Fatal Car Crashes and Marijuana Legalization

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An increasing number of states are legalizing recreational use of marijuana. There are concerns about its impact on road safety. This empirical study uses the experience from Michigan, California, and Colorado to test whether marijuana legalization has had any significant impact on cannabinoid-related fatal crashes. A Poisson difference-in-difference style estimation is applied in a panel data setting. MI, CA and CO are used as the treatment group, where recreational marijuana has been legalized. The control groups are the states of Ohio, Indiana and Texas, which did not have recreational marijuana legalized at the time. The treatment effect is found to be significant, thus legalization and retailing of marijuana have statistically significantly increased the number of cannabinoid-related and overall fatal crashes in the states that have legalized it in the period of study.

Keywords: cannabis legalization, recreational marijuana, cannabinoids, difference-in-differences, Poisson estimation, fatal crashes, panel data

INTRODUCTION

An increasing number of states in the US are legalizing medical and recreational marijuana, even though it remains federally illegal. According to the Routledge Handbook of Post-Prohibition Cannabis Research (2022), about 90 % of the US population has access to medical cannabis markets. About 24 states have legalized recreational marijuana. The state of Michigan legalized recreational marijuana in December 2018, but actual commercial retail began in December 2019. There is some time lag until retailers get registered and start selling. More recently, Ohio legalized recreational marijuana in 2023. As marijuana becomes legally available, one of the concerns is that it may impact driving safety. In fact, the federal government classifies it as a Schedule I banned substance that can impair cognitive skills with danger of abuse and without medical benefits.

Many studies suggest that marijuana hampers the cognitive skills required to drive in a safe manner (Blows et al., 2005; Larkin, 2015). It may numb some cognitive skills and reaction time. In states that have legalized it, it remains illegal to drive under the influence of marijuana. It is not coincidental that in Michigan when you buy marijuana from a dispensary, you have to put it sealed in your car. Similar to alcohol, you cannot have open containers with marijuana in your vehicle. The California Association of Highway Patrolmen opposed the recreational legalization of cannabis. Thus, it is a legitimate concern whether the legalization of marijuana and its increased availability have contributed to less safe roads. As some people call for its federal legalization, a careful examination of the risks it poses is needed, including the ones for road safety. Important policy implications could be drawn, as more states consider legalizing it.

This study will apply the well-known in social sciences difference-in-differences estimation to test whether the data indicate that roads have become less safe after legalization and retailing of recreational marijuana. Recreational sales (without prescription) make it widely available to so many more people than just legalization of medical marijuana. With medical marijuana, at least a medical professional will prescribe or verify someone's use of marijuana. Recreational sales make it available to anyone of age, like alcohol. This study focuses on how that availability affects fatalities on the road.

Legalization itself may be somewhat confusing (Goldstein and Sumner, 2022). Different degrees of legalization may refer to when it becomes legal to possess marijuana, when it becomes legal to buy and sell, and when it becomes legal to have retailers. I picked the date when marijuana retailing becomes available in the state as the relevant date of change. That is when recreational cannabis becomes widely available to the public to consume without medical permission, and retailing outlets are open. It is even immaterial whether marijuana consumption increased or not after retailing became legal; the point is that with commercial retailing, recreational cannabis becomes widely available to the public to purchase and can affect the average driver. It is the availability of marijuana I focus on, not whether consumption increased due to legalization.

The following section provides a brief overview of the literature, some of it unpublished. It is followed by a section on the methodology and a section presenting the data. The fifth section discusses the results and the final section concludes.

REVIEW OF THE LITERATURE

Marijuana legalization is a relatively new phenomenon, at least recreationally, thus, not many empirical studies address those issues. Leasure and Ridgway (2023) use arrest data without conclusive results (using daily time series). They use arrests for driving under the influence of marijuana in the state of Ohio, where medical marijuana was legalized at the time. They study the impact of that, combined with marijuana legalization in neighboring Michigan. Using time series data, they conclude there is no significant impact on road safety, as measured by arrests. Arrest data, however, could be unreliable and biased. Not all drivers under the influence get arrested. On the other hand, fatal crash data tend be more reliable. All fatal crashes have to be reported to authorities. Drug testing in those cases also will have to be much more dependable and rigorous, presumably.

Young (2019) uses panel data of US states and finds no relationship between medical marijuana legalization and number of fatalities. His study was done earlier when not many states had legalized recreational marijuana; thus, he focuses on medical use. Recreational marijuana represents a different phenomenon, as it makes marijuana available to a much broader class of people, essentially to anybody 21 years of age and older. Medical marijuana is available to people who possess medical cards and possibly a prescription by a doctor, as alluded earlier.

