2018

The Effects of Recreational Marijuana Legislation on the Opioid Epidemic in Washington State

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Submitted to
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for
Senior Thesis
Fall 2017
December 4th

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Abstract

This paper analyzes the impact of the 2012 legalization of recreational marijuana in Washington State on opioid abuse. Using synthetic control methodology, this paper finds that the legislation prevented 638 overdose deaths and lead to over 3600 individuals seeking treatment for opioid abuse disorders. Due to the large health, social, and economic impacts of the opioid epidemic, further research should be conducted into ways to reduce the number of opioid prescriptions, the number of opioid overdoses, and opioid abuse generally.

Acknowledgments

I would like to thank my thesis reader Professor David Bjerk for his guidance, advice, help, tolerance of my mediocre drafts, and outdoor adventure stories, Professor Yong Kim for his constructive criticism and counseling, Professor Angela Vossmeyer for her guidance and career advice, Professor Shannah Rose for her courses which developed and shaped how I think about public policy, and to all of my professors and teachers who have helped and inspired me in my academic pursuits. I would also like to thank Dr. Justin Fitzpatrick for his friendship, inspiration, and mentorship in my academic, personal, and videogame related pursuits throughout my life, I would like to thank all of my friends, Sam the wise for his honest advice, Luke the brave for his cooking, Devin the understanding for his understanding, Nedim for many things, Nicky, Steen, Amit, Rob, Max, Max, Spence, Kelly, Leah, and Jenna, and I would like to thank Chris Stapleton, Brockhampton, Tame Impala, and Pinegrove whose music has been in constant rotation during my thesis creation. Finally, I'd like to thank my mother and father for everything.

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Introduction

The negative impacts of opioids in the United States cannot be overstated: in 2015 there were 33,091 overdose deaths caused by opioids, 12,989 of which were due to the illicit opioid heroin. The heroin death rate increased 22.2% and total opioid related deaths increased 15.5% from 2014 to 2015 (David et al., 2016). On average someone dies from an opioid related overdose about every 15 minutes.

Opioids are a class of drug that includes prescription pain relievers (oxycodone, hydrocodone, codeine), illegal pain relievers (heroin), and synthetic opioids (fentanyl). Opioids treat chronic pain conditions but they also produce a feeling of euphoria. This feeling causes many opioids to be highly addictive− even when taken as prescribed by a physician (National Institute on Drug Abuse, 2017).

The sale of prescription opioid pain relievers quadrupled in the U.S. from 1999 to 2010 and opioid overdose death rates almost quadrupled over a similar period, from 1999 to 2008 (Center for Disease Control and Prevention, 2011).

During this same time period, various states began to legalize medical, and eventually, recreational marijuana. California was the first state to legalize medical marijuana in 1996 and Washington quickly followed suit in 1998 (Eddy, 2010). In November of 2012, Washington state legalized recreational marijuana use through ballot Initiative 502, which took effect on December 1, 2012 (Subbaraman and Kerr, 2016).

Thes legalization of medical marijuana opened the door for physicians to prescribe medical marijuana to treat chronic pain instead of opioids. Although medical literature has not reached a consensus on the possible long term effects of marijuana, there is growing consensus that marijuana can be effectively used to treat chronic and neuropathic pain (Hill, 2015). Furthermore, physicians have begun to argue that marijuana can be explicitly used to treat opioid use disorders (Hurd, 2017).

Previous literature has found a causal effect between states with medical marijuana legalization and a decrease in the level of opioid overdose death rates (Bachhuber et al., 2014; Cerdà et al., 2016; Shi, 2016). However, a recent study by Jacobson et al. (2017) has found that these effects do not hold in states that do not have dispensaries, which facilitate the retail sale of marijuana to qualified patients. This study draws upon Pacula et al. (2015), who showed that states with dispensaries had higher rates of medical marijuana usage, to conclude that "broader access to medical marijuana facilitates substitution of marijuana for powerful and addictive opioids". My study focuses on the effects of the marijuana policy that allows the broadest access to marijuana, the legalization of recreational marijuana, on opioid abuse.

However, I am not the first person to study this relationship. Barnett et al. (2017) studied the impact of the legalization of recreational marijuana in Colorado on opioid overdose rates. They use an interrupted time series model with monthly overdose data and find that the recreational marijuana legislation lead to a 6.5% decrease in opioid related deaths. I expand upon this result by employing a different empirical strategy to study the effects of recreational marijuana in Washington State instead of Colorado.

This paper provides succinct and relevant analysis on the effects of the recreational legalization of medical marijuana in Washington State on opioid abuse, treatment, and overdose deaths. This paper employs a synthetic control methodology with two commonly used datasets, the Treatment Admissions Episode Data Set (TEDS-A), and mortality overdose data provided by the National Vital Statistics System (NVSS) in order to estimate the effect of the legislation. I also use summary statistics from the National Survey on Drug use and Health (NSDUH) in order to help contextualize and corroborate these results.

The legalization of recreational marijuana could lead to a decline in the rates of opioid abuse and overdose by allowing individuals to shift away from using opioids to using marijuana to treat chronic pain conditions, by allowing individuals to use marijuana to lessen the negative effects of withdrawal symptoms, or by further destigmatizing the prescription of medical marijuana in place of opioids. However, the legalization of recreational marijuana could also lead to an increase in the rates of opioid abuse by providing a legal gateway drug to opioids or by destigmatizing general drug usage.

My analysis finds that recreational marijuana legalization in Washington State lead to a reduction in opioid overdoses but an increase in treatment admissions relative to a synthetic control group. However, due to the nature of the synthetic control methodology, causal inference remains intricate. I expand upon this in the empirical strategy and analysis sections. Self-reported opioid usage declines over this time period as well.

This paper is divided into 6 additional sections. The literature summary surveys the existing literature base. The data section presents the data sets. The empirical strategy section discusses the analysis techniques. The analysis section studies the data. The results section summarizes the findings. And the conclusion contextualizes the results and offers a direction for future research.

Literature Summary

The literature summary is broken up into three sections. The first section analyzes the opioid epidemic, the second section presents the history of marijuana laws in the United States and Washington, and the third section examines the recent literature on how marijuana laws affect opioid trends.

A History of the Opioid Epidemic

The opioid epidemic has many causes. The most direct are the aggressive, misrepresentative, and criminal advertising of OxyContin by Purdue Pharma in the 1990s and the changing beliefs about pain management in the United States (Lembke, 2012; Zee, 2009).

Beginning in 1996, Purdue Pharma (owners of OxyContin), aggressively marketed OxyContin, a sustained release oxycodone preparation (an opioid), to physicians around the country and misrepresented the risk of addiction (Maxwell, 2011). Purdue Pharma marketed OxyContin as having a risk of addiction at less than 1%, when the true risk was much higher. This marketing campaign helped grow OxyContin sales from $48 million in 1996 to nearly $1.1 billion in 2000 (Zee, 2009). In 2007, Purdue Pharma plead guilty to "misbranding OxyContin, a prescription opioid pain medication, with the intent to defraud or mislead… as less addictive, less subject to abuse and diversion, and less likely to cause tolerance and withdrawal than other medications" and paid monetary sanctions totaling $600 million (United States of America v. The Purdue Frederick Company, Inc., Et Al., 2007).

