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The Effect of Marijuana Legalization on Age-Adjusted Opioid Deaths

Motivation and Research Question

The first major wave of opioid overdose deaths began in the late 1990s, with opioid prescription pill abuse abuse steadily increasing since at least 1999. The second wave began in 2010 with rapid increases in heroin-related overdose, followed by the third wave in 2013 with rapid increases in synthetic opioid overdoses. Prescription drugs, such as OxyContin and other opioid prescription drugs, have long been prescribed to patients living with acute or chronic pain. However, research has found that medical marijuana has the ability to alleviate pain, reduce anxiety, reduce inflammation, relieve nausea, and relax tight muscles. Thus, some have begun to see medical marijuana as a potential substitute to prescription drugs that have high rates of addiction and overdoses. As more states begin to legalize marijuana for both medical and recreational use, it is vital that we analyze the effects that this may have on the opioid epidemic, specifically opioid overdose deaths. Thus, in the following empirical analysis we ask the question: **How does the legalization of marijuana for medical use and recreational use, respectively, affect the age-adjusted rate of opioid deaths by state?**

Literature Review

The scientific soundness of using marijuana as a pain reliever has been a controversial and oftentimes contentious debate amongst scientists for decades. As more states begin to legalize marijuana for medicinal and recreational purposes, scientists have begun conducting more prolific research on using marijuana as a pain reliever. In a study meant to find an alternative to opiates for pain relief in cancer patients, researchers found that patients who took THC reported less pain, less nausea, increased appetite, and increased ability to cope with discomfort (Mack). Additionally, multiple independent case studies have been conducted that suggest that THC is an effective pain reliever in MS patients and those suffering from migraine (Mack).

As more studies are done that suggest marijuana can be an effective pain reliever, scientists have begun to evaluate the viability of marijuana as a substitute for prescription medication. As a result, researchers are looking into the impact of the legalization of marijuana on opioid prescriptions and use. One study published in the Journal of Internal Medicine used a 10% sample of a nationally representative database of commercially insured populations to gather information on opioid use, chronic opioid use, and high-risk opioid use for the years 2006–2014 (Shah *et al*). They found that marijuana legalization was associated with lower odds of opioid use on a person-level analysis (Shah *et al*). This suggests that legalization of medical marijuana has some sort of impact on the prescription and subsequent use of opioids. Furthermore, a study published in the journal Systematic Reviews, researchers found that in nine studies including 7,222 patients there was a 64-75% reduction in opioid dosage when used in conjunction with medical cannabis (Okusanya *et al*). Additionally, researchers found that there was a reduction in mean hospital admissions and emergency department visits for patients receiving medical cannabis as adjunct to opioids in the treatment of non-cancer pain(Okusanya *et al*). With evidence of some sort of connection between opioid use and the legalization of medical marijuna outlined above, we are hoping to expand the discussion of the effect of marijuana on opioid use and subsequent overdoses.

Identification Challenges

Our control group consisted of states where marijuana is still illegal, and treatment groups were states who have legalized medical marijuana and recreational marijuana, respectively. Opioid-related death rates are obviously affected by more than just legalization of marijuana, so our main identification challenge was clear from the start: in the untreated state, the treated group (states who have legalized medical and recreational marijuana, respectively) and the untreated group (states who have not legalized any form of marijuana) have differing age-adjusted opioid death rates. This may be due to a plethora of outside factors, like income, health, crime, etc.

Identification Approach - Difference in Differences

The most suitable identification approach to use within the constraints of our data was the difference-in-differences approach. Legalization is an event that has a clear before and after.

Therefore, we plan to utilize the difference in differences approach to compare the death rates before and after legalization. With a common trends approach, the outside factors can be controlled for because with two parallel trends before the treatment (legalization), deviation from that trend once treatment happens can be attributed to the treatment as it is the only thing that changed. However, in practicality, common trends is more often not a reasonable assumption, so we must instead allow for time trends across each state by adding in an interaction term between each state's dummy variable and our time variable. We must also control for differences in each state by adding in state dummies on their own as well as year dummies to control for differences across time.

