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Medical Marijuana Laws and Opioid Overdose Deaths in the United States

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I. Abstract

Several studies have found that medical marijuana laws reduce opioid overdose death rates. I attempted to confirm these findings using the most recent data available. I used state-level death certificate data from 1999 to 2017 to compare changes in opioid overdose death rates following the implementation of medical marijuana laws in states that implemented such laws and states that did not. I found no significant difference in opioid overdose death rate changes following the implementation of medical marijuana laws. These findings do not undermine the primary justifications for legalizing medical marijuana, but they do suggest that legalizing medical marijuana will not solve the ongoing opioid epidemic.

II. Introduction

A. Background

The U.S. has been ravaged by an opioid epidemic that has occurred in three waves. The first wave began in 1991 when pharmaceutical companies assured the medical community that prescription opioids posed a low risk for addiction.[1] Doctors began prescribing opioids to patients with non-cancer related pain despite a lack of data regarding the risks and benefits, and opioid-related deaths increased accordingly.[2]

The second wave occurred around 2010 with a rapid increase in deaths from heroin abuse. Individuals increasingly turned to heroin as early efforts to decrease prescription opioid

[1] *Opioid Overdose Crisis*, National Institute on Drug Abuse (Mar. 2018), https://www.drugabuse.gov/drugs-abuse/opioids/opioid-overdose-crisis.
[2] *History of the Opioid Epidemic: How Did We Get Here?*, National Capital Poison Center (last visited Jan. 12, 2019), https://www.poison.org/articles/opioid-epidemic-history-and-prescribing-patterns-182.

use began to take effect.[3] Heroin overdoses rose by 286% between 2002 and 2013, and approximately 80% of heroin users admitted to using prescription opioids before turning to heroin.[4]

The third wave began in 2013 with the influx of fentanyl, a synthetic opioid. Pharmaceutical fentanyl is commonly used for surgical anesthesia and is prescribed to treat pain; however, almost all fentanyl on the streets is illegally manufactured, non-pharmaceutical fentanyl.[5] Drug dealers typically mix fentanyl, a fine-grained powder, into heroin or counterfeit prescription pills.[6] Fentanyl is extremely potent, 50 times more so than heroin, and has contributed to a staggering number of deaths in recent years.[7] From 2013 to 2017, the annual number of overdoses associated with fentanyl increased from 3,000 to more than 28,000.[8]

The severity of the opioid epidemic has prompted calls to combat over-prescription. In March 2016, the U.S. Centers for Disease Control and Preventions ("CDC") published guidelines for prescribing opioids that contained lower dosage recommendations and more comprehensive recommendations on monitoring and discontinuing opioids than did previous prescribing guidelines.[9] In April 2017, the U.S. Department of Health and Human Services ("HHS") unveiled a five-point Opioid Strategy which identified reducing the inappropriate use of

[3] *History of the Opioid Epidemic: How Did We Get Here?*, National Capital Poison Center (last visited Jan. 12, 2019), https://www.poison.org/articles/opioid-epidemic-history-and-prescribing-patterns-182.
[4] *Id.*
[5] Josh Katz, *Short Answers to Hard Questions About the Opioid Crisis*, NYT, Aug. 10, 2017, *available at* https://www.nytimes.com/interactive/2017/08/03/upshot/opioid-drug-overdose-epidemic.html.
[6] *Id.*
[7] *Fentanyl*, CDC (last visited Jan. 12, 2019), https://www.cdc.gov/drugoverdose/opioids/fentanyl.html.
[8] Josh Katz and Margot Sanger-Katz, *'The Numbers Are So Staggering.' Overdose Deaths Set a Record Last Year*, NYT, Nov. 29, 2018, *available at* https://www.nytimes.com/interactive/2018/11/29/upshot/fentanyl-drug-overdose-deaths.html.
[9] Deborah Dowell, MD, Tamara M. Haegerich, PhD, and Roger Chou, MD, *CDC Guideline for Prescribing Opioids for Chronic Pain — United States, 2016*, MMWR Recomm Rep 2016; 65 (No. RR-1):1-49, *available at* https://www.cdc.gov/mmwr/volumes/65/rr/rr6501e1.htm.

opioids as a priority in responding to the crisis.[10] In an October 2017 hearing before the Senate Committee on Health, Education, Labor & Pensions, witnesses from HHS identified two primary issues in connection with the opioid epidemic: (i) over-prescription of opioids and (ii) inadequate opioid addiction treatment.[11] The perceived need to address over-prescription is common outside the federal government as well.[12]

Some have suggested that the opioid crisis can be combatted through legalization of medical marijuana.[13] If doctors prescribe marijuana to manage pain instead of opioids, the theory goes, fewer patients will develop an opioid addiction and thus fewer individuals will overdose on opioids. Some proponents of legalizing medical marijuana to combat the opioid crisis, however, have recognized the possibility that marijuana could function as a gateway, leading to further substance use and thus increased opioid overdoses.[14] Although marijuana is a Schedule I controlled substance under federal law, 32 states plus the District of Columbia and Guam have what are called "effective" state medical marijuana laws as of November 2018.[15] The purpose of this paper is to test the validity of the claim that medical marijuana may reduce opioid-related

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[10] *HHS Acting Secretary Declares Public Health Emergency to Address National Opioid Crisis*, HHS (Oct. 26, 2017), *available at* https://www.hhs.gov/about/news/2017/10/26/hhs-acting-secretary-declares-public-health-emergency-address-national-opioid-crisis.html.