This issue was greatly exacerbated in Florida, and a few other states including Texas, by the existence of "pill mills", profit-motivated rogue pain clinics that misprescribed and over prescribed prescription opioids, and "doctor shopping", where an individual receives multiple prescriptions from different providers, in the 2000s (Chen et al., 2013; Chakravarthy et al., 2012; Alexander et al., 2016). Through a series of Prescription Drug Monitoring Program laws, pill mill laws, and raids carried out by the Drug Enforcement Agency, many of these operations have been shut down and opioid overdose rates have declined (Boyle et al., 2015; Herter et al., 2014). As of June 2012, every state and Washington D.C. had a Prescription Drug Monitoring Program in order to help physicians prescribe opioids more cautiously and responsibly, but further research needs to be done to judge their effectiveness at reducing opioid abuse and overdoses (Gugelmann et al, 2012).

Shifting opinions about how pain should be treated have also contributed to the opioid epidemic. Recently, with the improvement of medicine, there has been a paradigm shift from pain being a positive sign of vitality to pain being a symptom that doctors should aim to totally eliminate (Lembke, 2012). While this is a shift that is hard to quantify, it is important to consider when thinking about the incredible amount of prescriptions for opioids.

There is also an economic component to the opioid epidemic: as the unemployment rate increases by 1% then the opioid overdose emergency department visit rate has been shown to increase by 3.6% (Hollingsworth, 2017). There were also a myriad of other forces, incorrect prescribing practices, accessible legal and illegal supplies, and lethargic government responses, that contributed to the opioid epidemic (Maxwell, 2011).

The opioid epidemic wreaks havoc indiscriminately but there are more pronounced effects in certain demographic groups. The most common individuals to die from a drug overdose are white males between the ages of 25 and 54 (Hedegaard et al., 2017). In 2015, 2 million Americans (12 and older) had a substance use disorder involving prescription pain relievers and 591,000 had a substance use disorder involving heroin (Center for Behavioral Health Statistics and Quality, 2016).

After 2010, the landscape of the opioid epidemic began to change significantly. Heroin and fentanyl (a synthetic opioid) have been the major driving forces behind the soaring overdose rates (David et al., 2016). The number of heroin-related deaths was pretty constant from 2002-2010 but have increased in each subsequent year, possibly as a response to a reformulated abuse-deterrent formulation of oxycodone, which lead to a decrease in the abuse of oxycodone (Cicero et al., 2012, Dart, et al., 2015). The percentage of deaths from drug overdoses involving heroin tripled from 2010 to 2015 and the percentage of overdose deaths from synthetic opioids (such as fentanyl and tramadol) also tripled over this same time period (a time when total drug overdoses were also increasing) (Hedegaard et al., 2017).

This epidemic has lead to a wide variety of responses at the state and national level. In early 2016, Congress passed the 21st Century Cures Act which provided $1 Billion in new funding to combat the opioid epidemic− primarily through increasing access to substance use disorder treatment (The White House, 2016), and in 2017, the Center for Disease Control and Prevention (CDC) awarded an additional $29 million to 44 states and the District of Columbia to help combat the opioid epidemic (Center For Disease Control and Prevention, 2017). A majority of states have also implemented naloxone access laws and good samaritan laws; both these pieces of legislation were estimated to reduce opioid-related deaths by 9 to 11%, but the effects of good samaritan laws were not statistically significant (Argys, 2017).

The opioid epidemic has had obscene impact in terms of loss of life, but it also has impacted the economy as a whole. The opioid epidemic has been shown to have strong negative effects on employment-to-population ratios and labor force participation rates (Glenn et al., 2017). In 2013, the economic burden of prescription opioid overdose, abuse, and dependence was estimated to be $78.6 billion (Florence, 2016), and this number may have increased to $92 Billion in 2014 (Meisel et al., 2016).

The History of Marijuana Legislation in the United States

The first known usage of marijuana in the United States was in 1611 when Jamestown settlers used it in hemp production. The usage of marijuana for medical purposes soon followed. During the 1800s and early 1900s marijuana was widely prescribed by physicians and pharmacists for a variety of illnesses (Chriqui et al., 2002). Marijuana became illegal with the Marihuana Tax Act of 1937 and its position was solidified with the Controlled Substance Act of 1970 (Kamin 2014). As states began to legalize marijuana, they created a paradox of legality where marijuana was illegal at the federal level, but legal at the state level (Grabarsky 2013).

In contrast to the incredible economic cost of the opioid epidemic, medical and recreational marijuana legislation generates huge revenues for States. In 2016 Washington State and local governments collected $65 million from recreational marijuana sales (Washington State Department of Revenue, 2017) and in 2016, Colorado State and local governments collected $193 million in taxes from recreational marijuana sales (Colorado Department of Revenue, 2017).

Although the medical literature has not reached a consensus on the possible long term effects of marijuana, there is unambiguous consensus that marijuana is less harmful that prescription opioids and there is a growing consensus that marijuana can be effectively used to treat pain and neuropathic pain (Hill, 2015). Furthermore, physicians have begun to argue that marijuana can be explicitly used to treat opioid use disorders (Hurd, 2017).

There are also some other effects of marijuana legalization that are worth considering when making policy decisions. Medical marijuana laws might increase the labor supply of older adults− which could be particularly important when considering the toll the opioid epidemic is taking on the current labor supply (Maclean and Nicholas, 2016). In general medical marijuana laws have not had particularly negative effects (Hall and Weier, 2015). However, medical marijuana legalization is associated with higher rates of health care visits‒ particularly related to edible marijuana products (Heard et al., 2015).

The Effect of Marijuana Laws on Opioid Abuse

Medical marijuana laws have allowed physicians to substitute away from opioid prescriptions and shift towards marijuana when treating a variety of medical issues (Jacobson et al., 2017). Before 2010, medical marijuana laws had been shown to decrease opioid overdoses and other opioid related harm (Bachhuber, et al., 2014, Cerdà et al., 2016, Shi, 2016). However, a recent study concluded that only states with dispensaries, which make it easier to obtain medicinal marijuana, experience reductions in opioid overdoses (Jacobson et al., 2017).

This study by Jacobson et al. (2017) uses a difference-in-differences strategy that compares opioid abuse indicators in medical marijuana states versus states where medical marijuana is illegal. They use an event study analysis to estimate the effects after legalizing medical marijuana to assess the causal impact of the legislation. They find that when a state legalizes dispensaries as part of their medical marijuana legislation this leads to a decrease in opioid overdoses and a decrease in treatment admissions for opioid abuse. Jacobson et al. (2017) use treatment admissions as a proxy for opioid abuse instead of analyzing them on their own. I interpret treatment admissions differently and will discuss this in the results section.

A recent study by Barnett et al. (2017) use an interrupted time series model with monthly overdose data and find that the 2012 recreational marijuana legalization in Colorado lead to a 6.5% in opioid related deaths. However, they do not present a compelling argument about the causal impact of the recreational marijuana legislation because they lack a reasonable counter-factual for comparison.

They try to get around this issue by including two states, Nevada and Utah, as covariates in their regression analysis. But neither state has similar pre-treatment trends, so they do not serve as accurate control groups. Nevada follows a different trend particularly over the 2007-2012 period and Utah follows a similar trend but has an approximately 60% larger increase in their opioid overdose fatalities over the 2001-2012 period.