Previous research has reported little to no evidence that medicinal or recreational marijuana legalization or decriminalization increase use among state residents (e.g. Downs, Barcott and Corva, 2019; Ammerman et al., 2015; Diep, 2015). The mere act of decriminalization without retailing does not seem to increase marijuana use. It is the retailing/cannabis dispensaries that make a difference. Legalization and state licensing, on the other hand, indicate safety testing of the products to consumers (Bennett 2018), thus, some increase in demand could be expected, especially when retailing is available.

From the earlier literature, Tefft et al. (2016) found the prevalence of marijuana in drivers fatally injured in the state of Washington increased from 49 (8 percent of total fatalities) in 2013 to 106 (17 percent of total fatalities) in 2014. All those earlier studies were performed with scanty data when marijuana was in very early stages of legalization. Now we have more data available and states with longer legalization experience to be able to conduct such empirical studies. Monfort (2018) finds in a series of regressions that Colorado, Washington, and Oregon experienced a 5.2 percent higher police-reported crash rate than what they would have had without marijuana legalization for the years 2012-2016.

In a more recent panel study, Adhikari et al. (2023) examined all US states using the difference-in-differences method over 14 years of data. Their dependent variable is annual traffic fatalities per billion vehicle miles driven from 2007 to 2020. It appears that they focus on all fatalities, and not only ones linked to marijuana specifically. Interestingly, they find that texting bans and seat belt laws are statistically insignificant for the number of fatalities. In the parsimonious model, they conclude that recreational marijuana legalization has a positive impact on fatalities, with an average treatment effect of 1.2 traffic fatalities per Billion Vehicle Miles Driven. In other words, excess fatalities in recreational marijuana states exceed 1000 annually (Adhikari et al., 2023). Importantly, they conclude that states with longer experience of marijuana legalization experience higher increases in fatalities than states with recent legalization. That implies that the positive impact of legalization on fatalities grows over time.

DATA

I have obtained data on fatal accidents in the states from the Department of Transportation's National Center for Statistics & Analysis (NCSA) within the National Highway Traffic Safety Administration. They provided fatal motor crashes data for each state every month starting in 2010 to 2021. I focused on the states of Michigan, Colorado, California, Ohio, Texas and Indiana. The first three experienced recreational legalization during the period of study, the latter three did not. The data include total number of fatal crashes per month, fatal crashes involving drugs, fatal crashes involving cannabinoids, fatalities, etc. For crashes involving drugs, at least one of the drivers involved in the crash tested positive. The general category of Cannabinoids includes: Delta 9, Hashish Oil, Hashish, Marijuana/Marihuana, Marinol, and Tetrahydrocannabinols (THC). In short, it includes almost everything that can be obtained from Marijuana. Now, there is an increased interest in how the different chemical components of Marijuana affect human behavior. THC appears to be the most potent substance that can get people "high." All the effects of the various components and combinations have not been fully understood due to the limited empirical testing in the past (Wilson-Poe, 2022). Therefore, I include them all, as we do not have precise understanding as to which ratios of CBD to THC present the most adverse effect to driving. Cannabis products nowadays come in all sorts of varieties and combinations in the stores.

The treatment population will consist of the states of Michigan, California and Colorado that legalized recreational marijuana at different dates. I chose not the date of formal legalization but the date when recreational retailing began. The first month of treatment for Michigan will be the 120th month, which is December, 2019, when retailing of recreational cannabis began in the state. The first month of treatment for California will be the 97th month, or January 2018, when recreational retailing began in the state. The first month of treatment for Colorado will be the 49th month, or January 2014, when recreational retailing of marijuana began in the state. Thus, Colorado has had the longest experience with recreational marijuana. California is the largest state and the largest cannabis production market in the US. California and Colorado are representative of states that strongly favor cannabis. I choose the retailing dates rather than legalization dates, because legalization by itself does not increase the supply or availability of cannabis. It is the opening of commercial retailing and retailing dispensaries that make cannabis widely available.

The control population will include the states of Ohio, Texas and Indiana. They had not legalized recreational marijuana for the duration of the dataset. They are large, similar industrial states with some of them having strong opposition to marijuana, such as Texas and Indiana. Texas is a large industrial state comparable to California. Therefore, I have large populations in both the control and treatment groups. Moreover, we know that for the Difference-in-Differences method, the states don't need to have the same average number of fatal crashes, but only parallel trends. It is worth mentioning that Ohio legalized medical cannabis in 2016, but the focus of this study is on recreational cannabis. Thus, Ohio is included in the control group with recreational cannabis. Michigan legalized medical cannabis in 2008. Once again, there is a substantial difference between medical and recreational cannabis. Medical cannabis is limited only to people with certain conditions who qualify for a medical card. Recreational cannabis is available to anybody 21 and older who desires to visit a dispensary. Dispensaries make it widely available.

