to identify the effect of the legalization medical marijuana at the 2 state borders analyzed in this paper, where the differences between the states are minimized and we can better understand the impact of a policy.

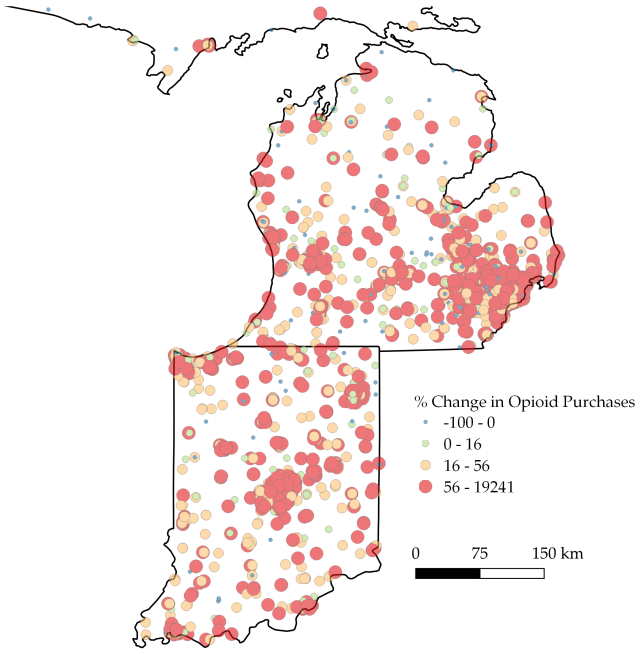
Formally, we estimate the following equation:

$$ln(purch)_{ist} = \theta_i + \lambda_t + \alpha \cdot post_t + \beta \cdot T_s \cdot post_t + f(geo_i) \cdot post_t + g(geo_i) \cdot T_s \cdot post_t + \xi_{ist} \quad (1)$$

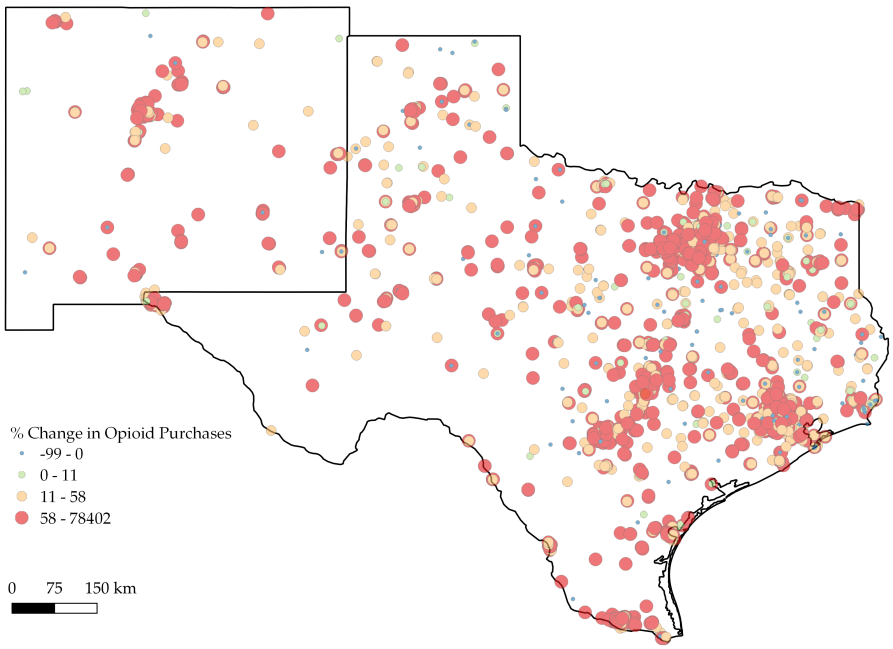
where $ln(purch)_{ist}$ denotes the log of the purchase of opioids by pharmacy i in state s and quarter t. We also define the following binary variables: first, $T_i = 1$ if the state i has legalized medicinal marijuana (MI and NM), and $T_i = 0$ if the state i has not (IN and TX); second, $post_t = 1$ if year t $>$ 2008 for MI-IN and year t $>$ 2007 for NM-TX, and $post_t = 0$ otherwise. We also include $f(geo_i)$ and $g(geo_i)$, which denote polynomials of the same order based on pharmacy i's distance to the state border. These functions of distance are crucial for identification in these settings as they allow for heterogeneity in opioid purchases depending on the pharmacy's distance to the