Because this study fails to effectively control for larger regional or national trends in the opioid epidemic, their causal interpretation is tenuous. However, this study does control for Colorado's Prescription Drug Monitoring Program which passed the same year as Washington's Prescription Monitoring Program (Washington State Department of Health, 2017). Barnett et al. (2017) found that their results held when Colorado made their Prescription Drug Monitoring Program mandatory.

Data

This paper examines data by state and year on overdose deaths, self-reported data on opioid usage, and data for the number of admission to treatment facilities for opioid abuse.

Opioid Overdose Crude Death Rate

The data on overdose deaths is provided through Center for Disease Control's (CDC) Wide-ranging Online Data for Epidemiologic Research (WONDER) system.[1] The WONDER multiple cause of death system provides data on overdose deaths from 1999-2015 by state and year. WONDER uses mortality data provided to the National Center for Health Statistics by the Vital Statistics Cooperative Program which uses information from all death certificates filed in the fifty states and the District of Columbia to generate detailed mortality information. These mortality records include coded information about cause of death.

In line with Jacobson et al. (2017), I have chosen to use the International Classification of Disease 10th revision (ICD-10) codes. I tallied every death record by year and by state that included one of the external cause of death and mortality codes, X40-X44, X60-64, X85, and Y10-Y14 and the drug identification codes T40.1-T40.4. These codes correspond to all types of death (unintentional, suicide, assault, or deaths of unclear intent) related to prescription, illicit, or synthetic opioids. From this database, I have also chosen to look at the opioid overdose crude death rate (per 100,000 individuals), as opposed to total number of deaths, in order to adjust for changing population sizes.

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[1] Further information on WONDER is available at, https://wonder.cdc.gov/wonder/help/main.html#.

Self-Reported Opioid Usage

The data on self-reported drug usage is provided through the National Survey on Drug Usage and Health (NSDUH) which is administered SAMHSA. The NSDUH which is an annual nationwide survey involving interviews with approximately 70,000 individuals aged 12 and older. This survey is conducted by a Research Triangle Institute (a nonprofit that provides research services) professional who visits each of the selected households and administers the NSDUH, which covers a wide variety of drug usage and mental health topics.[2] The state estimates in the publicly released survey results are based on a survey-weighted hierarchical Bayes estimation approach and they are generated by Markov Chain Monte Carlo techniques.

This study uses responses by state and year to a prompt about whether an individual uses or has used (in the last year) a pain reliever in any way that was not instructed by a doctor. Unfortunately, the NSDUH is only publicly available by state and year starting in 2009 and the SAMHSA stopped asking about pain reliever misuse in 2014, so responses to this question are only available from 2009 to 2014.

Treatment Admissions

The data for the number of admissions to treatment facilities by state and year for opioid abuse is provided through the Treatment Episode Data Set (TEDS-A) administered by the Substance Abuse and Mental Health Services Administration (SAMHSA). The TEDS-A data set only includes admissions to treatment facilities across

[2] Further information on the NSDUH available at, https://nsduhweb.rti.org/respweb/project_description.html.

the country and is accessible through the years 1999-2014. The only facilities that are captured in the TEDS-A data set are those that receive state alcohol and/or drug agency funds. Furthermore, there are many legal differences across states which affect reporting to TEDS-A.[3] However, a previous study has found that the TEDS-A data set captures a large portion of all admissions (Jacobson et al., 2017).

From the TEDS-A data set, I include all admissions to treatment facilities for methadone addiction (an opioid commonly used in addictions treatment facilities), heroin addiction, or a third generic opioid addiction category in my analysis of the overall opioid abuse treatment admission rates.

Empirical Strategy

In order to address the causal impact of the recreational marijuana legislation, it is important to have a reasonable counterfactual. Unfortunately, the perfect counterfactual for comparison is a hypothetical Washington where the recreational marijuana legislation failed to pass. This study constructs a synthetic control group to use as the counterfactual to estimate what would have happened in Washington in the absence of the legislation.

For the synthetic control group, Synthetic Washington, this study uses the methodology laid out by Galiani and Quistorff (2016) which builds upon work done by Abadie et al. (2010). The synthetic control method is similar to the difference-in-differences method but instead of giving equal weighting to each untreated group, a new control group is generated that it is a weighted average of the untreated

[3] Further information on TEDS-A is available at, https://wwwdasis.samhsa.gov/webt/information.htm.

groups which is designed to closely resemble the treatment group (Washington) in the pre-treatment period (2012 and earlier) (Galiani and Quistorff, 2016).

The synthetic control is constructed to very closely resemble Washington State up until the year the recreational marijuana legislation took effect. Technically this synthetic control group is constructed in order to minimize root mean squared prediction error between the synthetic control and the treatment group. To project the synthetic control group into the post-treatment period (2013-present), the observed value (for overdoses or treatment admissions) in each state is multiplied by its weight in the synthetic control group (Galiani and Quistorff, 2016).

The critical identifying assumption in my analysis is that in the post-treatment period the synthetic control group would have similar outcomes to Washington if the recreational marijuana legislation didn't pass. I will assess the specific validity of this claim with regards to particular outcomes in my analysis section. But, generally, because the synthetic control group has a similar trend to Washington in the pre-treatment period, I assume that the synthetic control group has a similar trend to Washington, if the recreational marijuana legislation was not passed, in the post-treatment period.

The validity of this assumption, that synthetic Washington is a good predictor of Washington without the recreational marijuana legislation, is addressed by running placebo tests. This means that a synthetic control group for each of the other 47 states (excluding Oregon and Colorado) is generated based on the pre-treatment data and then the synthetic control group for each state is compared to the observed values of the state in the post-treatment period. However, none of these states had the same recreational marijuana legislation, so the placebo test checks how well the synthetic control methodology does at predicting outcomes in the other 47 states where no treatment actually occurred. This assumption is measured by calculating a p-value which is the fraction of states that have larger absolute deviations from their synthetic control group than Washington has from its synthetic control group, Synthetic Washington (Galiani and Quistorff, 2016).

However, this is not a perfect method because many states have implemented policies aimed at reducing opioid abuse in the 2012-2015 period so that the observed difference between the synthetic control group and the "treated" state is larger than it actually would have been without any interventions. This would cause the observed p-value to go up because many states are likely experiencing larger than expected deviations from their predicted values. So it is likely that the p-values in this study are overestimates of the true value.

Finally, due to the possible spillover effects between Washington State and Oregon and the legalization of recreational marijuana in Colorado, this study excludes Oregon and Colorado from the synthetic control groups. The spillover effect exist because when marijuana became recreationally legal in Washington State, it became easier to obtain for Oregon residents. So the effects of the legalization of recreational marijuana in Washington would also have some effect in Oregon. Similarly with Colorado, because Colorado legalized recreational marijuana the same year as Washington State, it is probable that similar effects would exist in both states− so Colorado would not make an appropriate counterfactual.

Analysis

This section is broken up into analysis about the opioid overdose crude death rate, self-reported opioid usage, and treatment admissions related to opioid abuse.

Opioid Overdose Crude Death Rates

Washington's opioid overdose crude death rate increased steadily from 1999 to 2008 and then saw a slight decline, leveling off in 2011. Between 2012 and 2014 there was a decline and then in 2015 there was a sharp increase in the opioid overdose crude death rate. Figure 1 shows Washington's opioid overdose crude death rate (per 100,000) from 1999-2015. Without any control group, it is impossible to tell what the effect of the recreational marijuana legislation was on the opioid crude death rate.