Michigan's population is about 10.12 million, California's population is about 39 million, Colorado's population is about 5.84 million, Texas' population is about 30 million, Ohio's population is about 11.8 million and Indiana's population is about 6.83 million people. Roughly, there are 54.96 million in the treatment group and about 48.63 million in the control population. Therefore, in both the control and treatment groups, I have one large state, one medium-sized state and one less populated state. The two groups are roughly comparable in population and are all industrial and well-developed states. The diverse weather between those states could account for various trends in car accidents, but I have included states both with warmer weather, such as California and Texas, and cold weather, such as Michigan and Indiana.

A concern could be raised that although cannabis is illegal in Indiana, people can buy it in Michigan and drive to Indiana. That is, however, illegal both by Indiana and federal law. In fact, the federal government focuses on controlling cross-border trade of illegal substances. Theoretically, this should not happen. That makes Indiana a very good choice for a control group, because theoretically, there should be no spillovers from other states, where cannabis is legal. The same applies to Ohio when recreational marijuana was illegal as well. If people bring cannabis from another state, that is illegal and that would fall under illegal activity as before legalization. I focus on the effect of recreational cannabis legalization, thus illegal activities are outside of the scope of this study. In addition, all similar studies using comparisons between states are subject to the same criticism that there could be cannabis spillovers between states with legal cannabis and others.

The dependent variable in the first instance is the number of cannabinoid-related accidents. Those are fatal accidents where at least one of the drivers involved tested positive for a cannabinoid. A notable difference with Adhikari et al. (2023) is that I work with monthly data, not annual. That allows for more dynamic effects in time, instead of just focusing on annual aggregates.

The idea of difference-in-differences is to have similar groups with their major difference being the treatment. The trends of the populations already incorporate other factors, such as weather conditions. Similarly, all six states have been exposed to the Covid-19 pandemic. The state-fixed effects in the estimation also account for potential differences between the states. Summary statistics of the data appear in Table 1. It is perhaps noteworthy that the three control states differ in their average fatal crashes—Ohio and Texas have a higher average, while Indiana has a lower average. In the treatment group, California has a remarkably higher average of cannabinoid-related fatal crashes.

TABLE 1
DESCRIPTIVE STATISTICS. MONTHS = 1 to 144 (2010-2021)

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Cannabinoid-related fatal crashes in MI*	144	9.7	4.7	1	24
Cannabinoid-related fatal crashes in CA*	144	33.02	12.48	13	75
Cannabinoid-related fatal crashes in CO*	144	7.24	4.36	0	20
Cannabinoid-related fatal crashes in OH*	144	13.67	6.3	3	38
Cannabinoid-related fatal crashes in IN*	144	4.69	2.3	0	11
Cannabinoid-related fatal crashes in TX*	144	18.01	5.42	6	35
Cannabinoid-related fatal crashes overall*	864	14.4	11.53	0	75

*When at least one driver involved in the accident tested positive for a cannabinoid.

METHODOLOGY

One of the best-known methods for causal inference in social sciences is *the difference-in-difference estimation.* That method has been applied to study many policy and legal changes, where there is a treatment and control group. I chose this method over an event study because an event study focusing solely on treatment states may capture the effect of some other factor, such as a pandemic. The coronavirus pandemic started at roughly the same time when retailing of recreational cannabis began in Michigan. In its simplest form, difference-in-differences (*DID*) is an OLS regression with two time periods: one before and one after treatment and two groups: treatment and control. Units from the treatment group receive some kind of treatment (or policy change) in period 2, while units in the control group do not. A critical assumption is that both groups follow parallel linear trends prior to treatment. Then, after treatment, if the treated group exhibits a different trend, that will be attributed as the effect of the treatment. Another assumption is that the treatment has no causal effect before its implementation (Roth et al., 2023) (the so-called no anticipation as per Ganger causality). Those help identify the average treatment effect on the treated. Roth et al. (2023) observe a wave of new model applications, relaxing some of the classical assumptions. One of the extensions is to include more than 2 time periods.

As the dependent variable is a count variable (number of accidents), a Poisson regression will be run with the available panel data. That is another difference with Adhikari et al. (2023), who do not employ Poisson, when using fatalities per miles driven as the dependent variable. Poisson is appropriate because the outcome variable is a count variable.