Figure 3: Average Percentage Changes in Opioid Purchases

(a) Michigan and Indiana



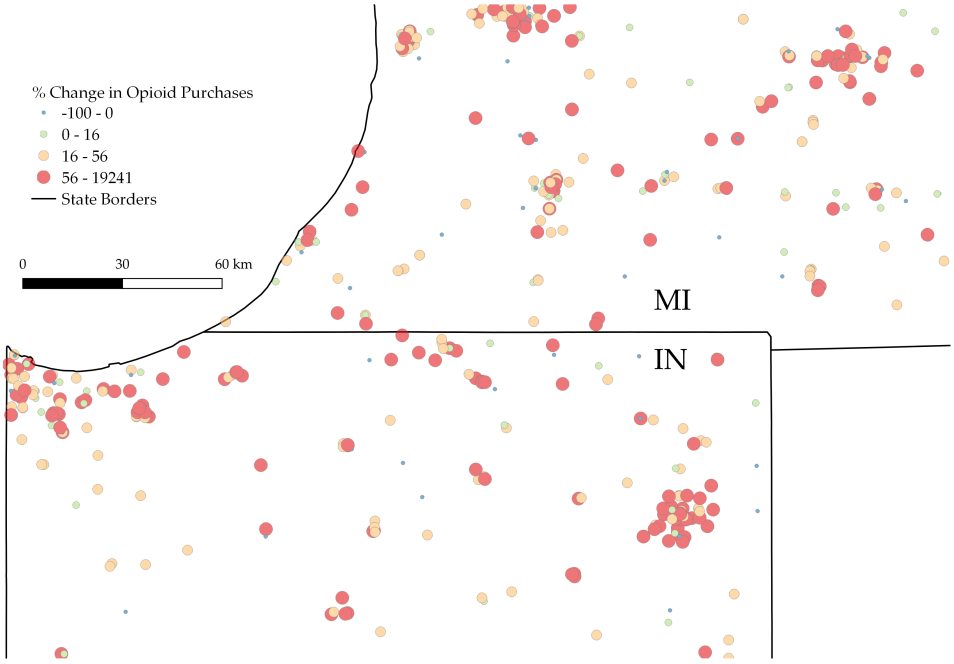
(b) New Mexico and Texas



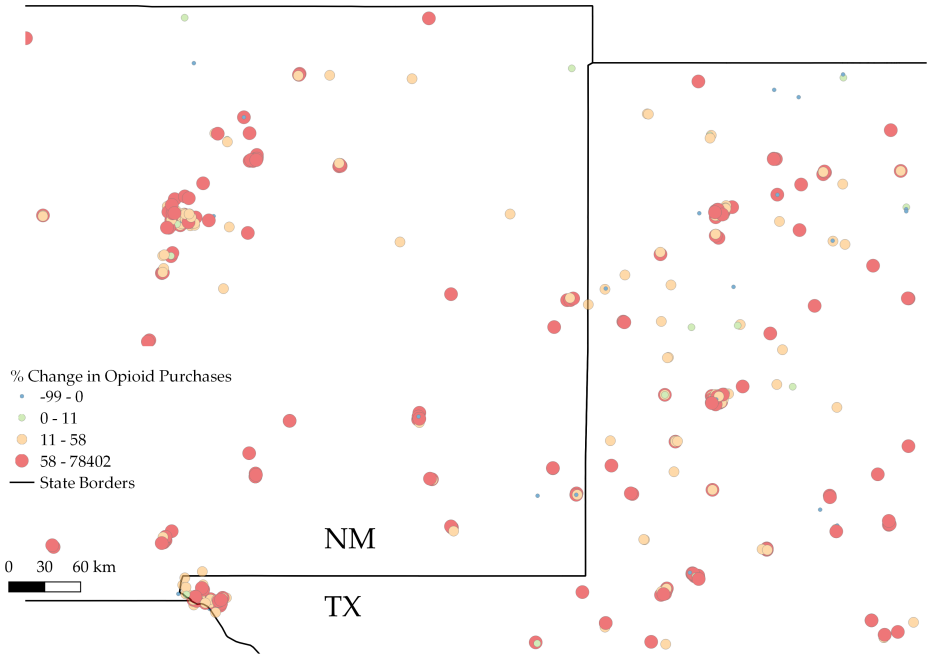
Note: In this figure we show the graphic representation of the average change in the intake of opioids by pharmacies in MI-IN and NM-TX, in the maps there are 4 types of circles, the big red and medium orange represent the pharmacies in which the average purchasing rate grew a lot. The green and blue dots represent pharmacies where the average intake increased in a much smaller quantity.

