Is Marijuana a Gateway Drug? The Impact of Recreational Marijuana Legalization in Colorado on Opioid Deaths

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Introduction

As the number of states that have legalized the use of recreational marijuana increases in the U.S., there is much heated political discussion about the effects of such a law change on public health. A question that has been very important to this discussion is what role marijuana plays in predisposing its users to abuse other controlled substances, such as opioids and alcohol. One study by Weinberger, Platt, and Goodwin suggests that "Cannabis use [is] associated with increased incidence of alcohol use disorders" (2016). If recreational marijuana leads to an increased use of addictive substances, this could have enormous negative public health consequences for the states that choose to legalize it.

One way to detect negative public health outcomes due to legalization of recreational marijuana is to observe the opioid mortality rate before and after legalization occurred. If opioid mortality rates increased in states where recreational marijuana is legalized relative to states where it was not, this would provide evidence of marijuana's role as a gateway drug. However, if the relationship between opioid mortality rates and recreational marijuana legalization is negative, this could indicate that marijuana and opioids are substitutes for each other, and that by making one of these legal, drug users will opt for the legal substance over the illegal one.

As Colorado was the first state to legalize private use of marijuana, we use a synthetic control approach to observe how opioid mortality rates in Colorado changed relative to synthetic

Colorado following a law change. Our findings suggest that opioid mortality did not increase significantly in Colorado following the legalization of recreational marijuana. If anything, the impact of this legalization decreased opioid mortality, which provides evidence that the substitution effect of marijuana is larger than the 'gateway drug' effect. As a robustness check, we create another synthetic control using only states that had legalized medical marijuana by 2008.

Background and Literature

According to the Controlled Substances Act of 1970, marijuana is a Schedule 1 controlled substance and is illegal on a federal level (United States Drug Enforcement Administration). However, since the passage of this act, many states have passed their own laws allowing for the sale and use of marijuana under certain circumstances. As of 2021, recreational marijuana is legal in 15 states, as well as the District of Columbia and two territories. Prior to the legalization of recreational marijuana, a number of states also passed laws allowing for the sale of cannabis for medicinal purposes. Currently, the only two states that do not allow consumption of marijuana or derivatives for any purpose are Idaho and Nebraska. Many states are expected to legalize recreational marijuana in the future, and there is speculation that the United States Congress may be considering federal legalization measures of some kind (Fertig 2021).

In 2012, the state of Colorado passed Colorado Amendment 64, which legalized marijuana for recreational purposes. The law permits adults over the age of 21 to possess up to one ounce of marijuana when traveling and to grow up to six marijuana plants in a locked space (Colorado State Ballot Initiative 2011). While private consumption became legal following the signing of the bill, specific provisions did not take effect immediately. Governor John

Hickenlooper created a task force to research implementation and make further suggestions as to how the growth and sale of marijuana should be regulated (Colorado General Assembly). On January 1, 2014, the first retail stores opened.

The idea that marijuana is a gateway drug, or the "stepping-stone hypothesis" was supported in some research from the 1980s and 1990s. One such study from 1980 found that marijuana use was indicative of a tendency to use other types of drugs (Budd). This study also found correlation between alcohol and later hard drug use. The theory behind this phenomenon is that cannabis users' brains are "primed" for enhanced responses to other drugs, and are therefore more likely to try and continually use more dangerous drugs. A 1998 study supports this theory and provides additional hypotheses to explain it. The study used data from the National Longitudinal Survey of Youth to examine the relationship between marijuana use and later cocaine use. The author suggests that previous marijuana use increased the probability that an individual used cocaine at the time of the survey by 29 percentage points. It is noted that this could be due to the fact that the type of person who uses marijuana possesses some unobservable characteristic that makes them likely to also try cocaine, rather than this being some kind of gateway effect (DeSimone 1998). In addition, the National Institute on Drug Abuse notes that "the majority of people who use marijuana do not go on to use other, 'harder', substances" (NIDA).