[11] *The Federal Response to the Opioid Crisis*, National Institute on Drug Abuse (Oct. 5, 2017), *available at* https://www.drugabuse.gov/about-nida/legislative-activities/testimony-to-congress/2017/federal-response-to-opioid-crisis.

[12] *See, e.g.*, Martin A. Makary, MD, Heidi N. Overton, DO, and Peiqi Wang, *Overprescribing is major contributor to opioid crisis*, *BMJ* 2017;359;j4792, *available at* https://www.bmj.com/content/359/bmj.j4792.full; Fred Muench, *We Must Stop Opioid Overprescribing – Now*, U.S. NEWS (Sept. 6, 2018), *available at* https://health.usnews.com/health-care/for-better/articles/2018-09-06/we-must-stop-opioid-overprescribing-now; Krishnadev Calamur, *An 'Overprescription of Opioids' That Led to a Crisis*, THE ATLANTIC (Jun. 23, 2018), available at https://www.theatlantic.com/health/archive/2018/06/opioid-epidemic/563576/.

[13] *Open Source: Could Medical Marijuana Help Address the Opioid Epidemic?*, HOPKINS BLOOMBERG PUBLIC HEALTH MAGAZINE (last visited Jan. 12, 2019), *available at* https://magazine.jhsph.edu/2018/open-source-could-medical-marijuana-help-address-opioid-epidemic.

[14] Marcus A. Bachhuber, MD, Brendan Saloner, PhD, Chinazo O. Cunningham, MD, MS, and Colleen L. Barry, PhD, MPP, *Medical Cannabis Laws and Opioid Analgesic Overdose Mortality in the United States, 1999-2010*, 174 JAMA INTERN MED. 1668, 1669 (2014), hereinafter referred to as "Bachhuber et al. (2014)."

[15] *States That Legally Regulate Medical and/or Adult Social Use of Marijuana*, DRUG WAR FACTS (last visited Jan. 12, 2019), https://www.drugwarfacts.org/chapter/medical_cannabis.

deaths by examining empirical evidence from the states that have legalized medical marijuana. My hypothesis is that the implementation of medical marijuana laws leads to a reduction in the number of opioid overdose deaths.

B. Literature Review

A 2017 literature review identifies ten articles that examine the effect of medical marijuana on the opioid crisis.[16] The Literature Review provides preliminary evidence that states with medical marijuana laws have experienced decreased prescription opioid use, abuse, overdoses, and costs.[17]

Two of the ten studies examined in the Literature Review focus on the impact of medical marijuana laws on opioid-related deaths. Bachhuber et al. (2014) analyzed opioid overdoses from three states with medical marijuana laws prior to 1999 (California, Oregon, and Washington), as well as ten states that implemented medical marijuana laws between 1999 and 2010 (Alaska, Colorado, Hawaii, Maine, Michigan, Montana, Nevada, New Mexico, Rhode Island, and Vermont) and nine states that did not have medical marijuana laws prior to 2010 (Arizona, Connecticut, Delaware, Illinois, Maryland, Massachusetts, Minnesota, New Hampshire, and New York).[18] They concluded that the age-adjusted opioid mortality rate was 24.8% lower in states with medical marijuana laws and that medical marijuana laws may be associated with lower rates of opioid overdoses.[19]

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[16] Marianne Beare Vyas, RN, MSN, ANP-BC, Virginia T. LeBaron, PhD, APRN, FAANP, Aaron M. Gilson, PhD, MSSW, *The use of cannabis in response to the opioid crisis: A review of the literature*, 66 NURSING OUTLOOK 56-65 (2018), hereinafter referred to as "Literature Review."
[17] *Id.* at 63.
[18] Bachhuber et al. (2014) at 1669.
[19] *Id.* at 1670.

Powell, Pacula, and Jacobson (2018) reviewed treatment admissions for opioid abuse and state-level opioid overdoses from 1999 to 2013.[20] They concluded that states with medical marijuana dispensaries experienced a relative decrease in prescription opioid addictions and overdoses compared with states that did not.[21] Notably, these decreases occurred only in states with medical marijuana dispensaries, indicating that the degree to which medical marijuana is available is an important factor in reducing opioid-related harms.

There are limitations associated with both of these studies. First, Powell et al. (2018) analyzed data that included deaths of any intent (unintentional, suicide, homicide, or undetermined).[22] This is problematic because suicides and homicides, even those carried out using opioids, are not relevant to the opioid crisis, which concerns opioid addiction. It is reasonable to assume that many of the suicides and homicides captured in the data would have occurred regardless of access to opioids.