To illustrate:

- Ydt denotes the age-adjusted opioid death rate in State s in year t
    - ML = marijuana legalized
    - MI = marijuana illegal
- Difference-in-difference estimate (δ_{DD}) of the effect of legalization of medical marijuna on age-adjusted opioid death rate:

    $$\delta_{DD} = (Y_{ML,\,1999} - Y_{ML,\,2017}) - (Y_{MI,1999} - Y_{MI,\,2017})$$

Data

Our data comes from a DataPlanet dataset sourced from the CDC. It contains the population, opioid deaths, crude rate, and age-adjusted rate for each state from 1999 to 2017. The age-adjusted death rate is a death rate that controls for the effects of differences in population age distributions, allowing for states with differing age structures to be compared. The initial exported data frame had years as rows with columns for each indicator from each state. To utilize the difference in difference approach, we needed a separate row for each data point, so we utilized pandas within python to clean the data. First, we dropped all indicators but the age-adjusted death rate. We then swapped the rows and columns and reset the index so that we had a state column and separate columns for each year. From there, the data frame was altered so that three columns were left; state, year, and death rate. This meant that we had one row for each

data point. The measurement of the death rate was per 100,000 and had a minimum of 0.7, a maximum of 49.6, and a mean of 8.3, as well as a standard deviation of 6.52.

To gather information on the legality of marijuana in all states, we used data from the National Conference of State Legislatures that outlined medical and recreational marijuana laws by state, including the year of law passing. We decided to make the year following the passing of the law as the implementation of the treatment, because there is typically a gap between passage of law and implementation of law. For instance, although Illinois's governor signed a bill legalizing medical marijuana in August 2012, the law was not effective until January 1st, 2013. We made sure to account for discrepancies such as this one in the dates when the treatment (legalization) is implemented. We added a dummy variable that was equal to 1 for the years in which each state had legalized medical marijuana and another dummy variable that was equal to 1 for the years in which each state had legalized recreational marijuana. We were also slightly concerned that an external variable, namely unemployment, could still create bias in our regression. However, after adding unemployment in as a control variable, it turned out to be statistically insignificant so it was not included.

Results

Five regressions were run, starting with pooled OLS, followed by only state-fixed effects, first differences, then two-way fixed effects, and, finally, allowing for state-specific time trends. For medical legalization, the final coefficient was not statistically significant at the 5% level (Figure 1). Whereas, recreational marijuana legalization resulted in a statistically significant decrease in the age-adjusted opioid death rate of 5.58 deaths per 100,000 (Figure 2). That coefficient is almost one full standard deviation (6.52) change in the death rate. The adjusted R-Squared of the regression is 0.54, meaning 54% of the variation in the death rate is explained by variation in the regressors. While this value leaves much to be desired, it indicates that the regression has at least moderate explanatory power.

Figure 3 illustrates a state-specific example of these results. As shown, both Colorado and Virginia have very similar trends in opioid deaths from 1999 until 2014. The dashed line, marked at 2013, represents when recreational marijuana was legalized and implemented in Colorado, while the dotted line, marked at 2014, represents when state-licensed retail sales went

into effect. The difference-in-differences in opioid death rates after this treatment is striking and very close to the recreational coefficient from Figure 1. Furthermore, the trend that is visible in Figure 3 seems to be confirmed by the nationwide trend. Nationwide, the opioid death rate has been increasing since the late 1990s. However, the rate of increase spiked up around 2013 or 2014, as seen in Figure 4. Virginia, in Figure 3, follows that nationwide trend more or less. However, the states that legalized recreational marijuana, like Colorado, do not follow that trend, and instead trail off in the mid-to-late 2010s.

Figure 1

Panel Regressions, Clustered SEs

	Opioid Deaths per 100,000				
	Age-Adjusted Rate				
	OLS	State-FE	FD	St-Yr-FE	St-Trend
	(1)	(2)	(3)	(4)	(5)
Medical	5.76***	9.82***	0.31	3.25***	2.06*
	(1.56)	(1.24)	(0.77)	(1.19)	(1.17)
Observations	882	882	836	882	882
Adjusted R2	0.12	0.24	-0.001	-0.02	0.53
Note:			*p<0.1; **p<0.05; ***p<0.01		