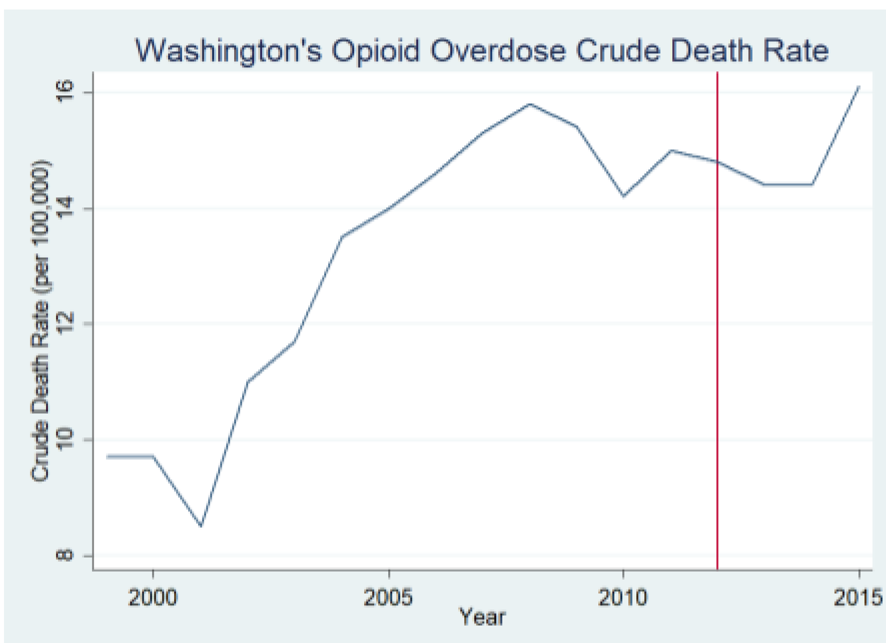

Figure 1. Showing Washington State's opioid overdose crude death rate from 1999 to 2015. The vertical line is at 2012, when Washington legalized recreational marijuana.

In the absence of this legislation, the opioid overdose crude death rate may have increased or decreased significantly and that would be impossible to measure without a control group. Washington had a high relative opioid overdose crude death rate from 1999 to the late 2000s but then in the 2010s many states's opioid overdose crude death rates began to surpass Washington's. Figure 2 shows Washington and the other 47 state's opioid overdose crude death rates.

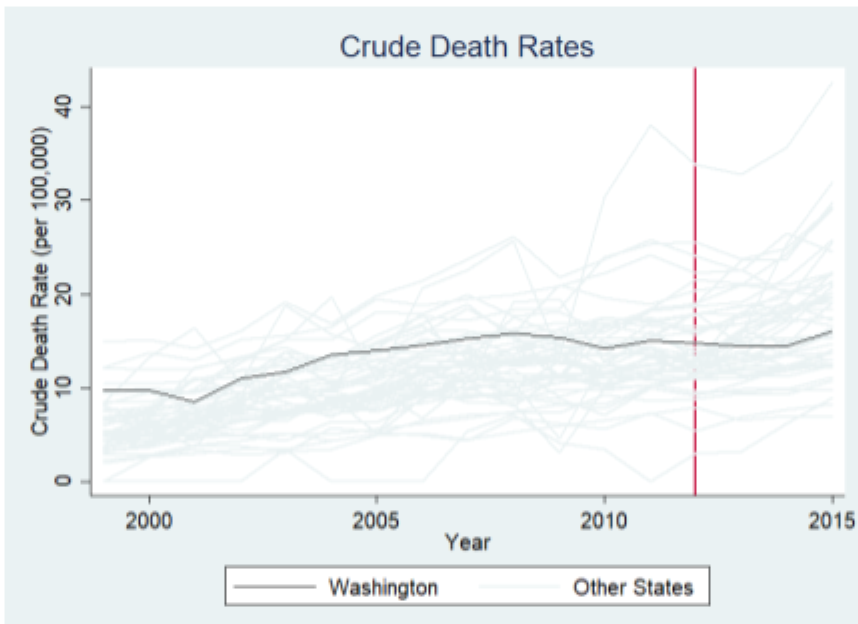

Figure 2. Showing every State's Crude Death Rate from 1999 to 2015. The vertical line represents the year Washington passed recreational marijuana legislation. The vertical line is at 2012, when Washington legalized recreational marijuana.

I created Synthetic Washington to serve as the control group to assess the impact of the recreational marijuana legislation. Synthetic Washington is the weighted average of the other 47 states (excluding Oregon and Colorado) that minimizes the root mean squared prediction errors of Washington compared to Synthetic Washington over the 1999-2012 pre-treatment period. Louisiana, California, Nevada, Connecticut, and

Maryland are the states with the largest weights in Synthetic Washington and many states that have dissimilar trends have a weight of 0.

Figure 3 presents the trends of Washington and Synthetic Washington over the 1999-2015 period. Washington and Synthetic Washington follow similar pre-policy trends but diverge after 2012. This divergence is pronounced. Synthetic Washington has a much larger opioid overdose crude death rate than the rate observed rate in Washington.

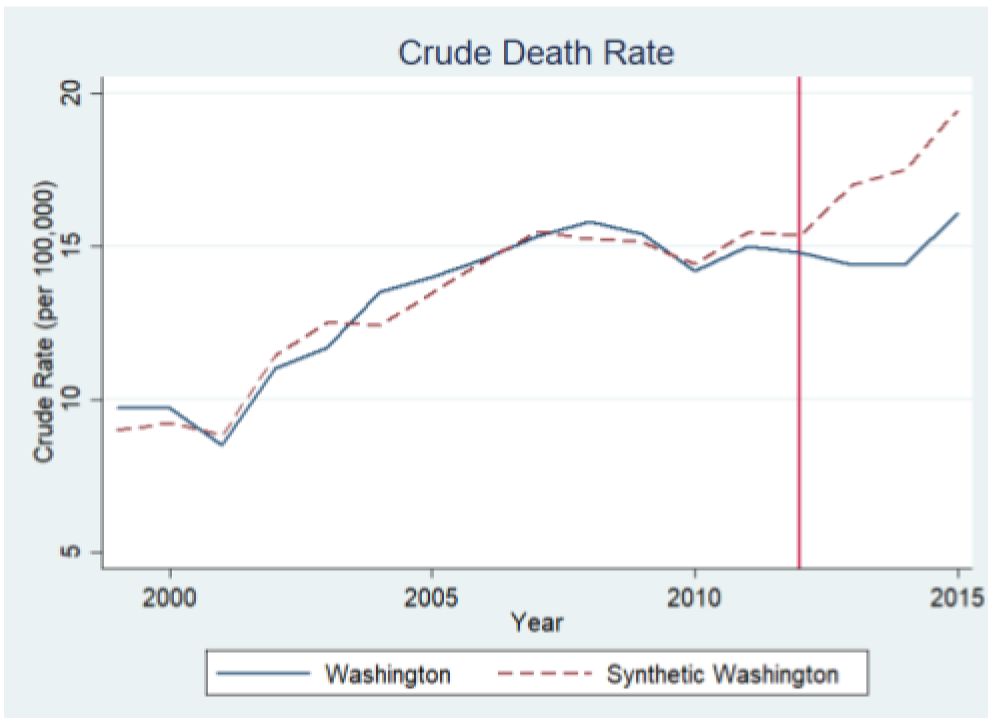

Figure 3. Showing Washington (solid line) and Synthetic Washington's (dashed line) crude death rates over the 1999-2015 period. The vertical line is at 2012, when Washington legalized recreational marijuana.