Figure 4: Average Percentage Changes in Opioid Purchases near State Borders

(a) Michigan and Indiana



(b) New Mexico and Texas



Note: In this figure we show the graphic representation of the average change in the intake of opioids by pharmacies in MI-IN and NM-TX, focusing in the border between the pair of states. In the maps there are 4 types of circles, the big red and medium orange represent the pharmacies in which the average purchasing rate grew a lot. The green and blue dots represent pharmacies where the average intake increased in a much smaller quantity.

Table 2: Summary Statistics - Purchases of Opioids
All Pharmacies

	Pre t <2008	Post t >2008	Percentage Change (%)
Michigan			
Oxycodone	114.01	141.87	24.43
Hydrocodone	144.12	197.58	37.09
Total	248.29	330.74	33.20
Indiana			
Oxycodone	136.94	199.35	45.57
Hydrocodone	183.97	254.32	38.24
Total	317.08	449.22	41.67
	Pre t <2007	Post t >2007	Percentage Change (%)
New Mexico			
Oxycodone	217.44	354.55	63.06
Hydrocodone	116.62	165.50	41.91
Total	326.16	514.13	57.63
Texas			
Oxycodone	62.40	71.62	14.78
Hydrocodone	168.95	211.15	24.98
Total	215.13	265.50	23.41

Note: Average purchases in mg, before and after the legalization of medical marijuana, of the purchasing of opioid by pharmacies in Michigan, Indiana, New Mexico and Texas, estimated from the data reported in the Washington Post

Table 3: Summary Statistics - Purchases of Opioids
Pharmacies located within 100km of the State Border

	Pre t <2008	Post t >2008	Percentage Change (%)
Michigan			
Oxycodone	122.52	142.61	16.40
Hydrocodone	148.91	200.69	34.77
Total	268.74	340.50	26.70
Indiana			
Oxycodone	101.95	147.51	44.69
Hydrocodone	137.95	200.57	45.39
Total	235.71	344.81	46.28
	Pre t <2007	Post t >2007	Percentage Change (%)
New Mexico			
Oxycodone	158.21	327.74	107.16
Hydrocodone	142.92	220.32	54.16
Total	299.24	544.53	81.97
Texas			
Oxycodone	64.65	67.37	4.21
Hydrocodone	143.12	210.98	47.41
Total	192.48	265.13	37.74

Note: Average purchases in mg, before and after the legalization of medical marijuana, of the purchasing of opioid by pharmacies within a 100km of the border in Michigan, Indiana, New Mexico and Texas, estimated from the data reported in the Washington Post

state border. Finally, θ_i and λ_t denote pharmacy and time fixed effects, respectively, and ξ_{ist} are residual determinants of the purchases of opioid by pharmacies. The coefficient β is the spatial difference-in-discontinuity estimate: it estimates the change in the average purchases of opioids by pharmacies, between before and after the the legalization of medical marijuana in the treatment states.

The main identification assumption behind this empirical strategy is that regions and individuals in locations near to the border had similar trends in opioid consumption before marijuana was legalized in one of the states. Notice that, this is a weaker assumption relative to a standard regression discontinuity approach, which would require that pharmacies and individuals from both sides of the border are quite comparable. We do not think this is true in this case given the US Federal system, which allows each state to set its own policies that sometimes have an important effect on the economic activity across the border. For instance, the fact that medical marijuana was legalized in Michigan in 2007 but it has not yet in Indiana, suggest the existence of important political and institutional differences. The assumption of the differences-in-discontinuity design is that as long as these differences remain constant over time, estimation of equation (1) renders a causal estimate of the policy. In addition, it is necessary that the trends of other confounders do not change significantly along the border. In a future version of the paper, we intend to formally test this assumption using event studies and balancing test.

4 Results

Some preliminary evidence about the effect of the legalization of medical marijuana on the opioid crisis is given in the previous section, a more formal estimation is found in Table 4, which reports our results from the main equation (1) of this paper, in this estimation $f(geo_i)$ and $g(geo_i)$ were specify as second order polynomials of the shortest distance from each pharmacy to the state border with its neighboring state (MI-IN and NM-TX). The estimate for the average effect of the legalization of medical marijuana on the purchasing of opioid by pharmacies in general is negative -column 1-, which can imply that the liberation of medical marijuana can slow down in 4.7% the expansion of the opioid crisis, this suggests that medical marijuana and opioids may be substitutes.