The impact of both medical and recreational marijuana legalization has been studied through a number of different lenses, and more recent studies suggest that marijuana may actually be a substitute for alcohol and other drugs rather than a complement. In their 2013 study, Anderson, Hansen, and Rees observed changes in traffic fatalities following medical marijuana legalization. Their study found that following the legalization of medical marijuana, traffic

fatalities decreased by 8-11 percent, with an even larger decrease when observing alcohol related traffic fatalities. The authors also suggest that their findings indicate that alcohol and marijuana are substitutes.

Another recent study by Chan, Burkhart, and Flyr used a difference-in-differences approach to study the impact of recreational marijuana laws on opioid mortality rates. Their findings suggest that opioid mortality is reduced by 20%-35% due to legalized recreational marijuana. They attribute this effect to the fact that legalizing medical marijuana increases the number of dispensaries in a state. Individuals who may have gone to the doctor to get prescription opioids for pain relief are using marijuana from nearby dispensaries instead (2020). This study provides strong evidence that marijuana is a substitute for opiates rather than a gateway drug that leads to more addiction.

Data

We use data from three main sources in our analysis. Opioid mortality data was retrieved from the CDC WONDER database's Multiple Cause of Death database. This database provides mortality rates aggregated by state and year. Throughout this analysis, 'opioid mortality' refers to ICD-10 codes T40.0-T40.4 as well as T40.6. These codes count drug overdose deaths with one of the following listed as a contributing cause of death: opium, heroin, 'other opioids', methadone, 'other synthetic narcotics', 'other and unspecified narcotics'.

Data for 5 year age groups comes from the CDC WONDER database's Bridged-Race Population Estimates. Additional data for demographic controls was retrieved and aggregated from the American Community Survey (ACS) conducted by the United States Census Bureau. The ACS data provides controls for household income, housing units per capita, sex, marital

status, education, race, and ethnicity. We converted discrete variables into rates by dividing by population. We also dropped Wyoming, North Dakota, South Dakota, and Nebraska from our dataset due to missing data.

For our analysis, we use data for the period 1999-2019. Colorado Amendment 64 was passed in 2012 and retail sales were allowed beginning in 2014, which leaves us with over 10 years of data before the law was passed.

Identification

We use a synthetic control to estimate opioid mortality rates in Colorado in the absence of recreational marijuana legalization. Our identification strategy depends on three assumptions. First, in the absence of the law which legalized recreational marijuana, the rate of opioid deaths in Colorado would be the same as in synthetic Colorado. Because synthetic Colorado is created to match Colorado before the law was implemented, this assumption is plausible. Second, the legalization of marijuana impacts Colorado but not synthetic Colorado. We drop states that legalized recreational marijuana before 2018 to ensure that this assumption holds. The third assumption is that the impact of the law had no effect before it was enacted. This could be an issue due to the fact that certain provisions of the law went into effect before others. Violation of this assumption may be possible if new dispensaries for medical marijuana opened between 2012 and 2014 in anticipation of being able to sell recreational marijuana as well. However, our robustness checks show that divergence of trends in opioid mortalities between Colorado and synthetic Colorado does not occur until treatment (2014), so we believe the assumption holds (see Figure 2). More research on specific dispensaries opened in Colorado during this time

period may shed more light on the validity of this assumption, but is outside the scope of this particular paper.

Another concern is that SUTVA may be violated if there is spillover across states that border Colorado. However, there are not many large cities near the border to Colorado and any spillover would attenuate the results towards zero. In addition, Utah was the only state that borders Colorado that was given any weight in the synthetic control. No urban communities in Utah are close to the Colorado border, so we believe that any SUTVA violations are negligible.