The estimated effect of the recreational marijuana legislation is that it reduced the opioid overdose crude death rate by 2.5961 people (per 100,000) in 2013, 3.089 people (per 100,000) in 2014, and 3.3305 people (per 100,000) in 2014. That implies that this legislation saved 181 lives in 2013, 218 lives in 2014, and 239 lives in 2015. Figure 4 explicitly shows this difference between Washington and Synthetic Washington's opioid overdose crude death rates.

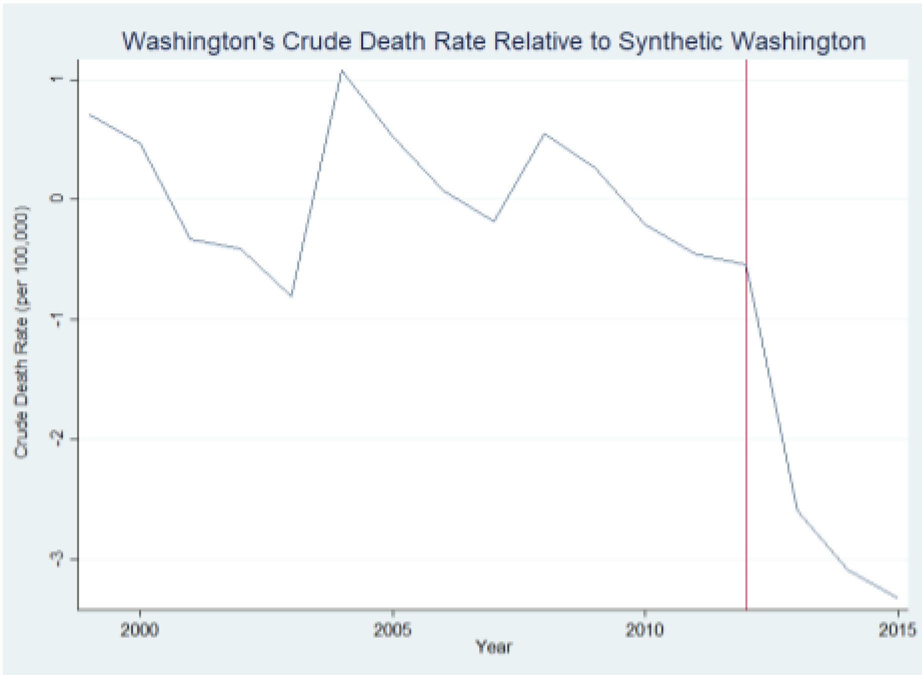

Figure 4. Depicting Washington's opioid overdose crude death rate relative to Synthetic Washington. The vertical line is at 2012, when Washington legalized recreational marijuana.

Concluding a causal inference is intricate. The p-values for the three post-legislation years are 0.13 in 2013, 0.19 in 2014, and 0.29 in 2015, which implies that 13% of states had a larger deviation from their synthetic control group in 2013, 19% in 2014, and 29% in 2015. Figure 5 illustrates each state's deviation from its synthetic control group.

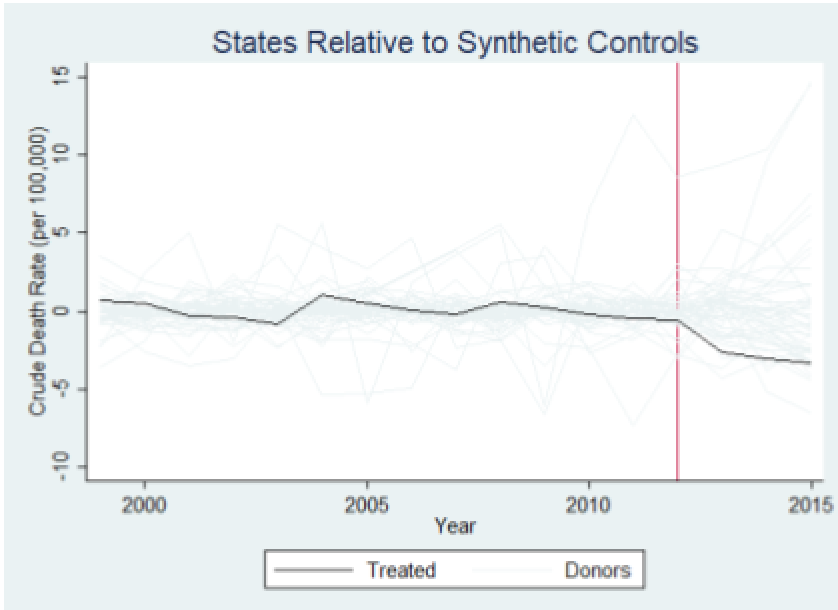

Figure 5. Showing the states relative to their synthetic control groups created as part of the placebo test. Washington is the treated group and the other 47 states are the donors. The vertical line is at 2012, when Washington legalized recreational marijuana.

For many of the states with large post-treatment deviations, their synthetic control groups do not accurately match the state in the pre-treatment period. For many of these outlier states, the root mean squared prediction error, a term that calculates the total deviation in the pre-treatment period, are between 3 and 10 times larger than the root mean squared prediction error for Synthetic Washington. For these states, the synthetic control groups do not predict the pre-treatment trends well, so I do not expect that they would predict the post-treatment trends well either.

In order to overcome this issue, I tried running the placebo tests again after removing states with root mean squared prediction errors which were larger than a multiple of Washington's root mean squared prediction error. I tried removing states that had root mean squared prediction errors that were 1000%, 500%, 300%, 200% and 150% larger than Washington's root mean squared prediction errors from the placebo test. The p-values were remarkably robust to this sort of deletion.

The only restriction that yielded a significant difference was the 150% restriction. After limiting the placebo test to states that had less than 150% of Washington's root mean squared prediction error, there were 25 remaining comparison states and the p-values were 0 for 2013, 0.08 for 2014, and 0.20 for 2015 which implies that none of the 25 states had larger deviations than Washington in 2013, 8% of the states that were involved in the placebo test had larger deviations than Washington in 2014, and 20% of these states had larger deviations in 2015.

Of the states that had reasonably accurate synthetic control groups (root mean squared prediction errors less than 150% of Washington's), Washington had the largest deviation from their synthetic control group in the first year after the legalization of recreational marijuana and one of the largest deviations in the 2nd and 3rd years after passage. This shows that the decrease in Washington's crude death rate was likely a result of the legislation instead of random variation or prediction error.

Self-Reported Opioid Usage

Due to the data limitations and availability for self-reported opioid usage discussed in the Data section, it is not possible to conduct analysis using synthetic control groups, so this paper only provides basic rates which are presented in Figure 5.

For the years available, self-reported misuse of prescription painkillers declined in Washington State. Whether this is due to the recreational marijuana legislation is hard to tell because it is hard to establish the pre-treatment trends. Furthermore, this decline may not represent a decline in opioid abuse because it might only be capturing a shift away from prescription opioid abuse to illicit opioid abuse.