This basic model can be further extended by relaxing some of the assumptions. One extension of interest is increasing the time periods to more than two, while keeping the other assumptions (parallel trends, no anticipation, and independent sampling). This is the model I will be applying in the current research. Assume there are *T time periods* $t=1,\ldots.T$. The treatment will be binary (either receive treatment or not) in any period $t > 0$. Once treated, individuals remain treated for the remainder of the panel.

Roth et al. (2023) demonstrate that the parallel trends assumption can be easily extended to that staggered setting. The assumption means that the average outcomes for all groups would follow parallel trends in the counterfactual without treatment. The no-anticipation assumption also extends easily to that setting. Intuitively, it means that units do not act on the knowledge of treatment in the future before treatment starts. Bester, Conley and Hansen (2011) show that using cluster-robust standard errors and critical values of a *t* distribution with $G-1$ degrees of freedom, where G is the number of groups, is asymptotically valid for a fixed number of groups and a growing sample size. Combined, the results of Bertrand, Duflo and Mullainathan (2004) and Bester, Conley and Hansen (2011) assure us that we can still obtain reliable standard errors even when the number of groups is not large. That is relevant to the current study, because we use three control states and three treatment states.

As the dependent variable is a count variable (number of accidents), I use Poisson regression with panel data. The estimation equation for the average treatment effects is the following:

$$Y_{i,t} = \alpha_i + \mu_t + \beta_1 Ret{*}MI_{i,t} + \beta_2 Ret{*}CA_{i,t} + \beta_3 Ret{*}CO_{i,t} + \varepsilon_{i,t}, \tag{1}$$

where Y will stand for the number of fatal crashes per month, the number of cannabinoid- related fatal crashes and number of fatalities in cannabinoid-related accidents in several separate estimations. $Ret{*}MI_{i,t}$ is the first treatment, equal to 1 for retailing in Michigan. It is equal to 1 if the state is Michigan in all periods with legal cannabis retailing in Michigan; 0 otherwise. $RetCA_{i,t}$ is the treatment for California, equal to 1 for retailing in California. $RetCO_{i,t}$ is the treatment for Colorado, equal to 1 for retailing in Colorado. Then α_i and μ_t are state and time effects, while $\varepsilon_{i,t}$ is a standard error term.

The Beta's are the coefficients of interest. They measure the average treatment effect on the treated (Roth et al., 2023). OLS estimates of β provide consistent estimates for T, the treatment effect, with just one additional assumption of independent sampling (Roth et al., 2023). With that assumption, the variance is consistently estimable using standard clustering methods allowing for arbitrary serial correlation at the unit level (Arellano, 1987 and others). By the same logic, we can extend that to observations that are individual units who are members of independently sampled clusters (such as states). The standard errors are clustered at the appropriate level, provided that both the number of treated and control clusters grow large (Roth et al., 2023).

RESULTS

There are 144 monthly observations per state. With 864 observations and 6 states, the results from the fixed effects Poisson regression appear in Table 2, regressing Cannabinoid-related fatal accidents on the three legalization terms for the three states. Once again, by legalization I mean legal cannabis retailing in the respective states.

TABLE 2
POISSON ESTIMATION WITH CANNABINOID-RELATED ACCIDENTS

Cannabinoid-related accidents	Coefficient	Standard Error	P>|z|
CA legalization	0.3858	0.0293	0.000
CO legalization	0.9348	0.0836	0.000
MI legalization	0.4066	0.0626	0.000

Rate Ratios		Increase in marijuana-related accidents:
CA legalization	1.47	47%
CO legalization	2.54	154%
MI legalization	1.50	50%

All the coefficients are significant at the 1% level. The associated rate ratios imply that cannabis-related fatal accidents have increased by 47% in California, 154% in Colorado and 50% in Michigan. Those are substantial increases compared to the states that had not legalized. I repeat the estimations with total number of accidents as the dependent variable in Table 3.

TABLE 3
POISSON ESTIMATION WITH TOTAL FATAL ACCIDENTS

Total fatal accidents	Coefficient	Standard Error	P>|z|
CA legalization	0.2021	0.0105	0.000
CO legalization	0.2811	0.0286	0.000
MI legalization	0.1459	0.0240	0.000

Rate Ratios		Increase in total accidents
CA legalization	1.22	22%
CO legalization	1.325	33%
MI legalization	1.157	16%

The total number of car accidents has increased in the respective states, but by not as much percentage-wise as the cannabis-related accidents. Therefore, the dramatic increases in cannabinoid-related accidents might account for the majority of overall increases in accidents. I observe increase in the total number of fatal crashes in all three states with legal marijuana sales. At the same time, the increase in the shares of cannabinoid-related accidents in those states is dramatic. One explanation for this may be that before legalization, drivers were not even tested for cannabis. So, the increase in cannabis-related accidents may be simply due to increased testing and awareness after legalization. The overall increase in fatal accidents, however, cannot be overlooked.

