Effects of Recreational Marijuana Legalization on Traffic Fatalities:Early Evidence from FARS

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Recreational Marijuana and Traffic Fatalities 2010-2019

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Abstract

Over the last few years, marijuana has become legal for recreational use in 18 states. However, policy makers and researchers still have little known about its effect since identifying a causal effect for a recent phenomenon requires more data after legalization. I examine the relationship between recreational marijuana legalization(hereinafter, RML) and traffic fatalities in U.S with a two-way fixed effect difference-in-differences method using records on fatal traffic accidents from 2010 to 2019. I find that RML states saw an 13% increase in fatalities related to alcohol and nearly 20% increase in fatalities for which at least one driver involved had a Blood Alcohol Concentration(BAC) greater than 0.1 grams per deciliter(g/dL). However, the effect of RML on total traffic fatalities is positive but not significant.

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1 Introduction

As of today, 18 states has legalized recreational marijuana (NORML 2021). In general, RMLs legalize the possession, sale, and consumption of marijuana for recreational purposes. At the federal level, on July 14th, 2021, the proposed Cannabis Administration and Opportunity Act would remove marijuana from Controlled Substances Act and begin regulating and taxing it (Fandos 2021). Public opinion polls show that roughly 70 % of Americans supporting the legalization of marijuana, this number has doubled from 2000s (Gallup 2020).

Opponents argue that marijuana poses a substantial risk to individual health, and public health as well. At the individual level, using and smoking marijuana on a daily basis increases chronic cough and phlegm frequent chronic bronchitis episod (Division, 2017). On the public health side, opponents also have expressed concern that RMLs can increase the use of marijuana among teenagers, which can lead to negative and long lasting effect on their cognitive development (CDC). Some opponents are simply morally against the legalization of marijuana.

On the flip side, proponents of legalizing marijuana say that the evidence proving the adverse health effect of marijuana is light-to-moderate(National Academies of Sciences, Engineering and Medicine 2017). Futhermore, in comparison with harmful effects from alcohol and opioid and considering substitutability of marijuana, those above-mentioned negative health effects are smaller, and by increasing the use of marijuana, we can have some public health gains. Proponents also point out that the annual cost of enforcing marijuana ban is up to hundreds of billions of dollars (American Civil Liberties Union 2019). In addition, for whom are convicted of marijuana-related crime, their job outlook is poor (Pager 2003; Agan and Starr 2018; Dobbie et al. 2018; Mueller-Smith and Schnepel 2021; Agan, Doleac and Harvey 2021).

For many studies using survey – self-reported – data about relationship medical marijuana laws and alcohol, they find strong evidence suggesting that medical marijuana laws enactment is associated with the reduction in alcohol consumption. Besides, studies using alcohol sales agree with those based on self-reported alcohol consumption (Anderson,2021). However, the relationship may not hold when we consider the legalization of marijuana for recreational purpose.

The reasons for society to adopt RMLs depends on whether the benefits of RML outweigh any external costs. In this study, I examine the impacts of RML on traffic fatalities. Using state-level data from Fatality Analysis Reporting System in the period 2010-2019 and difference-in-differences strategy, I find that the enactment of RMLs increased up to 19 percents in traffic fatalities for which at least one driver had BAC greater than 0.1.This result tentatively suggests that the relationship between marijuana and alcohol is not substitute. However, I find little evidence that RMLs significantly increased total traffic fatalities.

As more states begin legalizing recreational marijuana in 2021, more post-legalization data will be available, and researchers will be able to investigate any longer-term impacts on traffic fatalities from RMLs, especially after commercialization of recreational marijuana fully develop. However, my study to date, which only includes states that adopted RMLs before 2020, provides little evidence how RMLs can alter the big picture of traffic fatalities. The strong positive association of early RML adopters with traffic fatalities related to alcohol supports the idea that policymakers need to be more careful of implementing new RMLs since now the relationship between marijuana and alcohol become complicated after RMLs adoption.

2 Background

2.1 History of Recreational Marijuana Laws

The legalization of marijuana reached an important milestone in 2012, when ballot initiatives which explicitly legalized the use of marijuana for recreational use received enough votes for enactment in Colorado and Washington, Alaska and Oregon followed in 2014, and California, Nevada, Maine and Massachusetts legalized marijuana in 2016. All was done by ballot measures. The first state to legalize recreational use of marijuana via legislative action was Vermont in 2018. There were two states–Illinois and Arizona adopting RMLs in 2020, and RMLs have taken effect in four additional states –Connecticut, New York, New Mexico, and Virginia – in 2021. Consequently, Senator Chuck Summers introduced legislation to decriminalize marijuana at the federal level in the mid of 2021.

Unlike most medical marijuana laws (MMLs), RMLs do not require a doctor's recommendation and do not require registration; anyone 21 years of age or older can possess limited amounts of marijuana, and purchases of marijuana are typically made at recreational dispensaries. All but two RML states (Illinois and New Jersey) allow adults to grow marijuana plants at home (Sabia 2021)

2.2 Research on the relationship traffic fatalities and Recreational Marijuana Laws

Traffic accidents are a leading cause of death in the United States, so there has been considerable interest in understanding the relationship between various intoxicants, including marijuana, alcohol, and other drugs, and driving performance, accidents, and fatalities. Many studies on impaired driving have conducted both in a laboratory setting, using roadside surveys or difference-in-differences approach . The results is mixed (Hansen 2017) and the causal link have not been well-established.

When it comes to recreational marijuana laws, until now, there are only three studies , of which I am aware of, assessing the effects of RMLs on traffic fatalities for the reason that RMLs are new, recent phenomenon(Lane and Hall 2019; Hansen et al. 2020; Santaella- Tenorio 2020). Thus, adequate post-legalization data is necessary for researchers to fully identify valid effects. Using synthetic control approach on FARS data from 2000-2016 to examine the effects of RMLs in Colorado and Washington , Hansen et al.(2020) found no evidence that RMLs impacted total or alcohol-related traffic fatalities. The authors believed that the growth in recreational market could have come at the expense of black market and medicinal sales. Santaella-Tenorio et al. (2020), with one more year of post-legalization data and synthetic control method, drew a conclusion that RML in Colorado increased traffic fatalities. However, one thing we should keep in mind that Hansen et al. (2020a) and Santaella- Tenorio et al. (2020) did not use the same set of matching variables to create their synthetic controls, and synthetic control estimates can be quite sensitive to the choice of matching variables (Minard and Waddell 2019). Using CDC WONDER and RoadSafetyBC and census data, Lance and Hall (2019) found that traffic fatalities temporarily increased by an average of one additional traffic fatality per million residents in both legalizing US states of Colorado, Washington and Oregon and in their neighboring jurisdictions.