Second, the studies do not examine data beyond 2013. This is problematic because the third wave of the opioid epidemic began in 2013. The proliferation of fentanyl significantly impacted the number and geographical distribution of opioid deaths. Thus, it is necessary to examine data beyond 2013 to determine the impact of medical marijuana laws on the opioid epidemic as it exists today.

Third, the authors used state enactment of medical marijuana legislation as a proxy for use of medical marijuana by the state's residents. This is problematic because states experience delays between passing medical marijuana laws and actually implementing them. For example,

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[20] David Powell, Rosalie Laccardo Pacula, and Mireille Jacobson, *Do medical marijuana laws reduce addictions and deaths related to pain killers?*, 58 J. HEALTH ECON. 29 (2018), hereinafter referred to as "Powell et al. (2018)."
[21] *Id.* at 36.
[22] *Id.* at 30. The primary analysis from Bachhuber et al. (2014) included deaths of any intent; however, they performed an additional analysis excluding suicides. The additional analysis revealed a 31.0% lower age-adjusted mortality rate in states with medical marijuana laws. Bachhuber, et al. (2014) at 1670.

Bachhuber et al, (2014) coded California as initiating its medical marijuana program in 1996,[23] the same year Californians approved the Compassionate Use Act of 1996; however, California's medical marijuana program did not begin in earnest until 2005, when it began distributing medical marijuana identification cards in accordance with the Medical Marijuana Program Act, which was enacted in 2003.[24]

While Bachhuber et al. (2014) attempted to control for these delays in one of their models, they assumed uniform delays between enactment and implementation across states when in fact states experience different degrees of delay.[25] For example, while New York's first medical marijuana dispensary opened within two years of the state enacting its medical marijuana legislation, Maryland saw a delay of nearly five years between enacting legislation and opening its first dispensary. [26]

III. Methods

I analyzed the impact of legalizing medical marijuana on opioid overdose deaths using the difference in differences ("DD") method. DD is suitable for this particular question because it estimates the effect of a specific treatment (such as the passage of a law) by comparing the changes in outcomes over time between populations that are subject to the treatment (the intervention group) and populations that are not (the control group). In this case, the effect being examined is that of medical marijuana legalization on the number of opioid overdose deaths, the

[23] Bachhuber et al. (2014) at 1669.
[24] *Patient, Primary Caregiver, Medi-Cali and CMSP Card Data*, CAL. DEP'T PUB. HEALTH, (last visited Jan. 12, 2019) *available at* https://www.cdph.ca.gov/Programs/CHSI/Pages/MMP-Card-Data.aspx.
[25] Bachhuber et al. (2014) at 1669.
[26] Jesse McKinley and Eli Rosenberg, *First Medical Marijuana Dispensaries in New York Open*, NYT, Jan. 7, 2016, *available at* https://www.nytimes.com/2016/01/08/nyregion/first-medical-marijuana-dispensaries-in-new-york-are-poised-to-open.html; Fennit Nirappil, Rachel Siegel, and Aaron Gregg, *Medical marijuana has arrived in Maryland, and sales have begun*, WASH. POST, Dec. 1, 2017, *available at* https://www.washingtonpost.com/local/md-politics/friday-appears-to-be-the-day-medical-marijuana-will-go-on-sale-in-maryland/2017/12/01/62d66dee-d605-11e7-95bf-df7c19270879_story.html?utm_term=.67ae25baddb3.

intervention group consists of states that passed laws legalizing medical marijuana, and the control group consists of states with no such laws. Because states implemented medical marijuana laws in different years, I performed multiple analyses and grouped states according to the timing of implementation.

To calculate DD, I used the following formula:

$$DD = (\bar{y}_{Tr,Post} - \bar{y}_{Tr,Pre}) - (\bar{y}_{C,Post} - \bar{y}_{C,Pre})$$

where $\bar{y}_{Tr,Post}$ equals the rate of opioid overdose deaths in states that adopted medical marijuana laws in 2017[27], $\bar{y}_{Tr,Pre}$ equals the rate of opioid overdose deaths in those same states in the year prior to implementation, and $\bar{y}_{C,Post}$ and $\bar{y}_{C,Pre}$ equal the average rates of opioid overdose deaths in comparison states that have not adopted medical marijuana laws in the same respective years as those in the treatment group. Assuming that the differences in opioid overdose deaths across time would have been the same in the treatment and control groups but for the implementation of medical marijuana, DD equals the change in opioid overdose deaths attributable to medical marijuana laws. Whether this assumption is reasonable depends on the selection of comparison states, which is discussed below.