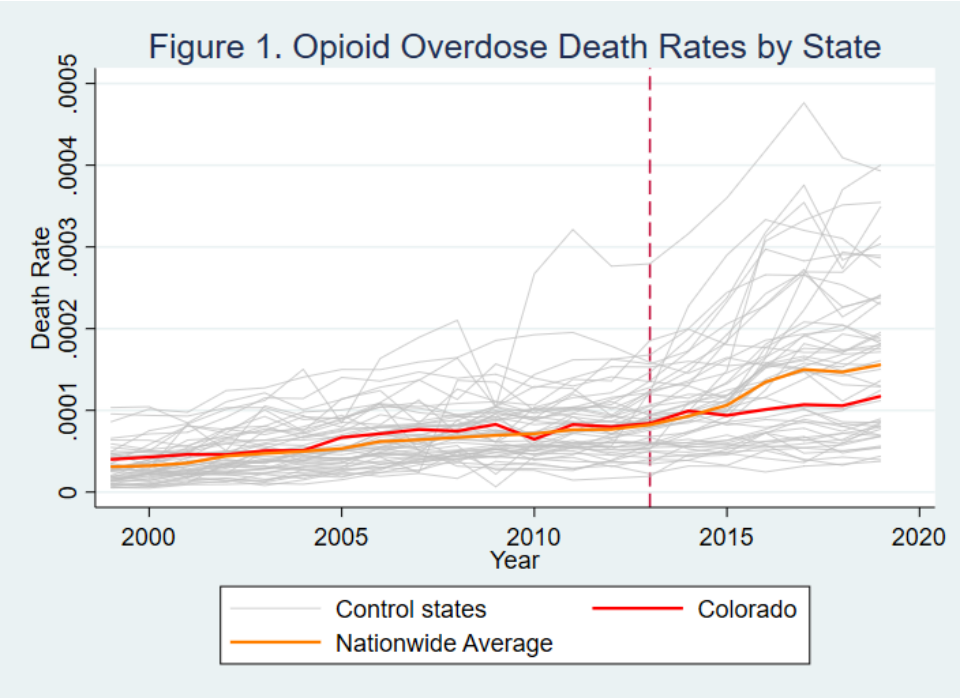
Experimental Design

We utilize a synthetic control model to observe the change in opioid mortality after the legalization of recreational marijuana in Colorado relative to synthetic Colorado. Colorado was chosen because it was the first state to legalize the use and sale of recreational marijuana. The law was passed in 2012, and all provisions had taken effect by January 1, 2014. The pre-treatment period we observed spans from 1999 to 2013, and the posttreatment period spans from 2014 to 2018. A number of states were removed from the synthetic control model due to legalization of recreational marijuana during the years of interest. These states were as follows: Washington, Alaska, Oregon, Massachusetts, Nevada. We also excluded the District of Columbia from the analysis.

We matched our synthetic control on the opioid mortality rates and demographic controls in 2008 and 2013. These demographic variables are 5 year age groups, sex, marital status, race, education, housing units per capita, average total household income as well as the natural log of average total household income. Because recreational marijuana can only be purchased by those over 21, we also added a control for the proportion of the population in certain age groups.

Results

Opioid overdose death rates in Colorado climbed steadily from 2000 to 2019. Figure 1 presents opioid overdose death rates by state. Rates in Colorado closely match the nationwide average until 2015, when the nationwide average continued to climb higher than the death rate in Colorado. This divergence lends support to the idea that the passage of Colorado Amendment 64 led to a lower rate of opioid deaths than the counterfactual.



Synthetic Colorado is a combination of states that resemble Colorado in pre-Amendment 64 opioid mortality and other demographic predictors. The weights of the control states used to construct synthetic Colorado are displayed in Table 1. The synthetic control is composed of Georgia, Maryland, Minnesota, Texas, Utah, and Virginia. The other states are each given a weight of zero, while dashes indicate states dropped from the dataset due to insufficient data or similar legalization laws during the period of interest.