2.3 Contribution

As I discussed above, RMLs are 2010s phenomenon, and there are not many studies on RMLs on traffic fatalities. The literature on the effects of MMLs is far more developed and widely discussed than RMLs, so policy makers usually depends on extrapolating the results from MMLs studies to notify the potential effect of RMLs for the public. However, the effects of RMLs can look different from the effects of MMLs due to different targeted population, differences in first-stage impact on marijuana consumption etc. (Sabia 2021)

Using two-way fixed effects (TWFE) difference-in-differences as my main analysis, my study will contribute some evidence to the rudimentary literature of RMLs on traffic fatalities. Additionally, a conventional two-way fixed effects DiD has some drawbacks. First, TWFE models often assume the effects to be constants, and they don't have any carryover effects. (Licheng Liu, 2021). If we have heterogenous treatment effects, we will be very likely to have biased estimates. Multiple studies on alcohol consumption, substances' consumption, crime and traffic fatalities confirms that RMLs have very dynamic effects on outcomes of interest. Thus, by using latest development in TWFE method, and under the staggered adoption situation of RMLs, I use method proposed by Callaway and Sant'Anna (2021) for event study analyses,. I also replaced RML and MML with Recreational Marijuana Dispensary (RMD) and Medical Marijuana Dispensary(MMD) [1], and different definitions of traffic fatalities rate as variables of interest for the robustness checks.

3 Data

To study the relation between recreational marijuana and traffic fatalities, I obtain data from the Fatal Analysis and Reporting System (FARS), which is a system maintained by the federal government that records every fatal car accident in the United States. For each accident reported,

[1] RMD and MMD are described in table 3

the system records information on the circumstances, total injuries and fatalities, and demographics of the drivers. Each entry in the system also includes additional reports on the results from tests for illegal drugs and alcohol, if such tests occurred. Using FARS data from 2010-2019, I constructed a state level panel of several key dependent variables to measure the impacts of recreational marijuana legalization on traffic fatalities. The summary statistics for our independent variables is provided in table 2. For variable of interest, I used 10 states that enacted RMLs before 2020 as my treated states [2]

Using Census data and data from Statistics Highway report, I created a rich set of state-level demographics control listed in table 3. Based on National Conference of State Legislatures and National Highway Traffic Safety Administration website, I produced a full set of state laws which Anderson et al.(2013) used in their paper. Since the timeframe of my data is from 2010 to 2019 and some of Anderson et al.(2013) laws were already applied to most of states..

4 Empirical Model

I use a difference-in-differences regression strategy to examine the effects of RMLs on each total traffic fatalities. Specifically, I begin by estimating the following two-way fixed effects (TWFE) regression equation:

$$ln(Fatalities\_total_{st}) = \beta_0 + \beta_1 MML_{st} + \beta_2 RML_{st} + \beta_3 X_{st} + \mu_s + \gamma_t + \epsilon_s t$$

where s indexes states and t indexes years. The estimate of interest, β_2, represents the effect of legalizing recreational marijuana. In alternative specifications, I replaced total traffic fatalities with outcomes listed in Table 2.

The vector X_{st} is composed of the controls described in Table 3, and μ_s and γ_t are state and year fixed effects, respectively. I also looked at event-study to examine the credibility of parallel

[2]Those states are Alaska, California, Colorado, District of Columbia, Maine, Massachusetts, Michigan, Nevada, Vermont, and Washington.

trend assumption. This will allow us to assess differential pre-treatment trends in our outcomes up to four or more years prior to adoption to ensure that outcomes across the treatment and control states were trending similarly prior to the enactment of RMLs.

However, according to Sun and Abraham (2021) , in the presence of heterogenous treatment effect over time, the evaluation of pre-trend in event-studies is untrustworthy. Early-adopters of RMLs will serve as control for later-adopters .And if the effects of RMLs on early-adopting states are dynamic, the estimators using TWFE method may be biased(Goodman-Bacon 2021). To solve this problem, I will apply difference-in-differences estimator proposed by Callaway and Sant'Anna (2021) to test common pre-trend assumption.

5 Results

Our main results are shown in Tables 4 to 8 and Figures 3 to 5 in the appendix.

5.1 Total Traffic Fatalities

In table 4, I evaluate the effect of RMLs on total traffic fatalities. Even by not controlling MMLs (column 1 and column 2), and allowing the effect of treatment effect of interest to be the effect of legalizing recreational marijuana plus already having liberalized medicinal marijuana, while regulating and taxing retail sales, there is not enough evidence to say RMLs has a significant effect on total traffic fatalities. In my most conservative specification, which includes state-specific linear time trends and controlling for MMLs, the effect is not statistically distinguishable from zero. This is consistent with Hansen et al (2018). Using either fractional values or binary indicator for RMLs doesn't make any difference in my evaluation.

In figure 3A, I present event study analyses based on my fully- saturated TWFE estimator and in figure 5B based on the Callaway-Sant's Anna (2021) estimators. First, I find that the leads in both case statistically insignifcant at 5 % level, and their trending are similar over the entire pre-RMLs period [3] However, in each event study, the divergence in total traffic fatalities between RML and control states doesn't manifest after the legalization year. In figure 2B which I included the state-specific linear trend, the effect of RMLs is null.