I obtained the opioid overdose death rate in each state from 1999 to 2017 from the Wide-ranging Online Data for Epidemiologic Research ("WONDER") interface to multiple cause-of-death data from the CDC.[28] I limited the analysis to 1999-2017 because ICD-9 codes were used to identify cause of death prior to the implementation of ICD-10 codes in 1999, and opioid-related deaths are difficult to link across ICD coding systems. I defined opioid overdose deaths

[27] I selected 2017 as the post-treatment year for all of the analyses despite varying implementation/pre-treatment years because I assumed that any impact of medical marijuana on opioid overdose deaths would increase over time. Thus, maximizing the post-implementation period should increase the likelihood of detecting an impact.
[28] CDC, National Center for Health Statistics. Multiple Cause of Death 1999-2017 on CDC Wonder Online Database, released December, 2018. Data are from the Multiple Cause of Death Files, 1999-2017, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed at http://wonder.cdc.gov/mcd-icd10.html on Dec. 12, 2018.

as fatal drug overdoses of unintentional and undetermined intent (ICD-10 codes X40-X44) where an opioid was also coded (T40.0-T40.4, and T.40.6). This covers all overdose deaths where an opioid was involved, including those involving opium, heroin, methadone, synthetic narcotics, and other opioids. I included non-prescription opioids (heroin and synthetic narcotics) because the vast majority of heroin users have used prescription opioids prior to using heroin.[29] While some people may have picked up heroin without first using prescription opioids, I assume that reducing opioid prescriptions leads to a reduction in overall opioid use.

Because states implemented medical marijuana laws in different years, I performed separate analyses in which the treatment groups consist of states that implemented laws in the same year. I categorized states based on the year of actual implementation instead of the year of passing medical marijuana legislation. As a proxy for actual implementation I used the opening of a state's first dispensary, the date of which can be found in state department of health reports. Accordingly, I excluded from the treatment group states with more restrictive medical marijuana laws that prohibit dispensaries. I further excluded states from the treatment group based on timing of implementation.[30]

Selecting comparison states required some degree of creativity. Ambiguity and subjectivity in the selection of comparison units is a widespread problem in comparative case study research.[31] In an effort to solve this problem, Abadie and Gardezabal (2003) developed the

[29] *Prescription opioid use is a risk factor for heroin use*, NATIONAL INSTITUTE ON DRUG ABUSE (last visited Jan. 12, 2019), https://www.drugabuse.gov/publications/research-reports/relationship-between-prescription-drug-heroin-abuse/prescription-opioid-use-risk-factor-heroin-use.

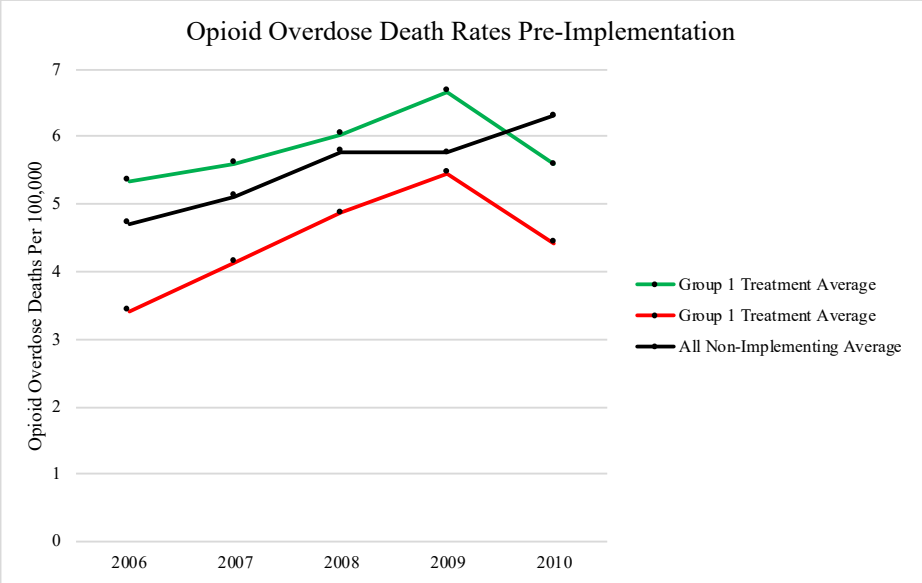
[30] I excluded Oregon and Washington because they implemented medical marijuana programs prior to the study period. I excluded California because it is unclear when it truly implemented its medical marijuana program. I excluded Alaska, Arkansas, Hawaii, Louisiana, Maryland, Missouri, Montana, North Dakota, Ohio, Oklahoma, Pennsylvania, Utah, and West Virginia because, although they have legalized medical marijuana in some form, they did not implement programs as of 2017.

[31] Alberto Abadie, Alexis Diamond, and Jens Hainmueller, *Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program*, Working Paper 12831, NBER, 2 (Jan. 2007), available at https://www.nber.org/papers/w12831.pdf.

synthetic control approach as a data-driven procedure to construct suitable comparison groups.[32] By assigning different weights to economic growth predictors in Spanish regions, Abadie and Gardezabal created a synthetic comparison unit with similar growth predictors to those of the Basque Country before it experienced terrorism in the 1970s, enabling them to approximate the per capita GDP path the Basque Country would have experienced in the absence of terrorism.[33]

Inspired by Abadie and Gardezabal but wanting in certain technical know-how, I devised a crude data-driven procedure to construct comparison groups. I first narrowed down all of the non-implementing states to those that experienced similar directional shifts (i.e., increases or decreases) in opioid overdose death rates from year to year as did the treatment states' average in the 4 years leading up to the implementation year.[34] From that selection of states, I selected a combination that produced a nearly parallel trendline to that of the treatment states in the 4 years leading up to implementation. For example, the average opioid overdose death rate in Group 1 treatment states (Colorado, Maine, and Michigan) increased from 2006 to 2007, increased from 2007 to 2008, increased from 2008 to 2009, and decreased from 2009 to 2010 (the year of implementation). The Group 1 comparison states (Alabama, Indiana, Iowa, Montana, North Carolina, and Pennsylvania) are those that (i) experienced a similar pattern of increases and decreases and (ii) produced a nearly parallel trendline to that of the treatment states' average across those years.