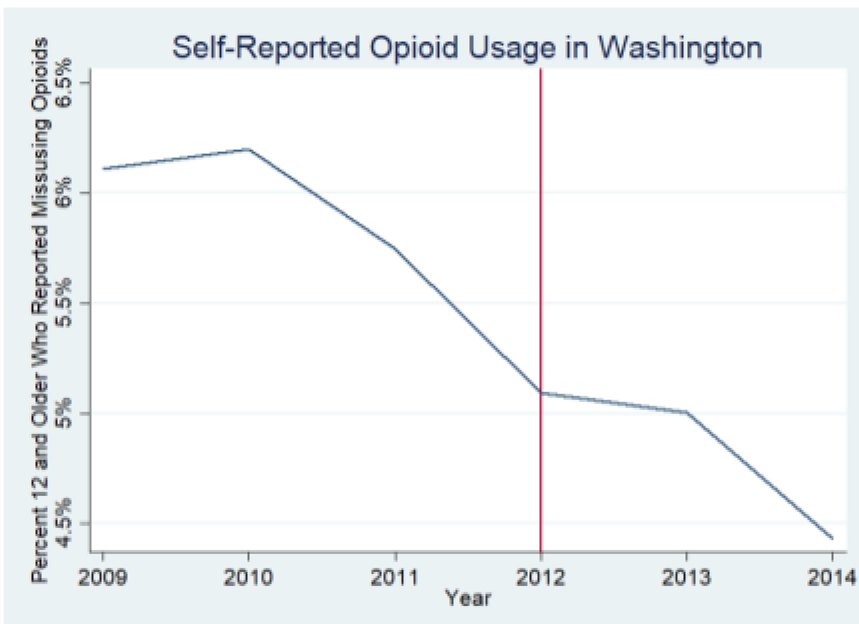

Figure 6. Showing the self-reported nonmedical opioid usage rates in Washington State from 2009 to 2014. The vertical line is at 2012, when Washington legalized recreational marijuana.

Opioid Abuse Treatment Admissions

This section employs a synthetic control methodology to analyze the impact of the recreational marijuana legislation on treatment admissions. Treatment admissions in Washington steadily increased over the 2000-2010 period, with a dip in the mid 2000s. This increase slowed over the 2010-2013 period and then, in 2014, the number of treatment admissions grew by nearly 2000. Figure 7 shows this graphically below.

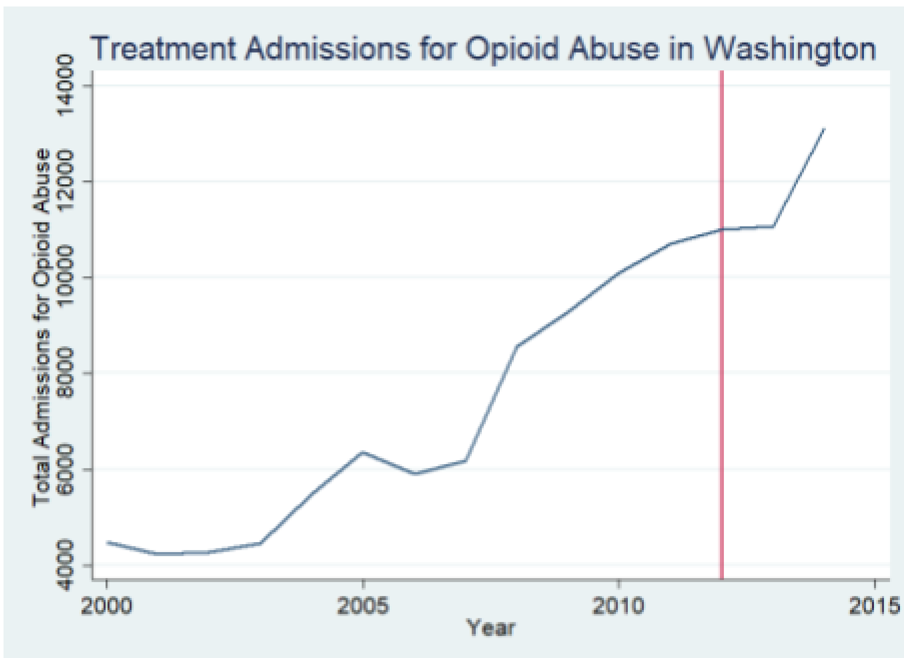

Figure 7. Showing the number of treatment admissions for opioid abuse in Washington from 2000 to 2014. The vertical line is at 2012, when Washington legalized recreational marijuana.

In a similar fashion to the opioid overdose crude death rate, the effect of the recreational marijuana legislation on treatment admissions is impossible to measure without a control group. In order to get around this issue, I constructed a synthetic control group from the 47 other states. Of the 47 other states, shown in Figure 8, Washington's number of treatment admissions was higher than most states over the entire 2000-2014 period. There is also a large variance in the number of treatment admissions across states− that is likely caused by differences in population size, amongst some other factors.

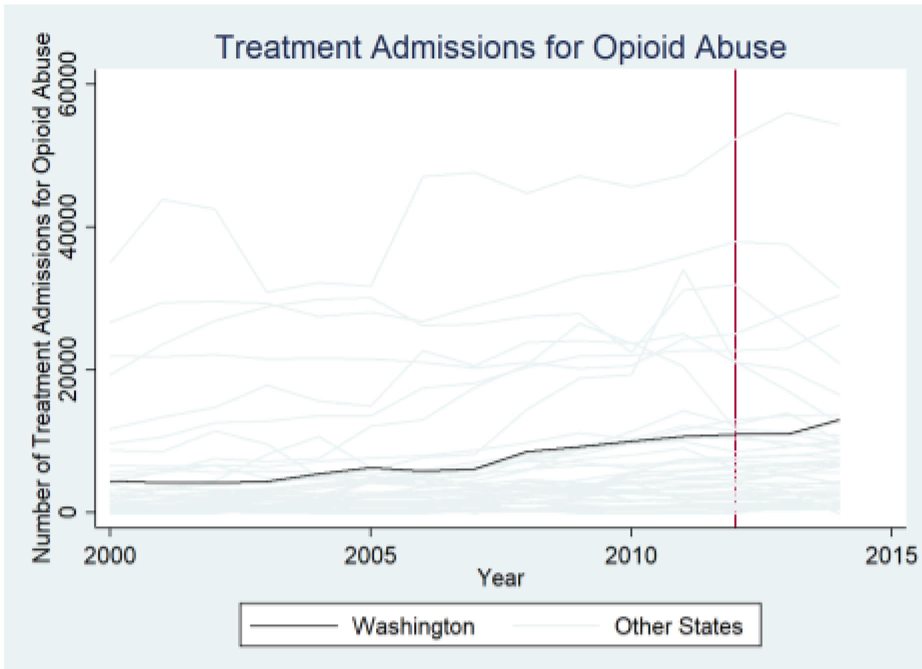

Figure 8. Showing the number of treatment admissions for opioid abuse from 2000 to 2014 for most states. California and New Mexico are not shown on this graph because they have a very large number of treatments. The vertical line is at 2012, when Washington legalized recreational marijuana.

The synthetic control group, synthetic Washington, is different than the synthetic control group used for the previous analysis. This control group has been generated in order to match the pre-treatment trend for Washington State in regards to treatment admissions for opioid abuse. Illinois, Mississippi, Michigan, Arkansas, Connecticut, and Maine receive the largest weights in Synthetic Washington. Figure 9 presents a graph of Washington and Synthetic Washington for 2000-2014. They are incredibly similar in the pre-treatment period and then diverge in the post-treatment period.