The estimation was also done individually for each type of opioid, finding a significant and negative relationship of Oxycodone and the intake of opioids by pharmacies, this result was obtain without discriminating by each pair of states. In Table 4, column 2 we can see that the legalization of medical marijuana can come with a 14.10% slow down in the increase of the average purchasing of opioids by pharmacies.

Nevertheless, when the estimation is done separately for each pair of states the results found are

somewhat different. In Table 5 we can see the results for New Mexico and Texas, in this pair of states the effect of the policy of medical marijuana has a positive effect on the average change of the intake of opioids by pharmacies, this means that for this pair of states we saw a much bigger grow in the purchase of opioid by pharmacies in the state that did legalized medical marijuana, New Mexico, than the change in Texas, the state where medical marijuana was not legalized. This same result was replicated when the estimation was done separately for oxycodone, which we can see in the second column and hydrocodone in column 3, for the same pair of states. This could suggest that the two goods may be complements and medical marijuana could be a gateway drug to harder drugs, as opioids are.

Contrary to the findings in New Mexico and Texas, in the estimation done for Michigan and Indiana, Table 6, we observe a negative relationship between the legalization of medical marijuana and the intake of opioid by pharmacies, this means that in areas close to the state border, Michigan–which legalized marijuana–had a much smaller increase of the intake of opioids than its counterpart Indiana–which did not. This suggests that medical marijuana could have an impact on the opioid crisis, due to the legalization of medical marijuana contributing to a smaller expansion of the opioid epidemic. This results alludes to the theory that medical marijuana and opioid are in fact substitutes and therefor the increase availability of medical marijuana can decrease the demand for opioids and consequently the necessity of purchasing opioid by pharmacies can decrease as well.

In the first column from Table 6, we observe the negative impact of 13.79% of the legalization of medical marijuana on the average intake of opioids by pharmacies, for Michigan and Indiana. This negative relationship was also found when the estimation was done separately for each type of opioid. When we focus on oxycodone -in column 2- we found that the legalization of medical marijuana can imply a 23.86% slow down in the average intake of opioids by pharmacies. The same was found for hydrocodone in the third column, where the impact of the legalization drove to a 10.56% slow down of the average purchasing of opioids by pharmacies.

A second set of estimations was done around the border of each pair of states, setting a maximum distance of 100km from the respective neighboring state line. In this estimations $f(geo_i)$ and $g(geo_i)$ were specify as first order polynomials of the shortest distance from each pharmacy to the state border with its neighboring state (MI-IN and NM-TX).

The same result were found in the estimations done around the border, for the general estimation in which we do not filter by the states in the study, in Table 7, we found a negative relationship (-6.8%), meaning that the legalization of medical marijuana has an overall negative impact on the purchasing of opioids, this does not mean that the legalization implies a reduction on the intake of opioids by pharmacies, due to the legalization of medical marijuana only being one of

the determinants of the opioid crisis in the US. The negative impact only implies a smaller grow in the states that did legalized medical marijuana. The result was also seen for the estimation done for oxycodone (-17.3%) and hydrocodone (-0.99%) separately, but we see a stronger and more significant effect in oxycodone than the effect obtain with hydrocodone.

When the estimation was dome individually for New Mexico and Texas -Table 8- we found a positive relationship between the legalization of medical marijuana and the average intake of opioids by pharmacies, this results were consistent in the three models run, without any opioid type distention in column 1, for oxycodone only in column 2 and for hydrocodone alone in the third column. This results hint at the idea that the two goods can be complements. Nonetheless, when we focus in the Michigan and Indiana -Table 9- we found again a negative relationship meaning that the legalization of medical marijuana can imply a slow down in the average intake of opioids by pharmacies, suggesting that medical marijuana and opioids are substitutes.

Given the opposite results found in the estimations done for both pairs of states, in Michigan - Indiana we found a negative relationship between the legalization of medical marijuana and the purchase of opioids by pharmacies, while in New Mexico - Texas the effect was positive. This could suggest that there is ambiguity in the results, and this subject need to be further studied to better understand the actual relationship between the legalization of medical marijuana and average intake of opioid by pharmacies and its effects on the opioid epidemic.