Secondly, the dynamics of treatment effect in both cases are highly similar to those being created by the Callaway- Sant's Anna approach. This is not surprising since a main source of potential bias in fully-saturated TWFE model is that earlier-treated states are considered as a counterfactual for the later-treated states. With respect to RMLs, from 2010 to 2019, there are only 10 states legalizing marijuana for recreational purposes, while the majority of states still have not enacted marijuana legalization over our sample period. To be certain, I used a Goodman-Bacon decomposition to identify which comparisons drive the estimated treatment effects. According to Figure 4 , this decomposition shows that 93.2 percent of the weight of our estimator can be attributed to the comparison of adopted states versus never-adopted states, and 4 percent can be attributed to earlier versus later-treated comparison [4] while the comparison using early-adopting states as a counterfactual for later-adopting states only drives 3.6 percent. In the following analyses, those decomposition pattern is consistent.

5.2 The Role of Alcohol

In table 7 and table 8, we use Fatalities (No Alcohol) [5] Fatalities (BAC > 0), and Fatalities (BAC ≥ 0.1) instead of Total Fatalities. The result suggests that RMLs has strong impacts on traffic fatalities related to alcohol. Enacting RML is associated with an 13% increase in traffic fatalities with BAC of drivers greater than 0, and 19.6% increase in traffic fatalities with BAC of drivers greater than 0.1. Put it in perspective, in the period from 2010 to 2019, on average for 100 people died because of traffic fatalities, nearly 20 people had BAC greater than 0 and 15 people had BAC greater than 0.1; if states had delayed RMLs , this could have saved around a thousand lives a year.

[3] One noticeable point here is that I used accumulated effects with only 4 leads and 3 lags in fully-saturated TWFE model. Using full leads and lags in fully-saturated TWFE still provide a similar trend as in Callaway- Sant's Anna (2021).

[4] Using later-treated states as a counterfactual

[5] Fatalities(No Alcohol) was identified from two sources in FARS. Either all drivers involved had to have registered a BAC of zero or, if BAC information was missing, the police had to report that alcohol was not involved.

However, using group-time average treatment effects by Callaway and Sant's Anna, the effect of RMLs on alcohol-related is negligible for all group. This can be explained by the fact that RMLs are recent phenomenon, and more states adopting RMLs in future are needed for a better analysis. A regular event study analysis of alcohol-related traffic fatalities doesn't confirm the pre-trend test, especially in three years prior RMLs enactment. Yet, Sun and Abraham (2020) indicated that the pre-trend test as a test of common trend is unreliable, thus I used event study from Callaway-Sant's Anna (2021) as a main method to do common trend test, and figure 5 confirmed that the common trend test is satisfied.

Based on MML studies, there are two potential mechanisms of why MMLs reduce traffic fatalities, especially traffic fatalities related to alcohol. First is driving under influence of marijuana is safer than driving under influence of alcohol. Second, MMLs disincentivized traveling since individuals prefer to stay at private places to consume marijuana(Anderson 2013) When it comes to RMLs, one of mechanism here could be when recreational marijuana law become effective, it changed the way how people use marijuana. The habituation of people in RML states to marijuana make frequency of using marijuana daily basis. Thus, marijuana doesn't replace alcohol as a way of socializing.

6 Robustness Checks

Our estimates from TWFE model yields little evidence to support the idea that the recreational marijuana legalization increases total traffic fatalities. [6]. I have 3 important robustness checks. [7]

First, I replaced RML and MML with RMD and MMD to further investigate the real effect on traffic fatalities when actual dispensaries were on the ground. Based on table 10, Using RMD and MMD instead of RML and MML does not fundamentally alter the result of my study. Furthermore,

[6] This is consistent with Hansen et al.(2018), and somewhat consistent with economic literature about the effect of RML on traffic fatalities(non-negative effect)

[7] I also used some non- DID such as generalized synthetic control proposed by Yiqing Xu (2017) and counterfactual estimators proposed by Licheng Liu (2021), and this effort is to overcome the challenge of the lack of post-legalization data. However, those models requires many pre-treatment data and since my data is from 2010 to 2019 ,it automatically removes Colorado and Washington from dataset. Without two early- adopting states in the analysis, we can't rely on those model to make any causal claims.

two potential problems that can make our estimates biased are selective migration and dominant effect coming from a specific state. States with RMLs in effective become more attractive to individuals who would drive at high speed, make dangerous maneuver, and drive at night frequently. I ran regression with total population, male population and many different types of population data to identify whether we have selective migration. Table 12 provides us some evidence that selective migration is not a serious concern. Secondly, I implemented a leave-one-out analysis (reported in Figure 6) where I re-estimated the treatment effects for our outcomes by removing each treated RML state in turn from the sample. The stability of the estimates for each outcome across all the alternate samples provides some degree of confidence that my result is not driven by any single RML state.

7 Discussions and Conclusions

One of the most main arguments offered by proponents of recreational marijuana laws is that marijuana would substitute alcohol, then RMLs would reduce traffic fatalities. My study comprehensively explores the effect of RML on traffic fatalities using FARS data from 2010 to 2019. I find light evidence, at least thus far, that RMLs is associated with a 2.4 percent increase the total traffic fatalities, and strong evidence that RMLs significantly increase traffic fatalities related to alcohol. This is contrary to some MML studies claiming that marijuana is a potential substitute for alcohol.

With regard to limitations of my analysis, I note that my estimates is average treatment effects over the post-treatment data available for our RML states, and the post-legalization data is around three to four years. Future research with more post-legalization data will be able to fully investigate the carryover effect of RMLs. In addition, future studies based on a natural experiment combining with TWFE strategy can provide stronger evidence for a casual claim. Furthermore, with the limitation in data, I can't do any analyses to explore what mechanism behind the phenomenon.

My findings are important to policymakers and the public. Policymakers should carefully weighing the costs of liberalizing recreational marijuana. My result provides some evidence that legalizing recreational marijuana is associated with increase in traffic fatalities, this can outweigh the benefits brought by recreational marijuana.