Table 1. State weights in synthetic Colorado

State	Weight	State	Weight	State	Weight	State	Weight
Alabama	-	Indiana	0	Nebraska	-	Rhode Island	0
Alaska	0	Iowa	0	Nevada	-	South Carolina	0
Arizona	0	Kansas	0	New Hampshire	0	South Dakota	-
Arkansas	0	Kentucky	0	New Jersey	0	Tennessee	0
California	0	Louisiana	0	New Mexico	0	Texas	0.062
Connecticut	0	Maine	0	New York	0	Utah	0.14
Delaware	0	Maryland	0.218	North Carolina	0	Vermont	0
District of Columbia	-	Massachusetts	-	North Dakota	-	Virginia	0.234
Florida	0	Michigan	0	Ohio	0	Washington	-
Georgia	0.174	Minnesota	0.171	Oklahoma	0	West Virginia	0
Hawaii	0	Mississippi	0	Oregon	-	Wisconsin	0
Idaho	0	Missouri	0	Pennsylvania	0	Wyoming	-
Illinois	0	Montana	0				

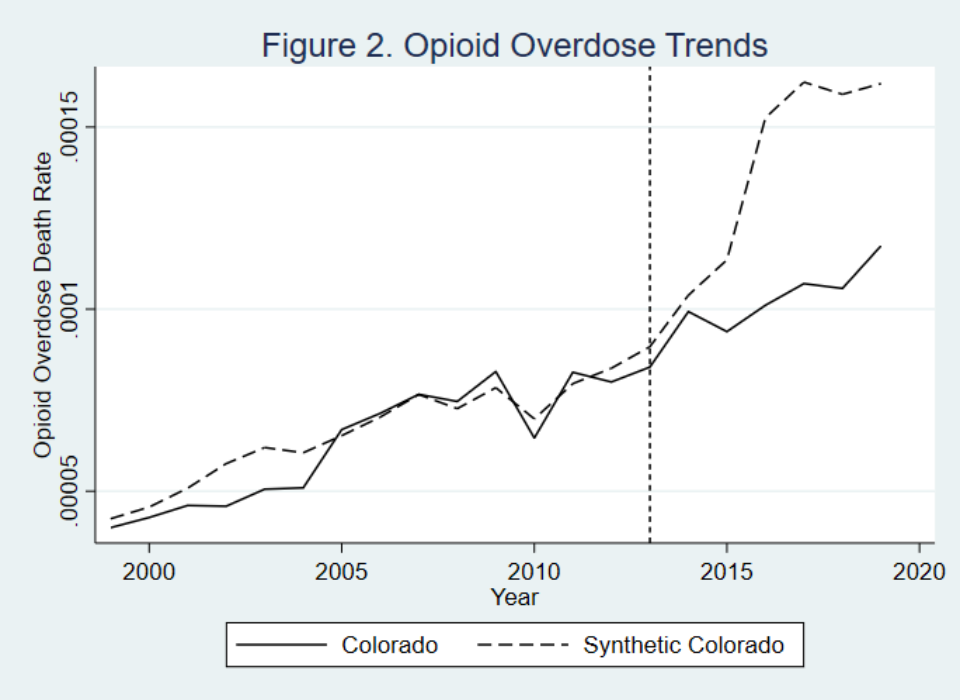
Table 2 compares select pre-treatment characteristics of Colorado with Synthetic Colorado as well as the average of the 40 control states. The table illustrates that synthetic Colorado is an accurate counterfactual of pre-treatment Colorado. Many of the variables of interest in Colorado and synthetic Colorado match very well in the pre-treatment period (1999-2013), namely ln(income) and the proportion of the population aged 20-29.