[32] Alberto Abadie and Javier Gardeazabal, *The Economic Costs of Conflict: A Case Study of the Basque Country*, 93 AM. ECON. REV. 113-132. (Mar., 2003).
[33] *Id.* at 116-17.
[34] I allowed changes under 1% in either direction to count as both increases and decreases to expand the selection.



The assumption behind this selection process is that similar directional shifts in opioid overdose death rates across years suggests similar relevant independent variables. This is a bold assumption, as discussed below in Section V. As the graph above demonstrates, however, this procedure yields treatment and comparison averages with relatively similar variations across years.

The table below shows the different treatment and comparison groups:

Group	Implementation Year	Treatment State(s)	Comparison States
1	2010	Colorado[35] Maine[36] Michigan[37]	Alabama Indiana Iowa Montana North Carolina Pennsylvania
2	2013	Arizona[38] New Jersey[39] New Mexico[40] Rhode Island[41] Vermont[42]	Ohio Pennsylvania Wisconsin
3	2015	Connecticut[43] Delaware[44] Illinois[45] Massachusetts[46] Minnesota[47] Nevada[48]	Idaho South Carolina Virginia West Virginia
4	2016	Florida[49] New Hampshire[50] New York[51]	Kentucky Ohio Pennsylvania South Carolina

[35] *Medical Marijuana Registry Patient Count*, CHPHE (last visited Jan. 12, 2019), *available at* https://www.colorado.gov/pacific/sites/default/files/CHED_MMR_2001-2017-average-count-year.pdf.
[36] *Maine Medical Use of Marijuana, Annual Report*, DEP'T OF HEALTH AND HUMAN SERVICES (March 2011), available at https://www.maine.gov/dafs/bbm/mmmp/sites/maine.gov.dafs.bbm.mmmp/files/inline-files/2011-MMMP-Annual-Report.pdf.
[37] Michigan did not have dispensaries in 2010, but there was significant usage. *2011 Michigan Medical Marihuana Act Statistical Report*, DEP'T OF LICENSING AND REGULATORY AFFAIRS (last visited Jan. 12, 2019), *available at* https://www.michigan.gov/documents/lara/Medical_Marihuana_Annual_Report_Statistics_FY_2011_409688_7.pdf
[38] *Second Annual Medical Marijuana Report*, A.R.S. §36-2809, ARIZ. DEP'T OF HEALTH SERVICES (November 8, 2013), *available at* https://www.azdhs.gov/documents/licensing/medical-marijuana/reports/2013/az-medical-marijuana-program-annual-report-2013.pdf.
[39] *The Department of Health Medicinal Marijuana Program 2013 Annual Report*, N.J. DEP'T OF HEALTH (Feb. 2014), *available at* https://www.nj.gov/health/medicalmarijuana/documents/annual_report.pdf.
[40] *Medical Cannabis Program First Quarter Report Summary*, N.M. DEP'T OF HEALTH (May 21, 2013), *available at* https://nmhealth.org/publication/view/report/3125/.
[41] W. Zachary Malinowski, *Summit medical marijuana facility submits new application for dispensary in Warwick*, PROVIDENCE JOURNAL, Nov. 30, 2013, *available at* https://www.providencejournal.com/breaking-news/content/20131130-summit-medical-marijuana-facility-submits-new-application-for-dispensary-in-warwick.ece.
[42] Nina Keck, *Behind The Scenes At A Vermont Medical Marijuana Dispensary*, VERMONT PUBLIC RADIO, Jan. 4, 2019, *available at* http://digital.vpr.net/post/behind-scenes-vermont-medical-marijuana-dispensary#stream/0.
[43] *State of Connecticut Medical Marijuana Program Presentation*, CONN. DEP'T OF CONSUMER PROTECTION (2015), *available at* https://portal.ct.gov/-/media/DCP/pdf/MMP/MMPCBACLE261515pdf.pdf?la=en.
[44] *Delaware Medical Marijuana Program Annual Report*, DEL. HEALTH AND SOCIAL SERVICES (2015), available at https://dhss.delaware.gov/dph/hsp/files/mmpannrpt2015.pdf.