Table 4: The Effect of Medical Marijuana on the Purchasing of Opioids by Pharmacies

	(1) All	(2) oxycodone	(3) Hydrocodone
Post	0.32^{***}	0.32^{***}	0.34^{***}
	(0.01)	(0.02)	(0.01)
Post*Dist	-0.00^{***}	0.00^{**}	-0.00^{***}
	(0.00)	(0.00)	(0.00)
Post*Dist^2	-0.00^{***}	-0.00^{***}	-0.00^{***}
	(0.00)	(0.00)	(0.00)
Post*T	-0.05^{*}	-0.15^{***}	0.00
	(0.02)	(0.03)	(0.02)
Post*Dist*T	0.00^{***}	0.00^{***}	0.00^{***}
	(0.00)	(0.00)	(0.00)
Post*Dist^2*T	-0.00^{***}	-0.00^{***}	-0.00
	(0.00)	(0.00)	(0.00)
N	209172	176425	208728

Note: This table reports the estimation of the effects of the legalization of medical marijuana in the intake of opioids by pharmacies in all four states of this study and both types of opioids, this is done using the equation (1) and employing second-order polynomials of distances. In the second and third column we explore the same estimation but specifically for each type of opioid, Oxycodone and Hydrocodone respectively. Robust standard errors are in parenthesis, $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 5: The Effect of Medical Marijuana on the Purchasing of Opioids by Pharmacies New Mexico and Texas

	(1) All	(2) oxycodone	(3) Hydrocodone
Post	0.26^{***}	-0.09^{**}	0.33^{***}
	(0.02)	(0.03)	(0.03)
Post*Dist	-0.00^{***}	-0.00^{***}	-0.00^{***}
	(0.00)	(0.00)	(0.00)
Post*Dist^2	-0.00^{***}	-0.00^{***}	-0.00^{***}
	(0.00)	(0.00)	(0.00)
Post*T	0.23^{***}	0.62^{***}	0.09
	(0.05)	(0.08)	(0.07)
Post*Dist*T	-0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)
Post*Dist^2*T	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
N	125318	97211	125033

Note: This table reports the estimation of the effects of the legalization of medical marijuana on the intake of opioids by pharmacies compering New Mexico and Texas, this is done using the equation (1) and employing second-order polynomials. In the second and third column we explore the same estimation for Oxycodone and Hydrocodone, separately. Robust standard errors are in parenthesis, $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 6: The Effect of Medical Marijuana on the Purchasing of Opioids by Pharmacies Michigan and Indiana

	(1) All	(2) oxycodone	(3) Hydrocodone
Post	0.40^{***}	0.40^{***}	0.45^{***}
	(0.01)	(0.02)	(0.01)
Post*Dist	0.00^{***}	0.00^{*}	0.00^{***}
	(0.00)	(0.00)	(0.00)
Post*Dist^2	0.00^{**}	0.00	0.00^{**}
	(0.00)	(0.00)	(0.00)
Post*T	-0.15^{***}	-0.27^{***}	-0.11^{***}
	(0.02)	(0.03)	(0.02)
Post*Dist*T	0.00^{*}	0.00^{***}	-0.00
	(0.00)	(0.00)	(0.00)
Post*Dist^2*T	-0.00^{***}	-0.00^{***}	-0.00^{***}
	(0.00)	(0.00)	(0.00)
N	83854	79214	83695

Note: This table reports the estimation of the effects of the legalization of medical marijuana on the intake of opioids by pharmacies compering Michigan and Indiana, this is done using the equation (1) and employing second-order polynomials. In the second and third column we explore the same estimation for Oxycodone and Hydrocodone, separately. Robust standard errors are in parenthesis, $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 7: The Effect of Medical Marijuana on the Purchasing of Opioids by Pharmacies 100km from the Border

	(1) All	(2) oxycodone	(3) Hydrocodone
Post	0.31^{***}	0.24^{***}	0.37^{***}
	(0.02)	(0.03)	(0.02)
Post*Dist	-0.00^{***}	-0.00^{*}	-0.00^{*}
	(0.00)	(0.00)	(0.00)
Post*T	-0.07^{*}	-0.19^{***}	-0.01
	(0.03)	(0.05)	(0.04)
Post*Dist*T	0.00^{***}	0.00^{***}	0.00
	(0.00)	(0.00)	(0.00)
N	18553	17360	18511