Table 2. Selected opioid mortality predictor means

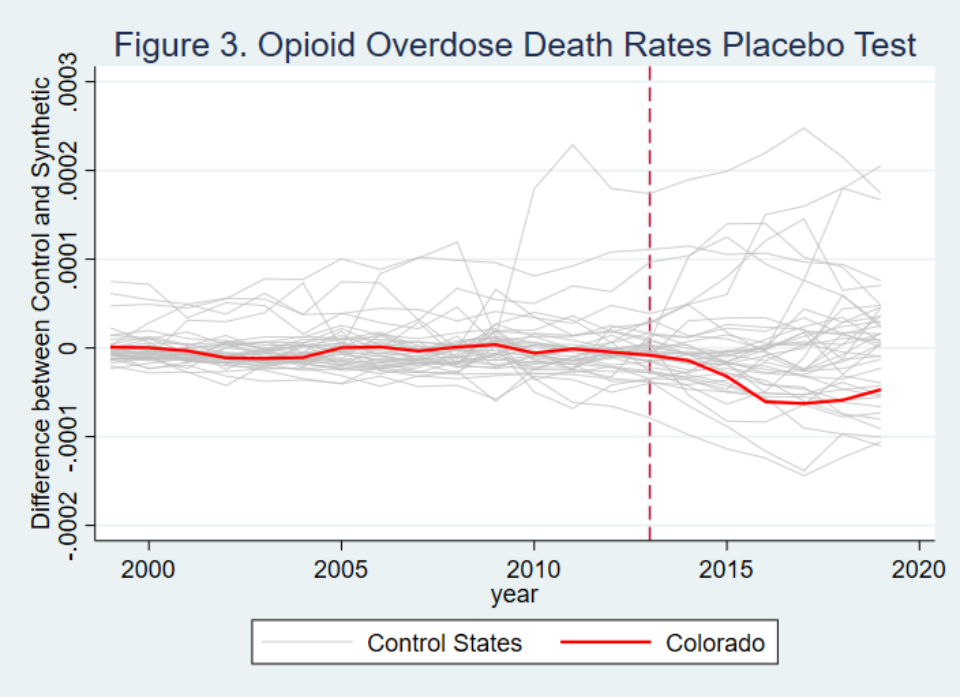
Variables	Colorado	Synthetic Colorado	Average of 40 control states
Ln(income)	11.14	11.22	10.89
Percent Aged 20 to 29	14.42	14.31	13.54
Percent with HS diploma	73.81	71.93	70.77
Percent White	86.33	74.59	80.68
Percent Married	44.99	43.86	44.89
Percent Male	50.39	51.28	51.56

Note: Age variables are averaged over 1999-2013. All other variables are averaged over the period 2001-2013. The variables are not a comprehensive list of controls, just a selection.

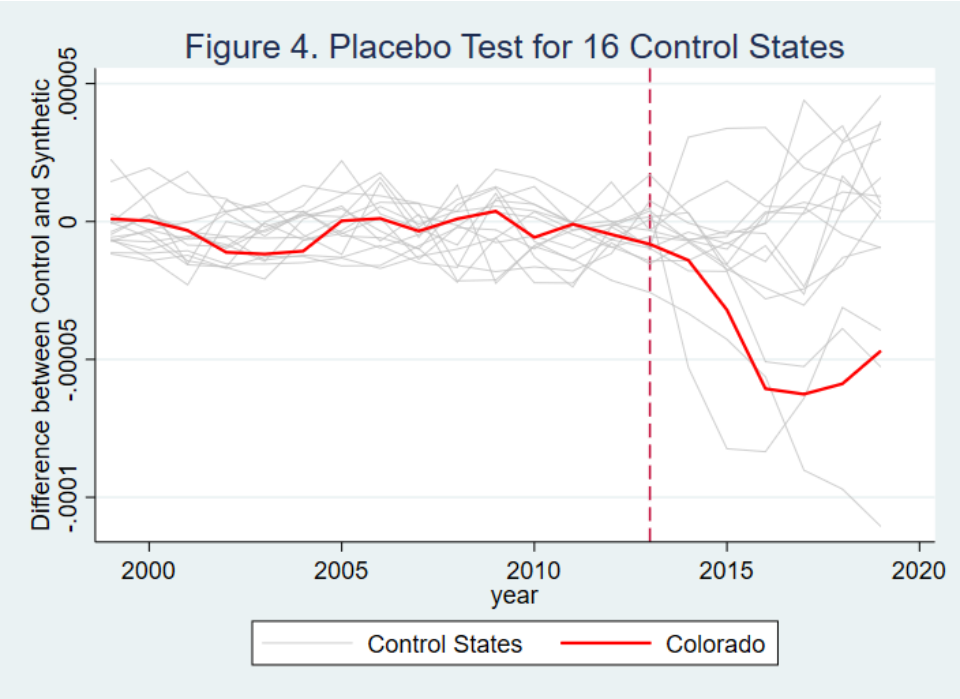
Figure 2 illustrates the differences between opioid overdose death rates in Colorado and synthetic Colorado. The estimated effect of the law is the difference between opioid overdose death rates in Colorado and its synthetic version after 2013. We chose 2013 as the treatment year in order to catch any anticipation effects. However, the two lines do not diverge until 2014 which is expected because dispensaries did not sell recreational marijuana until January 1, 2014. The trajectory of synthetic Colorado matches the trajectory of Colorado prior to law but diverges after the law went into effect in 2014. The results show that while the opioid related death rate continued to increase in Colorado after treatment, it did not increase at the same rate as synthetic Colorado. The difference suggests that the legalization of marijuana decreased opioid overdose death rates in Colorado. Our results suggest a 32% decrease in opioid mortality rates by year 3 of treatment, which is consistent with the effect estimated in the study conducted by Chan, Burkhart, and Flyr (2020).