8 Appendix: Tables and Figures

8.1 Tables

Table 1: **Marijuana Laws by State**

State	MML	MMD	RML	RMD
Alaska	3/4/1999	10/29/2016	2/24/2015	10/29/2016
Arkansas	11/9/2016	5/11/2019		
Arizona	11/29/2010	12/6/2012	11/30/2020	
California	11/6/1996	11/1/1996	11/9/2016	1/1/2018
Colorado	12/28/2000	7/1/2005	12/10/2012	1/1/2014
Connecticut	10/1/2012	9/22/2014	07/01/2021	
Delaware	7/1/2011	6/26/2015		
District of Columbia	7/27/2010	7/29/2013	2/26/2015	
Florida	1/3/2017	12/19/2018		
Hawaii	6/4/2000	8/8/2017		
Illinois	1/1/2014	11/9/2015	1/1/2020	
Louisiana	5/19/2016	8/6/2019		
Maine	12/23/1999	4/1/2011	1/30/2017	10/09/2020
Maryland	6/1/2014	12/1/2017		
Massachusetts	1/1/2013	6/4/2015	12/15/2016	11/20/2018
Michigan	12/4/2008	12/1/2009	12/6/2018	12/1/2019
Minnesota	5/30/2014	7/1/2015		
Missouri	12/6/2018			
Montana	11/2/2014	4/1/2009	1/1/2021	
Nevada	10/1/2001	7/31/2015	1/1/2017	7/1/2017
New Hampshire	7/23/2013	4/30/2016		
New Jersey	6/1/2010	12/6/2012	2/22/2021	
New Mexico	7/1/2007	6/1/2009	06/29/2021	
New York	7/5/2014	1/7/2016	03/31/2021	
North Dakota	12/8/2016	3/1/2019		
Ohio	9/8/2016	1/16/2019		
Oklahoma	7/26/2018	10/26/2018		
Oregon	12/3/1998	7/1/2009		
Pennsylvania	5/17/2016	1/17/2018		
South Dakota	Not yet operational			
Rhode Island	1/3/2006	4/19/2013		
Utah	12/3/2018			
Vermont	7/1/2004	6/1/2013	7/1/2018	
Virginia	10/17/2020		07/01/2021	
Washington	12/3/1998	10/1/2009	12/6/2012	7/8/2014
West Virginia	7/1/2019			
Total	**34**	**28**	**18**	**7**

Notes. I obtained effective dates of marijuana laws directly from Meinhofer et. al (2021), (Marijuana Reviews), and NORML(2021). And South Dakota's amendment is being legally challenged. If affirmed by the state Supreme Court, the law will take effect on July 1, 2021.

Table 2: **Dependent Variables for the Fatality Analysis Reporting System Analysis**

Dependent Variable	Mean	SD	Description
Total Fatalities	10.92	3.75	Fatalities per 100,000 people
Fatalities Weekends	3.70	1.27	Fatalities per 100,000 people on weekends
Fatalities Weekdays	7.22	2.53	Fatalities per 100,000 people on weekdays
Fatalities Daytime	5.27	1.95	Fatalities per 100,000 people during the day
Fatalities Nighttime	5.57	1.96	Fatalities per 100,000 people during the night
Fatalities Male	15.70	5.41	Fatalities per 100,000 males
Fatalities Female	6.27	2.24	Fatalities per 100,000 females
Fatalities Male, 20-29	24.84	8.51	Fatalities per 100,000 males 20-29 years of age
Fatalities, 15-19	11.88	5.00	Fatalities per 100,000 people 15–19 years of age
Fatalities, 20-29	5.71	2.48	Fatalities per 100,000 people 20–29 years of age
Fatalities, 30-39	6.11	2.75	Fatalities per 100,000 people 30–39 years of age
Fatalities, 40-49	6.13	2.73	Fatalities per 100,000 people 40–49 years of age
Fatalities, 40-49	5.90	2.56	Fatalities per 100,000 people 50–59 years of age
Fatalities, 60+	12.80	3.59	Fatalities per 100,000 people 60 years old and above
Fatalities F-S night	1.37	0.50	Fatalities per 100,000 people in Friday night or Saturday night
Fatalities (BAC $>$ 0)	2.18	0.90	Fatalities per 100,000 people for which at least one driver involved had a BAC $>$ .00
Fatalities (No alcohol)	5.64	2.48	Fatalities per 100,000 people with no indication of alcohol involvement
Fatalities (BAC $>$ 0.1)	1.69	0.73	Fatalities per 100,000 people for which at least one driver involved had a BAC $>$ .10
Fatalities Marijuana	0.12	0.29	Fatalities per 100,000 people with indication of marijuana involvement

Notes: The data are weighted means based on the Fatality Analysis Reporting System state-level panel for 2010-2019. SD is standard deviation.

Table 3: **Independent Variables for the Fatality Analysis Reporting System Analysis**

Independent Variable	Mean	SD	Description
MML[a]	0.45	0.49	Equals one if a state had a medical marijuana law in a given year and zero otherwise
RML [a]	0.08	0.27	Equals one if a state had a recreational marijuana law in a given year and zero otherwise
MMD[a]	0.28	0.44	Equals one if a state had a actual opening medical marijuana dispensary in a given year and zero otherw
RMD[a]	0.03	0.17	Equals one if a state had a actual opening recreational marijuana dispensary in a given year and zero ot
Beer Tax	0.26	0.21	Real Beer tax (2000$)
Unemployment	6.21	2.34	State unemployment rate
Secondary Seat Belt[a]	0.21	0.41	Equals one if a state had a secondary seat belt law in a given year and zero otherwise
Primary Seat Belt[a]	0.78	0.41	Equals one if a state had a primary seat belt law in a given year and zero otherwise
Handheld Ban[a]	0.33	0.47	Equals one if a state had a hands-free cell phone law in a given year and zero otherwise
Texting Ban[a]	0.72	0.45	Equals one if a state had a cell phone texting ban in a given year and zero otherwise
Speed 70	0.86	0.35	Equals one if a state had a speed limit of 70 mph or greater in a given year and zero otherwise
Drug Per Se	0.12	0.32	Equals one if a state had a drug per se law in a given year and zero otherwise
Zero Tolerance	0.26	0.44	Equals one if a state had a zero-tolerance drunk-driving law in a given year and zero otherwise
ALR	0.84	0.36	Equals one if a state had an administrative license revocation law in a given year and zero otherwise
BAC .08	0.99	0.10	Equals one if a state had a .08 BAC law in a given year and zero otherwise
Decriminalized	0.37	0.48	Equals one if a state had a marijuana decriminalization law in a given year and zero otherwise
Driver License	9.4 m	7.4 m	Number of driver license in a state
Miles Driven	14.16	2.20	Vehicle miles driven per licensed driver (thousands of miles)
Income	10.75	0.10	Natural logarithm of state real income per capita (2012 $)
Median Age	37.87	2.17	Median age of state population

Notes: The data are weighted means based on the Fatality Analysis Reporting System state-level panel for 2010-2019. SD is standard deviation.