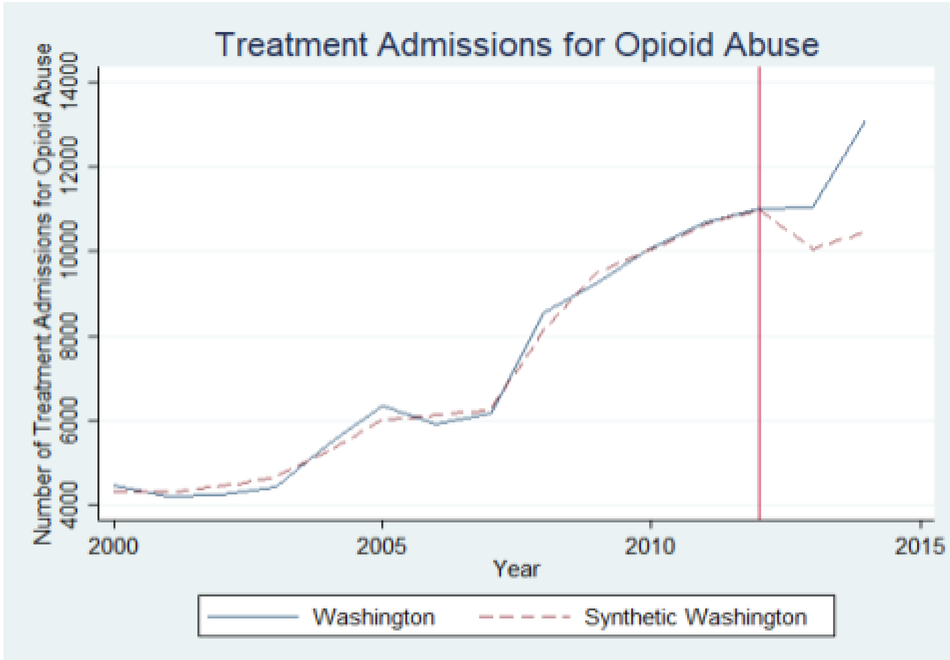

Figure 9. Showing Washington and Synthetic Washington's number of treatment admission for opioid abuse from 2000 to 2014. The vertical line is at 2012, when Washington legalized recreational marijuana.

Relative to Synthetic Washington, Washington State in the post-treatment period has a large increase in treatment admissions. Figure 10 shows Washington's number of treatment admission relative to Synthetic Washington. In 2013 there were 990 more treatment admissions than in Synthetic Washington, and in 2014 there were 2,637 more treatment admissions.

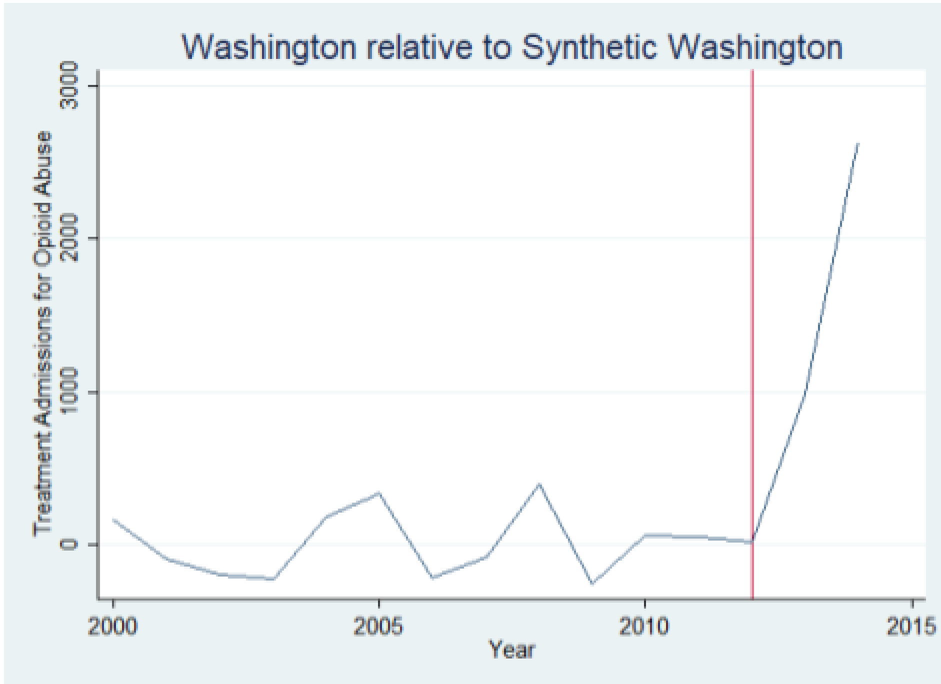

Figure 10. Showing Washington's number of treatment admissions for opioid abuse relative to Synthetic Washington. The vertical line is at 2012, when Washington legalized recreational marijuana.

The p-values for these two years are 0.28 in 2013 and 0.20 in 2014, which imply that 28% of states had larger deviations from their synthetic control groups in 2013 and 20% of states had larger deviations from their synthetic control groups in 2014. This appears to convey a relatively high-degree of uncertainty about the true predicting power of the synthetic control group methodology with respect to the number of opioid abuse related treatment admissions. However, as is shown in Figure 11, many of the states with large deviations also have very large root mean squared prediction errors so they do not have similar accuracy to Synthetic Washington, so therefore, they should not be considered in the placebo test.

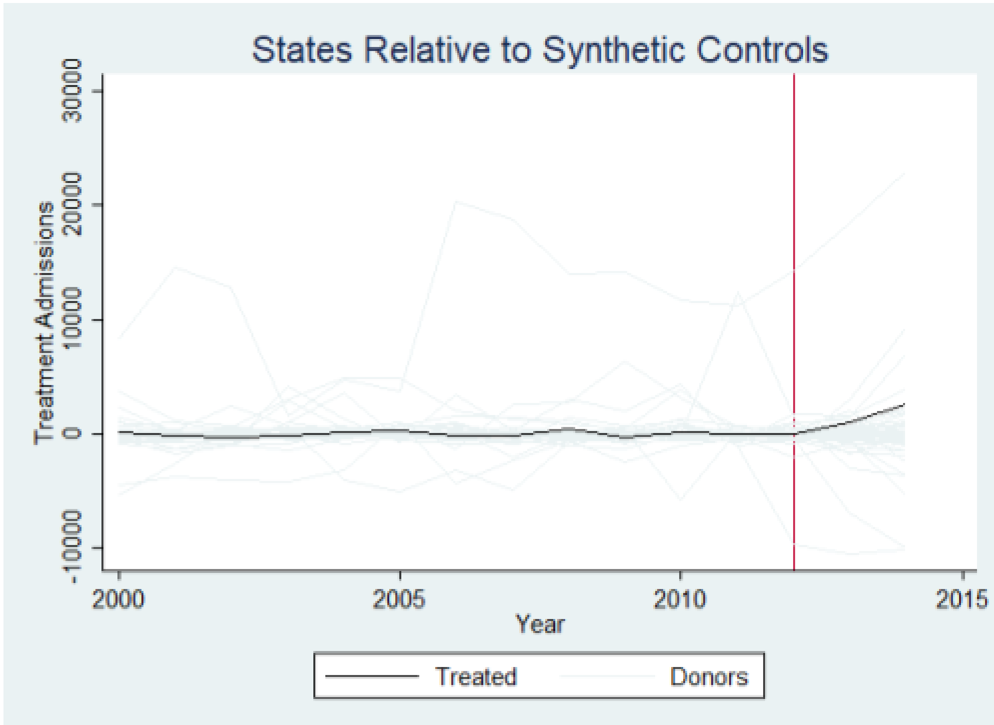

Figure 11. Showing the states relative to their synthetic control groups created as part of the placebo test. The vertical line is at 2012, when Washington legalized recreational marijuana.