Note: This table reports the estimation of the effects of the legalization of medical marijuana on the intake of opioids by pharmacies in the four states and both types of opioids, a maximum distance of a 100km was set to get a more specific estimation around the border. We use the equation (1). In the second and third column we explore the same estimation for Oxycodone and Hydrocodone, separately. Robust standard errors are in parenthesis, $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 8: The Effect of Medical Marijuana on the Purchasing of Opioids by Pharmacies 100km from the Border - New Mexico and Texas

	(1) All	(2) oxycodone	(3) Hydrocodone
Post	0.28^{***}	0.09	0.32^{***}
	(0.03)	(0.06)	(0.03)
Post*Dist	-0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)
Post*T	0.20^{**}	0.43^{***}	0.10
	(0.06)	(0.12)	(0.06)
Post*Dist*T	0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)
N	5964	5051	5955

Note: This table reports the estimation of the effects of the legalization of medical marijuana on the intake of opioids by pharmacies in New Mexico and Texas and both types of opioids, a maximum distance of a 100km was set to get a more specific estimation around the border. We use the equation (1). In the second and third column we explore the same estimation for Oxycodone and Hydrocodone, separately. Robust standard errors are in parenthesis, $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 9: The Effect of Medical Marijuana on the Purchasing of Opioids by Pharmacies 100km from the Border - Michigan and Indiana

	(1) All	(2) oxycodone	(3) Hydrocodone
Post	0.33^{***}	0.30^{***}	0.42^{***}
	(0.03)	(0.04)	(0.03)
Post*Dist	-0.00^{**}	-0.00^{**}	-0.00
	(0.00)	(0.00)	(0.00)
Post*T	-0.17^{***}	-0.38^{***}	-0.07
	(0.04)	(0.05)	(0.05)
Post*Dist*T	0.00^{***}	0.01^{***}	0.00
	(0.00)	(0.00)	(0.00)
N	12589	12309	12556

Note: This table reports the estimation of the effects of the legalization of medical marijuana on the intake of opioids by pharmacies in Michigan and Indiana and both types of opioids, a maximum distance of a 100km was set to get a more specific estimation around the border. We use the equation (1). In the second and third column we explore the same estimation for Oxycodone and Hydrocodone, separately. Robust standard errors are in parenthesis, $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

5 Conclusions

The legalization of medical marijuana has been a topic of extreme debate in the United State for a long time, the effects that the liberation of medical marijuana could have on all aspects, is subject of discussion across the nation, policymakers and researchers are activity trying to find an answer in order to make better decisions. The aim of this paper is to find what is the impact of the legalization of medical marijuana in the intake of opioids by pharmacies, in order to better understand the relationship between marijuana and opioids and how can this improve or diminish the opioid crisis in the United States.

To find the result we use data from the Washington Post, a data set on the transactions made from distributors to pharmacies all across the United States, and we explore a spatial difference-in-discontinuity model, with this we found a general negative effect on the intake of opioids by pharmacies in thee states that legalized medical marijuana. Opposite to those effects in the estimations done specifically for each pair of states, for New Mexico and Indiana we found a positive effect, contradictory to that in Michigan and Indiana where we found a negative relationship between the purchase of opioid and the legalization of medical marijuana. This totally polar results support the current literature on ambiguity of this topic.

However, this contradictory results should not end up in the conclusion that previous efforts on the legalization of medical marijuana have been somewhat harmful or not effective enough and that ongoing liberalization on marijuana will similarly have no effects or generate very little harm to

society. Given the way most studies have use the information and data available is not surprising we obtain mix results. Current regulatory policies and the environment are complex and dynamic, and in a rapidly expanding industry, governments and policy makers change constantly adapting the existing legislation to adapt. Minding this circumstances, research moving forward should consider the given differences and similarities in the regulatory frameworks established by each state, as well as the effect that the multiple types of policies could have depending on the population group studied. Therefore in future research we would like to explore the heterogeneity of this results.

Finally, conducting research and the support of the development of authentic and genuine information on the legalization of marijuana and its effect is crucial for the rapidly changing cannabis laws within each state and a expanding new industry. State official and policy makers, in charge of analyzing and regulating marijuana as a legal consumer product and as form of medical treatment, are being pressed to make critical choices in a developing sector, that will undeniably affect the population of each state. This is why the study of this policies and its effets on all aspects monumental and significant and should continue.

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