"m" means million

[a] take on fractional values for the years in which laws changed.

Table 4: Recreational Marijuana Law and Total Traffic Fatalities

	Fractional Values			Binary Indicator		
	(1)	(2)	(3)	(4)	(5)	(6)
RML	0.024	0.015	-0.009			
	(0.032)	(0.029)	(0.025)			
MML		-0.046	-0.010			
		(0.030)	(0.015)			
RML_1				0.027	0.019	0.001
				(0.032)	(0.029)	(0.025)
MML_1					-0.046*	-0.022**
					(0.025)	(0.010)
State-speific linear trend	No	No	Yes	No	No	Yes
Within R-squared	0.328	0.348	0.621	0.329	0.352	0.623

Note. The dependent variable is equal to the natural log of the total fatalities per 100,000 people. Regressions are weighted using state population.Years fix effects, states fixed effects and state covariates are included in all specifications.
MML = medical marijuana law, RML = recreational marijuana laws. N = 510
Standard errors in parentheses, corrected for clustering at the sate level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Recreational Marijuana Law and Traffic Fatalities by Day and Time

	(1) Fatalities Daytime	(2) Fatalities Nighttime	(3) Fatalities F-S night	(4) Fatalities Weekends	(5) Fatalities Weekdays
MML	-0.025	-0.067*	-0.084*	-0.036	-0.051*
	(0.030)	(0.035)	(0.044)	(0.036)	(0.029)
RML	0.007	0.007	0.048	0.020	0.010
	(0.025)	(0.036)	(0.038)	(0.027)	(0.034)
Within R-squared	0.178	0.345	0.162	0.227	0.298

Note. The dependent variables are equal to the natural log of fatalities per 100,000 people. Regressions are weighted using state populations.
Year fixed effects, state fixed effects, state covariates, are included in all specifications
Standard errors in parentheses, corrected for clustering at the state level. MML,RML are fractional values. N = 510
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Recreational Marijuana Law and Traffic Fatalities by Sex

	(1) Fatalities Male	(2) Fatalities Female	(3) Fatalities Male,20-29
MML	-0.041	-0.056*	-0.068*
	(0.032)	(0.030)	(0.035)
RML	0.012	0.024	-0.045
	(0.028)	(0.035)	(0.039)
Within R-squared	0.343	0.184	0.230

Note. The dependent variables are equal to the natural log of fatalities per 100,000 people.
Regressions are weighted using state populations.
Year fixed effects, state fixed effects, state covariates, are included in all specifications.N = 510
Standard errors in parentheses, corrected for clustering at the state level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: **Recreational Marijuana Laws and Traffic Fatalities: The Role of Alcohol, Using Binary Indicator**

	Fatalities, No Alcohol			Fatalities, BAC > 0			Fatalities, BAC >0.1		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RML_1	0.001	-0.007	0.018	0.130**	0.117*	0.023	0.196***	0.185***	0.103
	(0.047)	(0.045)	(0.054)	(0.064)	(0.065)	(0.063)	(0.059)	(0.061)	(0.063)
MML_1		-0.044*	-0.015		-0.073	-0.074*		-0.064	-0.049
		(0.026)	(0.021)		(0.045)	(0.037)		(0.041)	(0.038)
State-specific linear trend	No	No	Yes	No	No	Yes	No	No	Yes
Within R-squared	0.257	0.268	0.478	0.110	0.122	0.394	0.108	0.117	0.386

Note. The dependent variables are equal to the natural log of fatalities per 100,000 people.Regressions are weighted using state populations. Year fixed effects, state fixed effects, state covariates are included in all specifications. Standard errors, clustering at the state level, in parentheses. N = 510

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: **Recreational Marijuana Laws and Traffic Fatalities: The Role of Alcohol, Using Fractional Values**

	Fatalities, No Alcohol			Fatalities, BAC > 0			Fatalities, BAC >0.1		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RML	0.003	-0.005	0.034	0.111	0.096	-0.038	0.192***	0.178**	0.082*
	(0.052)	(0.050)	(0.057)	(0.080)	(0.082)	(0.066)	(0.065)	(0.067)	(0.044)
MML		-0.041	-0.008		-0.080	-0.066		-0.074	-0.046
		(0.033)	(0.024)		(0.051)	(0.052)		(0.046)	(0.051)
State-specific linear trend	No	No	Yes	No	No	Yes	No	No	Yes
Within R-squared	0.257	0.266	0.479	0.101	0.115	0.392	0.099	0.109	0.382

Note. The dependent variables are equal to the natural log of fatalities per 100,000 people.Regressions are weighted using state populations. Year fixed effects, state fixed effects, state covariates are included in all specifications. Standard errors, clustering at the state level, in parentheses. N = 510

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Selective Migration Check

	Population							
	(1) Total	(2) Male	(3) Female	(4) Female,20-29	(5) Male,20-29	(6) Male,30-39	(7) Licensed Driver	(8) Miles Driven
MML	-39069	-16143	-22926	-8192	-8209	8883	37444	-982
	(-0.34)	(-0.29)	(-0.39)	(-1.33)	(-1.21)	(0.81)	(0.34)	(-0.57)
RML	75733	40925	34808	3527	2809	25208	196900	-240
	(0.57)	(0.61)	(0.54)	(0.59)	(0.42)	(1.17)	(0.83)	(-0.13)

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Recreational Marijuana Dispensary and Total Traffic Fatalities

	Fractional Values			Binary Indicator		
	(1)	(2)	(3)	(4)	(5)	(6)
RMD	0.013	0.009	-0.033			
	(0.030)	(0.029)	(0.021)			
MMD		-0.064	-0.015			
		(0.039)	(0.030)			
RMD_1				0.011	0.007	-0.023
				(0.026)	(0.025)	(0.021)
MMD_1					-0.053	-0.013
					(0.036)	(0.026)
State-speific linear trend	No	No	Yes	No	No	Yes
Within R-squared	0.326	0.359	0.624	0.326	0.354	0.622