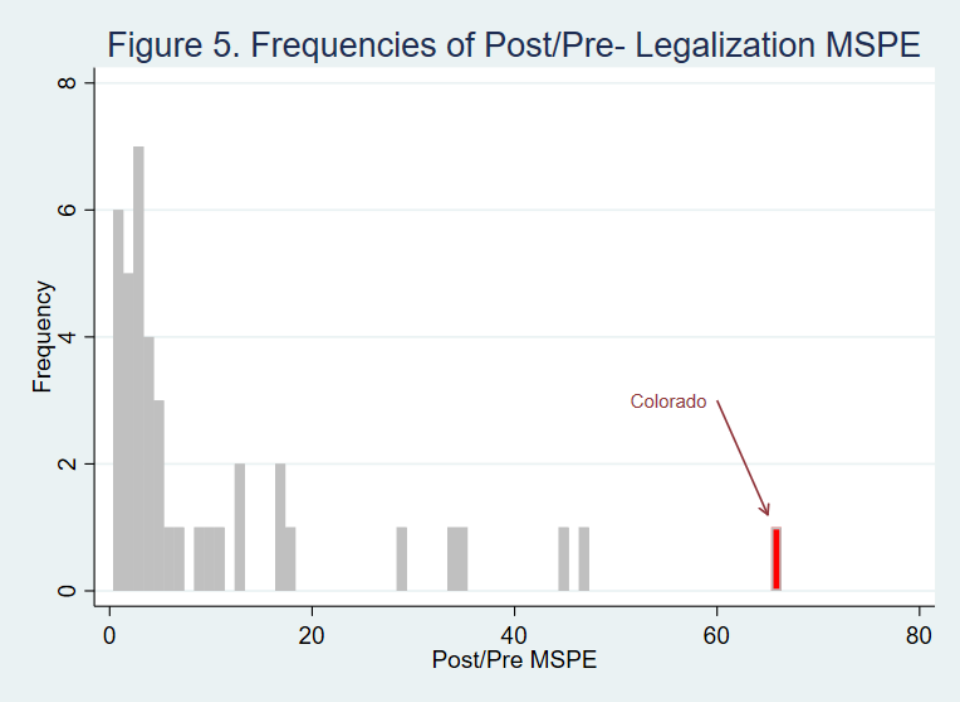
To test for statistical significance, we create synthetic controls for each of our control states. The synthetic controls for control states allow us to estimate the significance of our finding. Figure 3 shows the difference between each control state and its respective synthetic control. In this figure, the divergence between synthetic and treated Colorado is not among the largest. However, pre-treatment divergence between synthetic and treated Colorado is small compared to other states. This suggests that some of the control states have synthetic controls that do a poor job of predicting opioid mortality rates.