IV. Results

Group	Treatment Period (years)	DD[52] (deaths/100,000)	Average Annual DD (deaths/100,000)	*p*-value
1	8	+5.07	+0.63	0.20
2	5	-6.25	-1.25	0.18
3	3	+1.37	+0.46	0.38
4	2	-3.09	-1.55	0.12

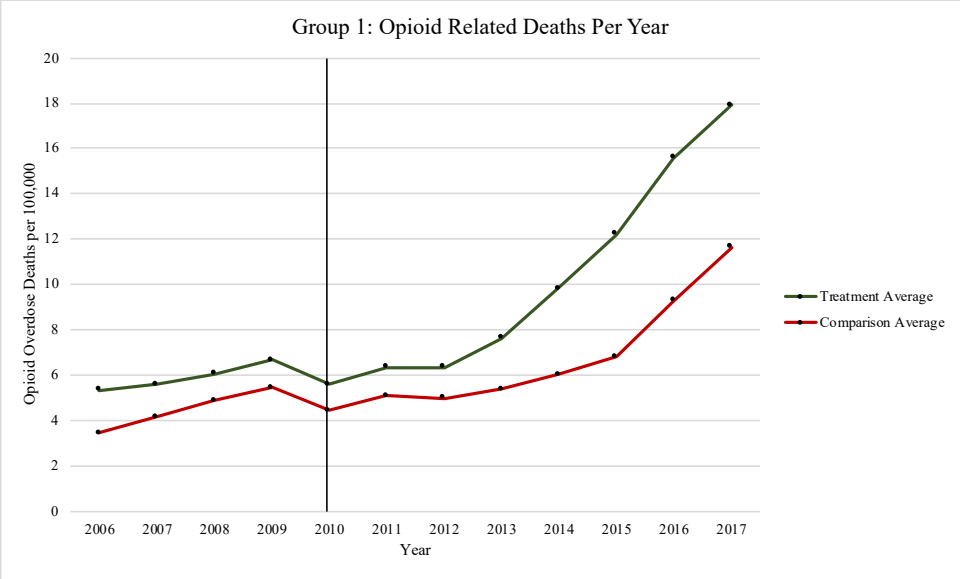
Legalizing medical marijuana does not appear to have a significant impact on the rate of opioid overdose deaths. As the table above reveals, the average annual DD varied across groups, with Group 1 and Group 3 showing larger post-implementation opioid overdose death rate increases in treatment states than in control states and Group 2 and Group 4 showing smaller post-implementation opioid overdose death rate increases in treatments states than in control states.

The *p*-values for each analysis are large, indicating that the disparities in opioid overdose death rates can be explained by the play of chance rather than the presence of medical marijuana laws. I derived the *p*-values using the excel t-Test function, where one array consisted of the

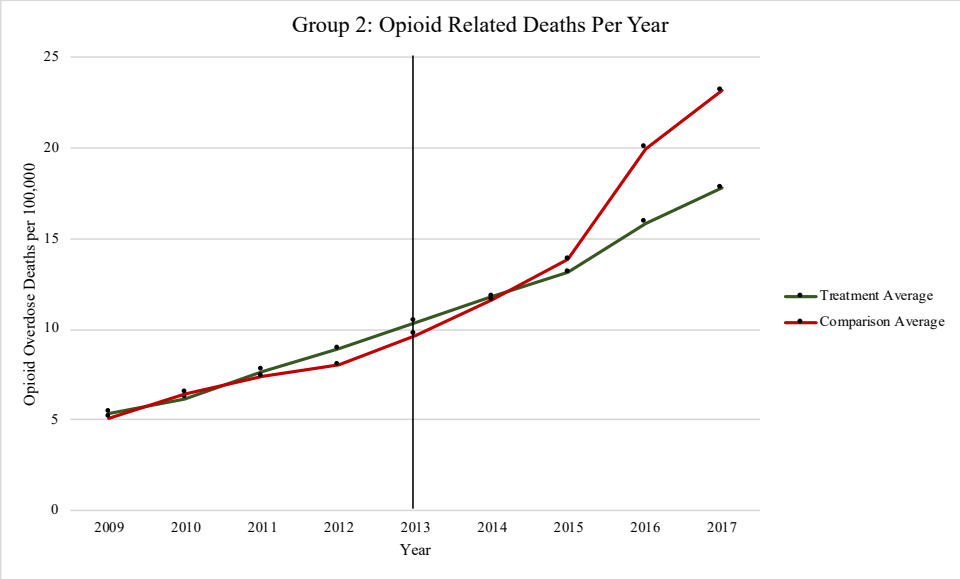
[45] *Illinois Medical Cannabis Registry Pilot Program, Mid-Year Report – January 2016*, ILL. DEP'T OF PUBLIC HEALTH (2016), *available at* http://www.dph.illinois.gov/sites/default/files/publications/mid-year-data-report-january-2016-040616.pdf.
[46] *Medical Marijuana Trust Fund Annual Report*, MASS. DEP'T OF PUBLIC HEALTH (April 2016), *available at* https://www.mass.gov/files/documents/2017/11/02/mmj-annual-trust-fund-report-2016.pdf.
[47] *Medical Cannabis Program Update*, MINN. DEP'T OF HEALTH (April 2016), *available at* http://www.health.state.mn.us/topics/cannabis/about/update0416.pdf.
[48] *Marijuana Establishments*, NEV. DEP'T OF TAXATION (last visited Jan. 12, 2019), *available a*t https://tax.nv.gov/MME/Marijuana_Establishments_-_Home/.
[49] *Office of Medical Marijuana Use Bi-Weekly Update*, FLA. DEP'T OF HEALTH (August 10, 2016), *available at* http://www.floridahealth.gov/programs-and-services/office-of-medical-marijuana-use/ommu-updates/_documents/160810-bi-weekly-update.pdf.
[50] *Therapeutic Cannabis Program 2016 Data Report*, N.H. DEP'T OF HEALTH AND HUMAN SERVICES (2017), *available at* https://www.dhhs.nh.gov/oos/tcp/documents/tcp-data-report-2016.pdf.
[51] *N.Y.S. Dep't of Health Adds Five New Registered Organizations to Medical Marijuana Program*, N.Y.S. DEP'T OF HEALTH (August 2017), *available at* https://www.health.ny.gov/press/releases/2017/2017-08-01_mmp.htm.
[52] From pre-implementation year to 2017.