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: Recreational Marijuana and Total Traffic Fatalities by different definitions

	Fatalities rate per licensed driver			Fatalities rate per 1000 driving miles		
	(1)	(2)	(3)	(4)	(5)	(6)
RML	0.030	0.024	0.004	0.027	0.021	0.004
	(0.038)	(0.035)	(0.024)	(0.039)	(0.037)	(0.025)
MML		-0.032	-0.002		-0.031	-0.002
		(0.032)	(0.015)		(0.029)	(0.014)
State-speific linear trend	No	No	Yes	No	No	Yes
Within R-squared	0.398	0.406	0.684	0.285	0.294	0.613

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

8.2 Figures

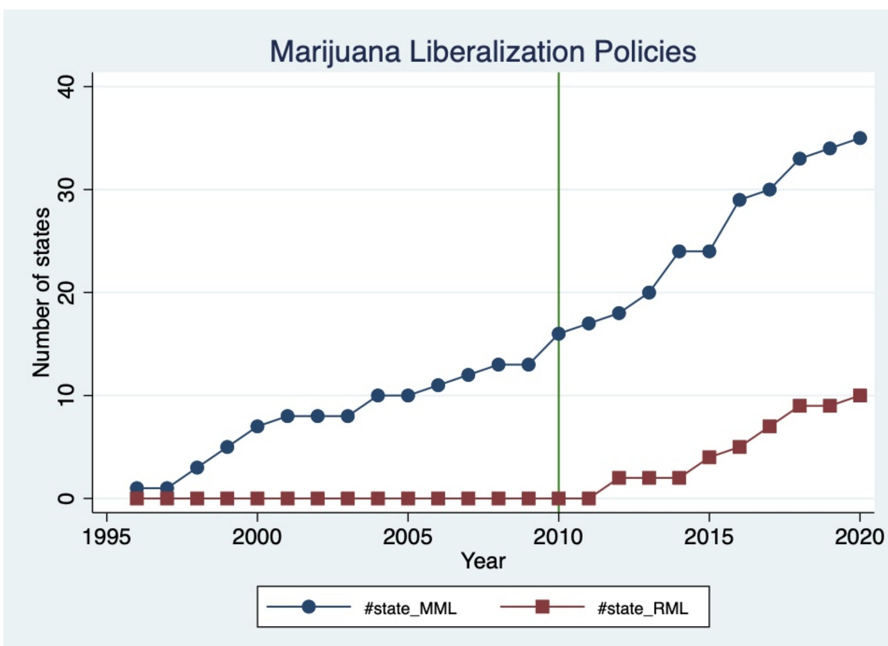


Figure 1: Marijuana Legalization Trend

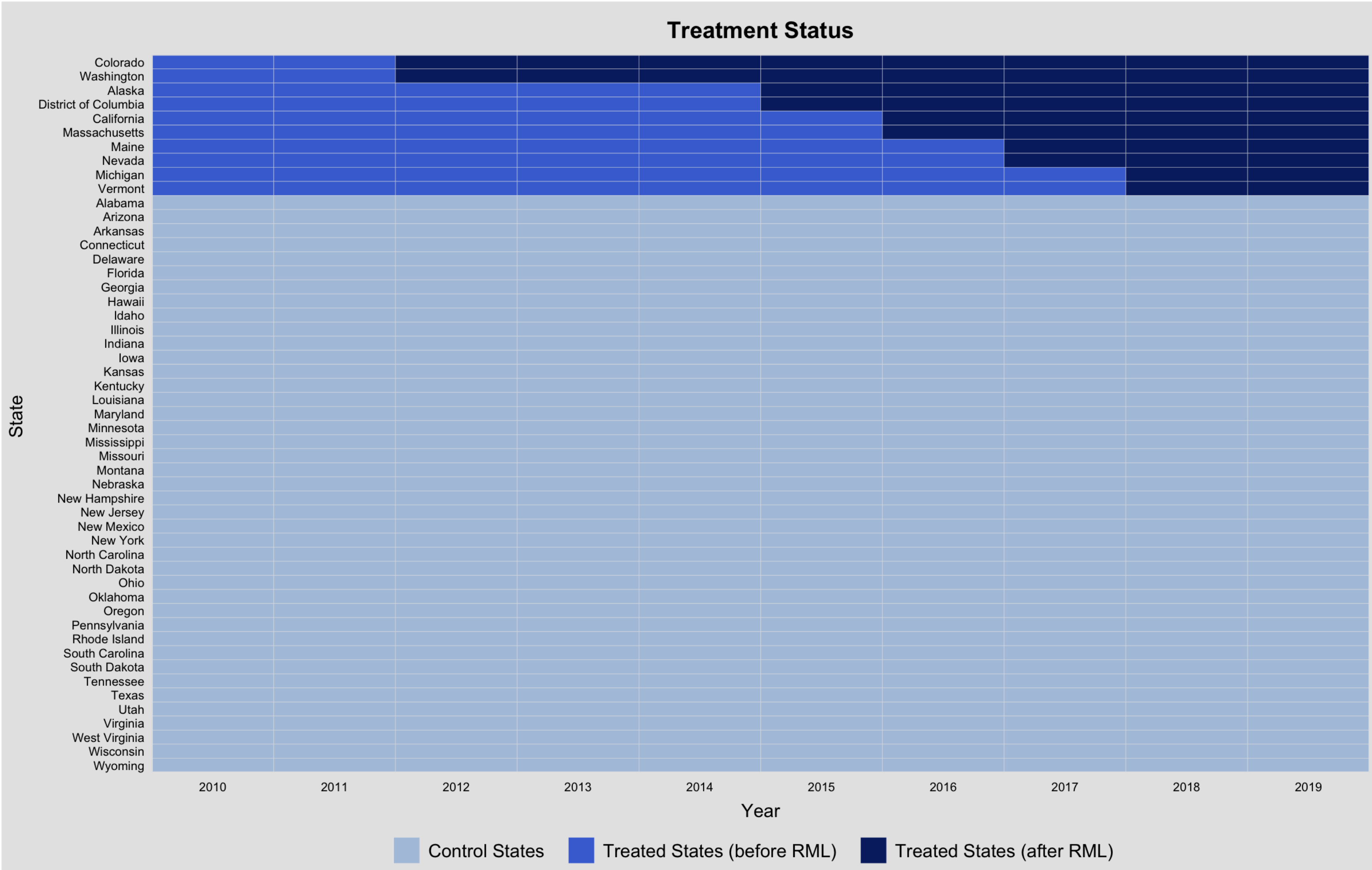
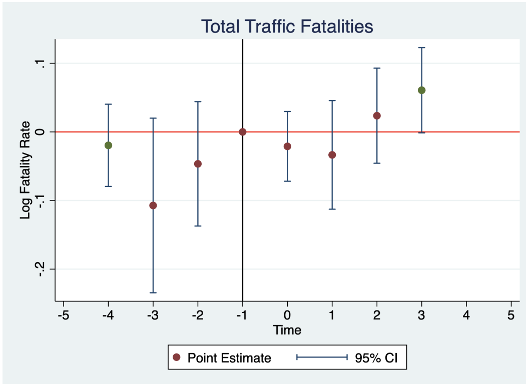
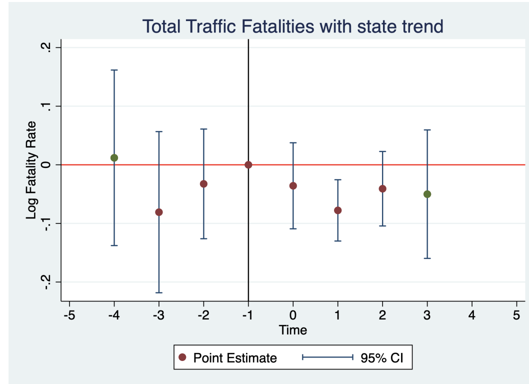