In Figure 4, we drop states from our analysis that do not have a synthetic control that matches well pre-treatment. Specifically, we drop controls that remain have a pre-treatment mean squared prediction error (MSPE) more than 5 times higher than Colorado's pre-treatment MSPE. Once we drop these states, Colorado has one of the more extreme post-treatment deviations.



As another test of significance, we observe the ratio of post/pre- legalization MSPE. This test is a way of controlling for pre-legalization MSPE when analyzing post-legalization MSPE. States with a higher pre-legalization MSPE are more likely to have a higher post-legalization



MSPE. Figure 5 is a histogram that shows the distribution of post/pre- legalization MSPE for Colorado and the control states. Colorado, highlighted in red, has a MSPE significantly higher than that of any of the control states. Since there are 40 control states, the probability that Colorado's MSPE is so extreme by chance is 2.44%. This provides evidence that the result is statistically significant at the .05 level.

Robustness Checks

The main limitation on our data is that medical and recreational marijuana laws vary from state to state. Each state has different prerequisites for receiving a license, limits on quantity that can be transported, and additional requirements for dispensaries. While we dropped states who passed recreational marijuana laws from our model, we did not control for the types of medical marijuana laws that were passed which may impact the validity of our results.

Before Amendment 64 was passed, medical marijuana was already legal in Colorado which suggests that the effect of the law on opioid deaths was due to the change from medical to recreational marijuana. To test this, we calculate another synthetic control in which we drop states that had not legalized medical marijuana before 2008. When we control for medical marijuana legality, the resulting divergence between Colorado and synthetic Colorado is still evident and the effect actually becomes more significant. Figures 6 and 7 show the results of these specifications.

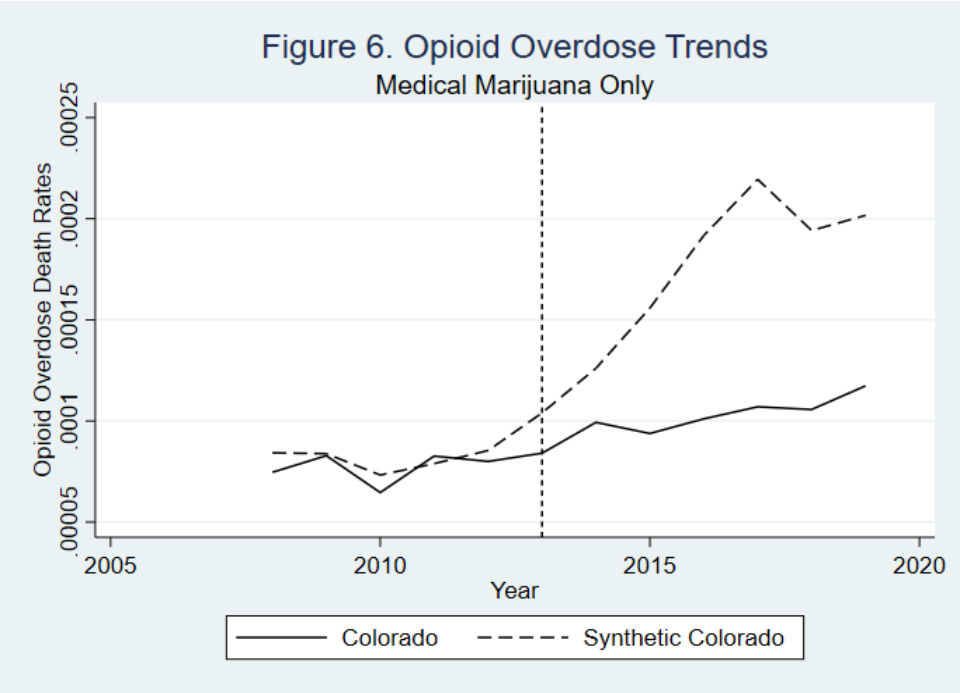


Figure 6. Opioid Overdose Trends
Medical Marijuana Only
Opioid Overdose Death Rates
.00005
.0001
.00015
.0002
.00025
2005
2010
2015
2020
Year
Colorado
Synthetic Colorado