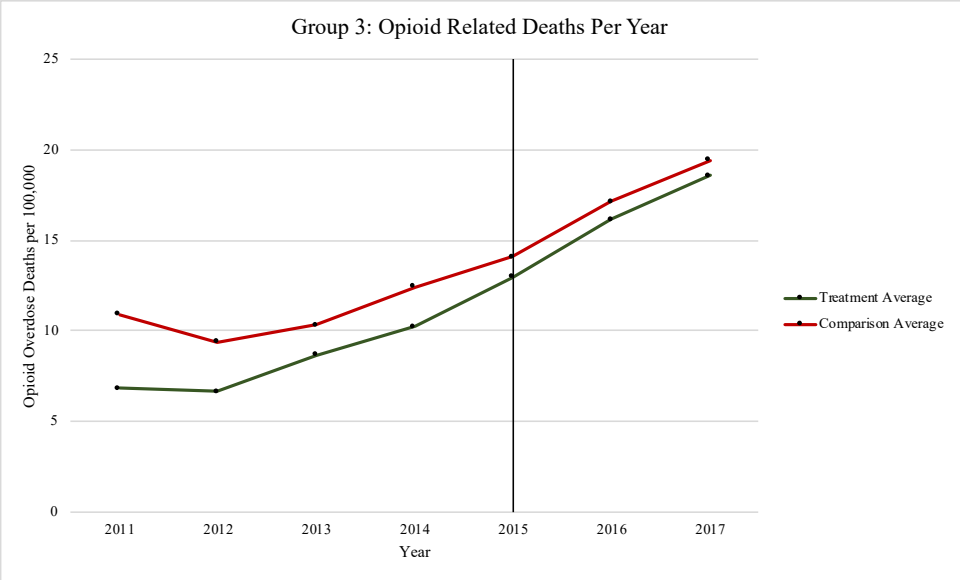
differences in opioid overdose death rates between 2017 and the year prior to implementation for each treatment state, the other array consisted of the differences in opioid overdose death rates between 2017 and the year prior to implementation for each control state, "tail" was set to 1, and "type" was set to 3. The *p*-values far exceed 5%, the significance level most commonly used in social science.[53] Thus, the null hypothesis (i.e., medical marijuana laws do not impact opioid overdose death rates) cannot be rejected.

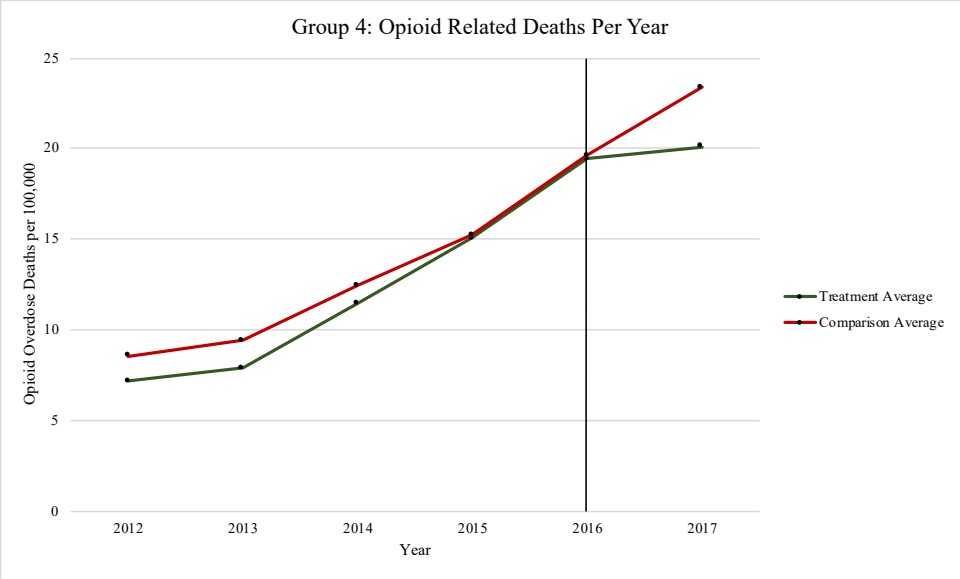
The graphs below show the opioid overdose death rates per year for the treatment and control groups:



[53] NATIONAL RESEARCH COUNCIL, *Reference Manual on Scientific Evidence: Third Edition*, Washington, DC: The National Academies Press (2011), 251.