The states with large root mean squared prediction errors have synthetic control groups that are bad at matching the pre-treatment trends, so I do not expect these synthetic control groups to do a good job predicting the outcomes in the post-treatment period. So I would like to only include states in the placebo tests that have relatively small (relative to Washington) root mean squared prediction errors because these are the states that are likely to have more accurate post-treatment predictive power.

I tried restricting the placebo tests to states with 1000%, 500%, 300%, 200%, and then 150% of the root mean squared prediction error that Washington and Synthetic Washington have. When I made this criterion more restrictive, the p-values for

Washington became smaller. The p-values dropped from 0.28 to 0.08 in 2013 and from 0.20 to 0.04 in 2014 as more states were exclude from the placebo tests.

There were 23 states left in the placebo test when the states, whose Synthetic control groups had root mean squared prediction errors greater than 150% of Synthetic Washington's root mean squared prediction error, were removed. Of the states that had reasonably accurate synthetic control groups, only 8% had larger deviations from their synthetic control groups in 2013 and only 4% of these states had larger deviations from their synthetic control group in 2014. This shows that the increase in the number of opioid abuse related treatment admissions in Washington was likely a result of this legislation instead of random variance or prediction error.

Results

At the end of this sections I have included a subsection, titled "Limitations and Critiques", where I provide responses to a couple possible critiques and explicitly discuss the limitations of this analysis.

In terms of both opioid related overdoses as well as self-reported usage there has been a decline. However, of these two indicators, this paper only shows that the recreational marijuana legislation had a causal impact on opioid overdoses. There is insufficient data to draw a reasonable conclusion about the causal impact about the legislation's effect on self-reported usage. However, due to the causal impact on the opioid overdoses, it is likely that there was also a causal impact on the self-reported usage. Further, it is reasonable to assume that if less individuals are overdosing on opioids, then less individuals are also abusing opioids. This is congruous with the decline in both the opioid overdoses as well as the self-reported usage. This is a large and likely unforeseen benefit from recreational marijuana legalization in Washington State.

Despite the decline in these two indicators, treatment admissions have a sharp increase in the post-legalization period, particularly in 2014. Previous literature relied on treatment admissions as a proxy for opioid usage. However, with the presence of mortality statistics as well as limited data available from the NSDUH, this paper does not interpret treatment admissions as an indicator of opioid usage. This paper interprets treatment admissions as treatment admissions, which are a benefit to society.

This is because the number of treatment admissions is likely a function of many variables, one of which is definitely the rate of drug usage– but this is not the only variable that affects the number of treatment admissions. Treatment admissions continued to increase in the mid/late 2000s even when the opioid overdose crude death rate remained constant (or even decreased). So, it is clear that the opioid overdose crude death rate is not the only factor which affects the number of treatment admissions. Social stigma, quality of treatment, financial conditions (funding and insurance structures), and a wide variety of more nuanced factors, all of which the legalization of recreational marijuana could impact, also affect the number of treatment admissions.

It should be noted that recent studies have shown that cannabis can be used in the treatment of opioid abuse disorders (Hurd, 2016). The passage of recreational marijuana in Washington expanded treatment options available to treatment facilities, could have helped to de-stigmatize medical marijuana usage at large, and could have helped opioid abusers begin self-treating before going to enter a formal treatment facility.

Regardless of the link, *Ceteris paribus*, an increase in treatment admissions would have a positive influence on opioid abuse and overdoses. By this rationale, because recreational marijuana legislation has not lead to an increase in opioid usage, the increase in treatment admissions should be interpreted as a positive effect of this legislation.

Limitations and Critiques

One possible critique is that there are no control variables in this analysis. This could lead to omitted variable bias. However, when testing different synthetic control groups, using the male/female population ratio, median household-income, percent of individuals who are white, and other demographic factors at the annual and state level, there are only very small changes to the outcomes of Washington relative to Synthetic Washington for opioid overdoses. The changes in the effects on treatment admissions are larger, but not more than 1,600 treatment admissions.

Another possible critique is that Washington State passed a Prescription Monitoring Program in 2007 that took effect in 2011 (Washington State Department of Health, 2017), so some of the decrease in opioid related overdoses or increase in treatment admissions observed in the 2013-2015 period could be due to this legislation. However, this is unlikely because previous literature has shown that similar Prescription Drug Monitoring Programs have had little to no effect on drug overdoses (Desai 2011), since 2010 the main drivers of the opioid epidemic have been the synthetic opioid fentanyl and the illicit opioid heroin (David et al., 2016), and, because this legislation was passed in 2007 and took effect in 2011, there were many years for doctors to adjust their prescription habits to comply with the legislation before the implementation date.

Furthermore there were two years where this legislation could have impacted overdose rates and the number of treatment admissions before the recreational marijuana legislation took effect.

One limitation is that part of the decrease in opioid overdoses is likely partly explainable by the increase in treatment admissions. However, treatment admissions have been steadily increasing over the entire 2000-2014 period, but there have been no large declines in opioid abuse overdoses over the same period. Furthermore, even if the increase in treatment admissions explained the decline in opioid overdoses, there is no other factor that would likely have lead to an increase in treatment admissions for opioid abuse. Hence, this legislation would still have a large positive impact.

A third limitation is the amount of data; due to the recent nature of this epidemic and legislation there limited data available. This study cannot analyze the long term impacts of the recreational marijuana legislation and it remains challenging to create a control group due to the limited pre-treatment data.

Conclusion

Previous literature showed a link between medical marijuana and a reduction in opioid abuse, predicate on medicinal marijuana being available through dispensaries. These studies use the opioid overdose crude death rate as well as the number of treatment admissions as proxies for the total amount of opioid abuse. Additionally, Barnett et al. (2017) employed an interrupted time series model to show that Colorado’s legalization of recreational marijuana in 2012 lead to a decrease in the opioid overdose crude death rate.

I expand upon this literature by using a synthetic control group methodology in Washington State to study the impact of their 2012 legalization of recreational marijuana on opioid overdoses and treatment admissions in Washington State. In terms of the opioid overdose crude death rate, my result corroborate Barnett et al. (2017) and show that the legalization of recreational marijuana lead to a decline in the opioid overdose crude death rate in Washington State.

But, in terms of the treatment admissions, my results contradict previous findings. Previous literature has shown that medical marijuana laws lead to a reduction in treatment admissions but my study finds that the legalization of recreational marijuana lead to an increase in the number of treatment admissions. Because the opioid overdose crude death rate was declining over the post-treatment time period, I propose that treatment admissions should be seen as a benefit, instead of as a proxy for opioid abuse. Further research should be conducted in order to determine the linkage between the number of treatment admissions and the opioid overdose crude death rate, the long-term impacts of recreational marijuana legislation, and the impact of this policy across different states and times.

The opioid epidemic is and has been one of the most pressing societal and policy issues facing our nation. It is ruining lives, destroying families, and killing thousands every year. Due to the incredible societal harm and death toll that the opioid epidemic is causing, it is imperative to continue analysis of and find effective responses to every facet of the opioid epidemic.

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