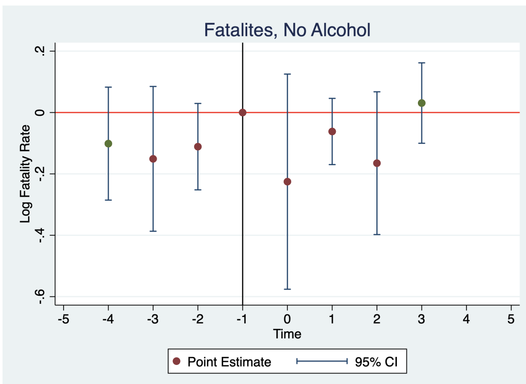
Figure 2: Treatment Status Panel View



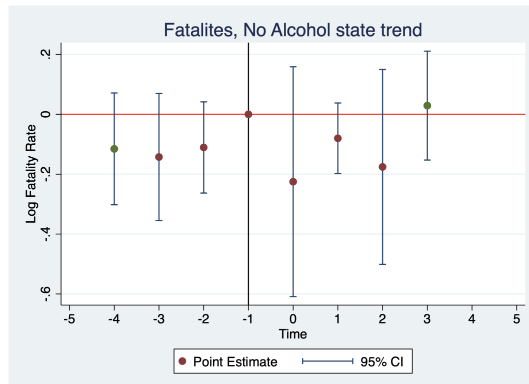
(a) Total fatalities



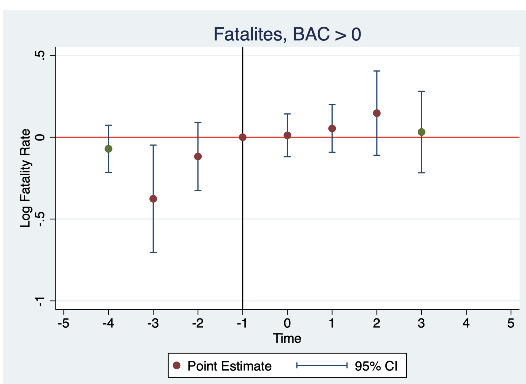
(b) Total fatalities with trend



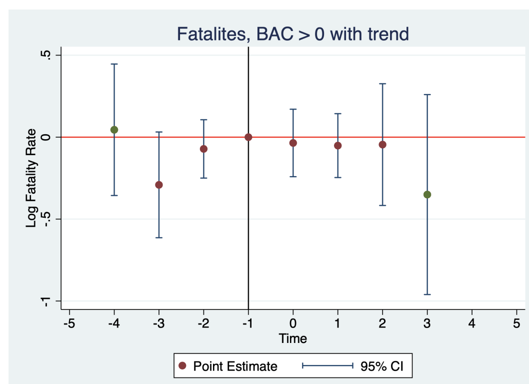
(c) Fatalities, No Alcohol



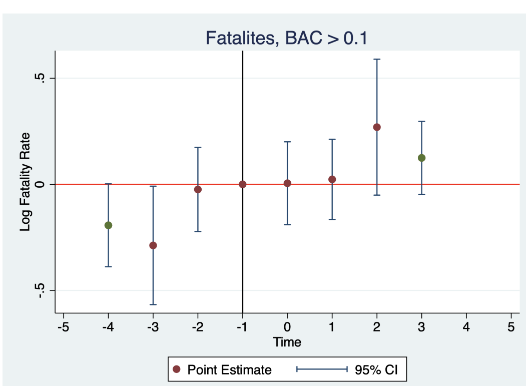
(d) Fatalities, No Alcohol with trend



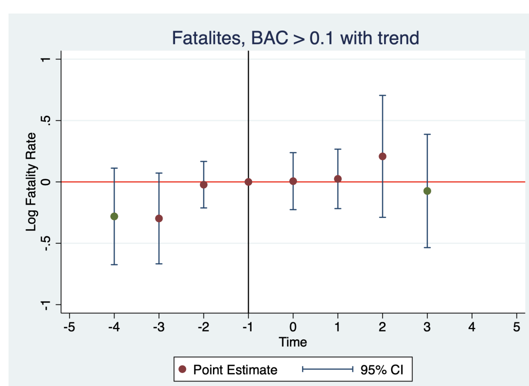