Group 2: Opioid Related Deaths Per Year
Opioid Overdose Deaths per 100,000
25
20
15
10
5
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
Year
Treatment Average
Comparison Average


Group 3: Opioid Related Deaths Per Year
Opioid Overdose Deaths per 100,000
25
20
15
10
5
0
2011
2012
2013
2014
2015
2016
2017
Year
Treatment Average
Comparison Average



Given the discrepancy between these results and those of Bachhuber et al. (2014) and Powell et al. (2018), I decided to conduct a second set of analyses, identical to the first in every respect except that the control groups consisted of all non-implementing states instead of only those selected via my crude synthetic method. It occurred to me that the selection method I devised in an attempt to avoid overly subjective and arbitrary comparisons may have produced just that.

Secondary analysis: All non-implementing states as comparison groups				
Group	Treatment Period (years)	DD[54] (deaths/100,000)	Average Annual DD (deaths/100,000)	*p*-value
1	8	+4.54	+0.57	0.44
2	5	+3.18	+0.64	0.16
3	3	+4.20	+1.40	0.07
4	2	+1.77	+0.88	0.10

The table above shows the results of the secondary analysis. All four groups showed larger post-implementation opioid overdose death rate increases in the treatment states compared to all non-implementing states. As with the first analysis, however, the *p*-values are greater than 5%. Accordingly, whether using only states with comparable pre-implementation opioid

[54] From pre-implementation year to 2017.

overdose death rate changes or all states that have not implemented medical marijuana laws as the control group, there is no significant difference in the opioid overdose death rate between states with medical marijuana laws and those without.

V. Discussion

These results show that there is no significant relationship between medical marijuana legalization and opioid overdose death rates. There are several possible explanations for these results. First, it is possible that the gateway effect of medical marijuana (discussed in Section II) counteracts the effect medical marijuana may have on limiting initial opioid exposure. In other words, although fewer patients are being introduced directly to opioids via opioid prescriptions, they are still being introduced via a gateway effect of marijuana.

Second, it is possible that the effect of medical marijuana on opioid overdose deaths is delayed. It may take years for individuals to progress from taking prescribed doses of opioids to injecting heroin, which accounts for a significant portion of opioid overdose deaths. The potential impact of medical marijuana on these types of deaths may not have manifested yet because most states have implemented medical marijuana within the last decade.

Third, and most likely, the proliferation of fentanyl may have nullified any potential effect of medical marijuana on opioid overdose deaths. As the data shows, opioid overdose deaths have increased significantly after 2012, largely due to fentanyl use. Even if medical marijuana leads to a reduction in opioid use, the reduced number of opioid users may still experience more deaths in absolute numbers because of the lethality of fentanyl. Moreover, the illicit production of pills containing fentanyl may offset any reduction in the availability of prescription opioid pills that may occur as doctors shift from prescribing opioids to prescribing medical marijuana.

This study has several limitations. First, the control states may not be appropriate comparisons. I attempted to create synthetic comparison units using a crude data-driven procedure in an effort to avoid subjectivity and ambiguity in handpicking comparisons. It is entirely possible, however, that the similarity in the pre-implementation opioid overdose death rate changes between the treatment and control averages was a product of chance instead of similar relevant variables.

Potential relevant variables include (i) the presence of state-level prescription drug monitoring program, (ii) the presence of laws requiring pharmacists to request patient identification before dispensing medications, (iii) the presence of regulations establishing increased state oversight of pain management clinics, and (iv) economic conditions.[55] Using regression would have simplified accounting for these variables; however, there would still be no guarantee that these are the right variables or that they are properly weighed.

Second, death certificate data, which is used to record ICD-10 codes in WONDER, may not correctly classify cases of opioid overdose deaths, and reporting of opioids on death certificates may differ among states. These misclassifications could bias the results in either direction.

Finally, as discussed above, some of the states examined, particularly those in groups 3 and 4, implemented medical marijuana laws one or two years prior to the end of the study period. It is unlikely there would be any observable effects of medical marijuana on opioid overdose deaths so soon after implementation.

VI. Conclusion

[55] Bachhuber et al. (2014) at 1669.

This paper presents evidence that medical marijuana does not have a significant impact on opioid overdose death rates. The results show that the goal of combatting the opioid epidemic does not justify legalizing medical marijuana; however, medical marijuana provides other benefits which may still justify legalization. Marijuana is an effective remedy for a wide range of medical conditions, and many states have concluded that the benefits of legalizing medical marijuana outweigh the costs.[56]

The dramatic increase in fentanyl deaths suggests that reforming medical and pharmaceutical practices alone will not solve the opioid epidemic. In order to reduce the number of opioid overdose deaths, policymakers must find a way to prevent the illicit production and distribution of fentanyl.

[56] *Medical Use*, NORML (last visited Jan. 12, 2019), https://norml.org/marijuana/medical.