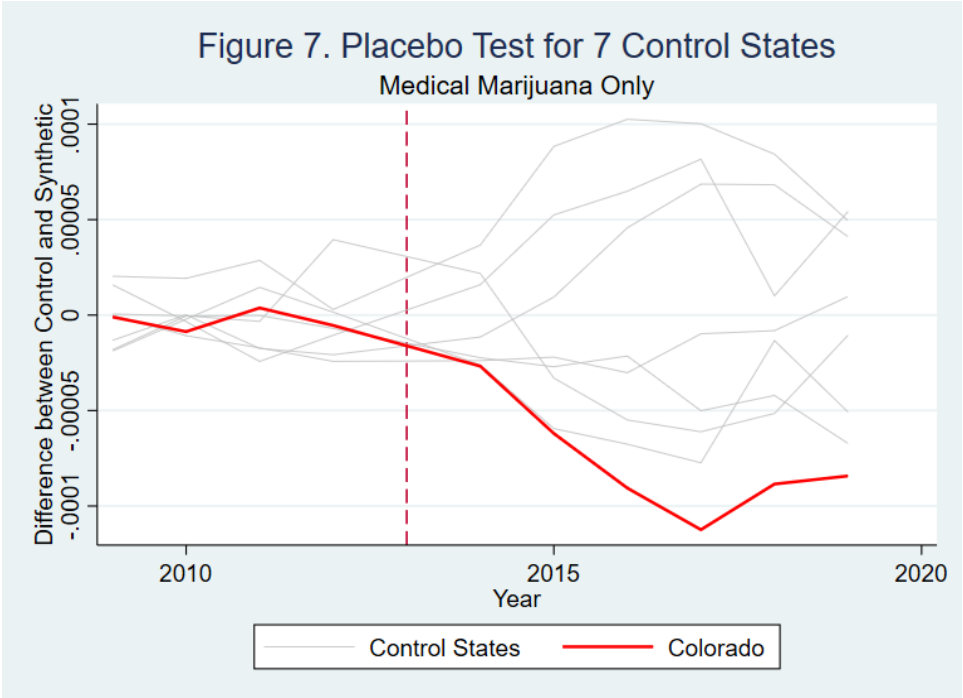


Figure 7. Placebo Test for 7 Control States
Medical Marijuana Only
Difference between Control and Synthetic
-.0001
-.00005
0
.00005
.0001
2010
2015
2020
Year
Control States
Colorado

Conclusion

The legalization of recreational marijuana is a complicated, contentious issue that many states are currently discussing. Its effect on opioid mortality is just one piece of the puzzle when considering changes in legislation. Using a synthetic control model, we find evidence that the legalization of recreational marijuana does not significantly increase opioid mortality rates in Colorado. In fact, the marijuana legalization likely decreases opioid mortality by roughly 32%. Each subsequent specification and robustness check provides further evidence that the legalization of recreational marijuana decreased opioid deaths relative to synthetic Colorado. Our analysis is consistent with the hypothesis that the legalization of recreational marijuana decreases opioid mortality because it allows new dispensaries to open and serve a larger area than medical dispensaries alone. The increased availability gives more individuals the option to use marijuana for pain management rather than trying to obtain a prescription for opiates (Chan, Burkhart, & Flyr, 2020). It also gives recreational drug users a legal option, possibly lowering the demand for other substances that achieve similar effects but are illegal. Ultimately, our analysis provides evidence that the substitution effect of marijuana is stronger than any ‘gateway drug’ effect.

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