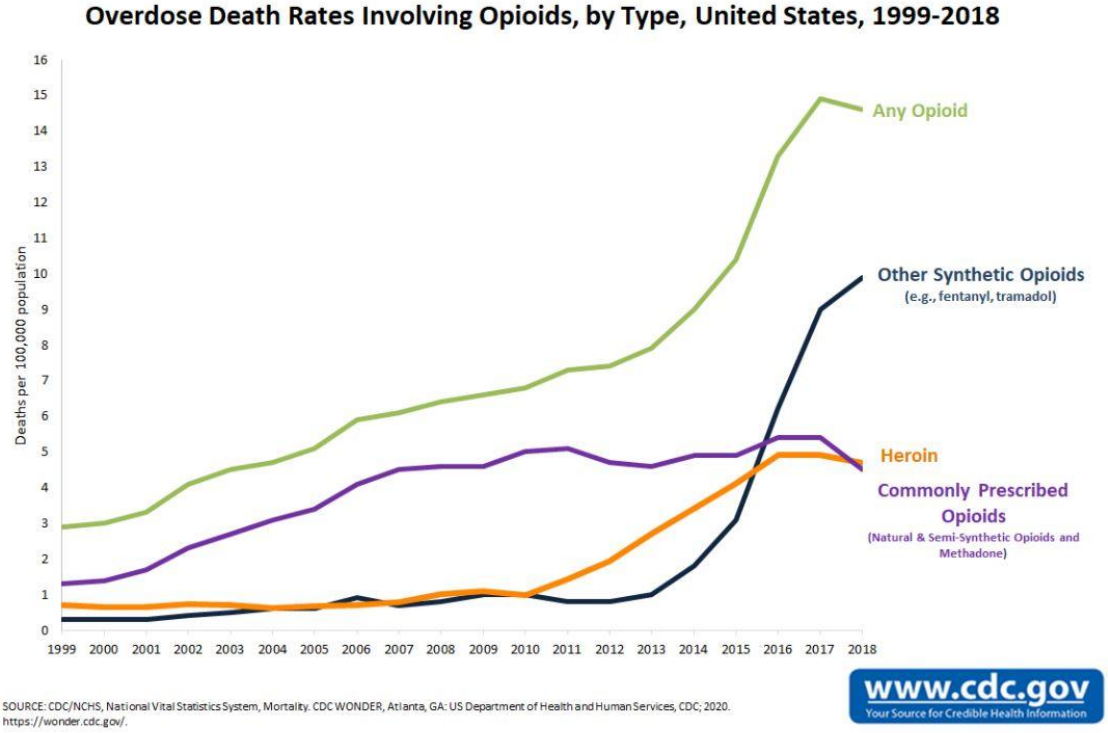
Figure 2

Panel Regressions, Clustered SEs

	Opioid Deaths per 100,000				
	Age-Adjusted Rate				
	OLS	State-FE	FD	St-Yr-FE	St-Trend
	(1)	(2)	(3)	(4)	(5)
Recreational	1.44*	1.70***	-0.81***	-6.57***	-5.58***
	(0.75)	(0.63)	(0.21)	(1.24)	(1.15)
Observations	976	976	925	976	976
Adjusted R2	0.0000	-0.05	-0.0003	-0.02	0.53
Note:			*p<0.1; **p<0.05; ***p<0.01		

Figure 3

Figure 4



Conclusions

Our results indicate that there is a statistically significant decrease in age-adjusted opioid death rates with the legalization of recreational marijuana, but no significant change due to medical legalization. Most studies tend to focus on the impact of medicinal marijuana on opioid prescriptions due to the fact that marijuana can serve as a substitute for pain relief and management. This study, on the other hand, takes a closer look at the impact of marijuana legalization on the prevalence of opioid-related overdoses.

The fact that a correlation was found with recreational legalization, but not medicinal legalization suggests that recreational legalization is more effective in combating the opioid epidemic. This may be the case because recreational legalization is more comprehensive than medicinal legalization. Recreational legalization may bring broader impacts on cultural attitudes and acceptability of marijuana, as well as make it more accessible. Recreational legalization also impacts a broader range of people aside from solely patients being treated for pain. Therefore, marijuana can not only act as a substitute for pain relief, but a substitute for recreational opioid use in the broader public. Figure 4 helps support this idea as well. The spike in opioid deaths around 2013 nationwide is mainly due to synthetic opioids, not commonly prescribed opioids. Therefore, it makes sense that it was recreational marijuana that helped mitigate this trend rather than medical marijuana. Ultimately, this study shows the potential of recreational legalization of marijuana in combating the nationwide opioid epidemic.

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