TABLE 4
POISSON ESTIMATION WITH FATALITIES IN CANNABINOID_RELATED ACCIDENTS

Fatalities in cannabinoid-related accidents	Coefficient	Standard Error	P>|z|
CA legalization	0.3791	0.0276	0.000
CO legalization	0.8869	0.0777	0.000
MI legalization	0.3673	0.0598	0.000

Rate Ratios		Increase in fatalities in cannabinoid-related accidents
CA legalization	1.46	46%
CO legalization	2.43	143%
MI legalization	1.44	44%

Finally, the estimation with the number of fatalities from cannabinoid-related accidents reveals that they have also increased substantially in the periods of legalization in Table 4; by 46% in California, 143% in Colorado and 44% in Michigan. It is worth investigating how to account for the very dramatic increase in the state of Colorado, one of the pioneers in cannabis legalization. That increase holds for all dependent variables: cannabinoid-related fatal crashes, total fatal crashes and fatalities in cannabinoid-related fatal crashes. As stated previously, Adhikari et al. (2023) find that states with longer experience of marijuana legalization experience higher increases in fatalities than states with recent legalization. I confirm the results with Colorado. It is the state in the sample with the longest history of marijuana legalization and sales. That has resulted in the highest increase in the sample for total and cannabis-related accidents, as well as fatalities. And I can state this specifically for number of accidents increases, not just as a percentage of miles driven, which are the variable of interest in Adhikari et al.'s (2023) paper. I can state that the absolute numbers of fatal accidents and cannabis-related fatal accidents have risen substantially in all three legalized states, but particularly in Colorado. In my study, control and treatment states are comparable in size and population. Adhikari et al. (2023) do a comprehensive study of the US including all states, where treatment and control groups may not be comparable.

CONCLUSION

This paper used DID methodology with a Poisson estimation to test whether the legalization and retailing of recreational cannabis in Michigan, California and Colorado has had any significant effect on the number of cannabinoid-related fatal accidents and total fatal accidents. The states of Ohio, Indiana and Texas were used as control groups. That gave us enough clusters to meaningfully apply difference-in-differences and have data with parallel linear trends and no anticipation of treatment. Those are critical assumptions for using DID. The month of December, 2019 was used as the beginning of 'treatment' in Michigan, which in this case is legal retailing of cannabis in Michigan and the respective dates in other states also refer to legal recreational retailing. Essentially, I tested for the impact of legal cannabis retailing on fatal car accidents using Poisson estimation due to the dependent variables being count data. I estimated the average treatment effects, which turned out to be extremely significant and large. Thus, we conclude that the legal retailing of recreational cannabis in Michigan, California and Colorado has had a significant effect over the number of cannabinoid-related fatal car accidents, all fatal car accidents and fatalities in cannabinoid-related accidents in this period. That may exacerbate some concerns about road safety when legalizing cannabis. We used a very general measure of cannabis, cannabinoids, which include many substances that come from cannabis, not just the 'high'-producing THC. The state of Colorado has seen the largest increase in all three measures of accidents.

Further study is warranted as to what explains that increase, especially the dramatic rise in Colorado. Perhaps the longer period of legalization there (from January 2014) has contributed to higher incidence rate. The longer exposure to cannabis retail may have led to abuse of cannabis that occurs over time. If confirmed, that is bad news indeed, saying that longer exposure to cannabis retail significantly increases the number of fatal accidents. That effect grows over time. It could potentially take time for the negative trends in car accidents to materialize after legalization. Moreover, Colorado's legalization happened well before the Covid pandemic, which may contribute to explaining the results. The decline in traffic during the pandemic might explain the not so dramatic increase in accidents at that time. However, Colorado's experience from well before the pandemic may account for its dramatic increase in fatal crashes.

Marijuana legalization appears to be associated with a much higher number of cannabis-related and total fatal car accidents in this analysis. That may be a serious concern policy-makers should consider regarding further marijuana legalization. The study can be extended further by including control variables that are related to fatal accidents and can add more explanatory power. However, that may not be necessary for DID to work. The results, however, are robust and I do not expect explanatory variables, such as weather, to overturn them. More clusters can be included for more robust inference. We can include more states that have legalized cannabis in the said period as treatment groups and states that have not, as control groups. But the six states already included provide a large population in both the treatment and control groups.

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