(e) Fatalities, BAC > 0



(f) Fatalities, BAC > 0 with trend



(g) Fatalities, BAC > 0.1



(h) Fatalities, BAC > 0.1 with trend

Figure 3: Regular Event Study Analyses

8.3 TWFE Robustness Checks

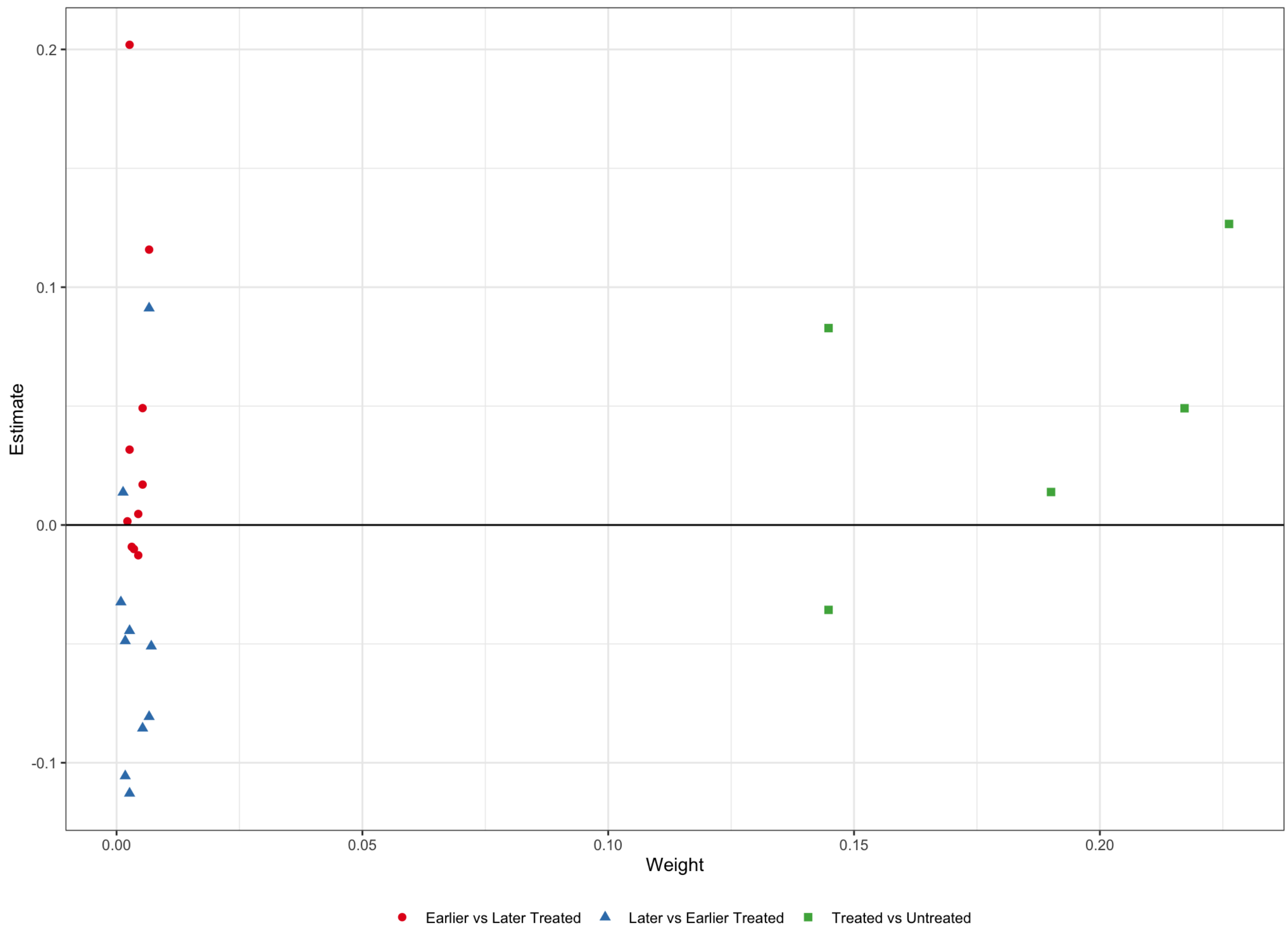
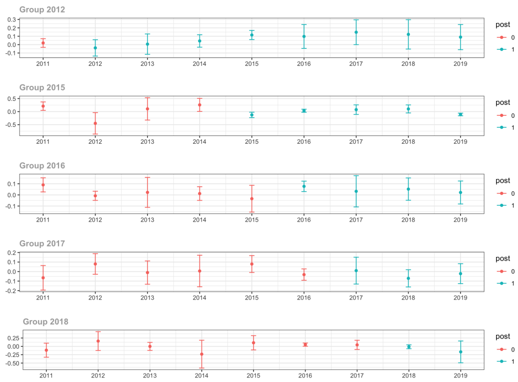
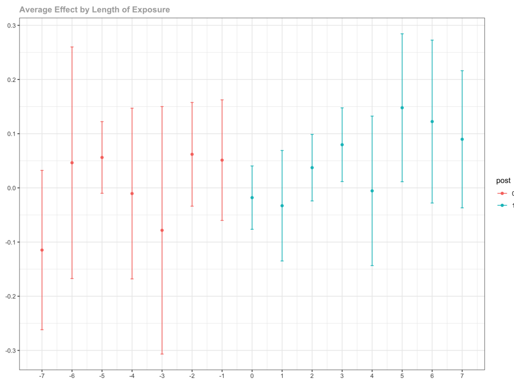


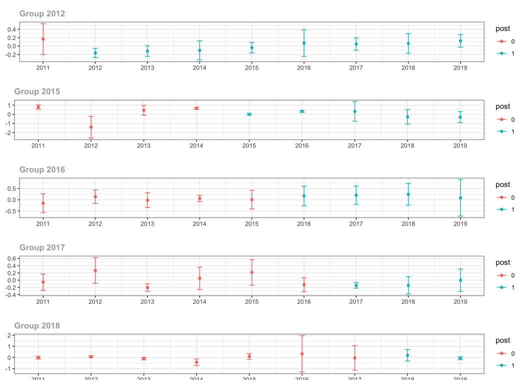
Figure 4: Bacon decomposition diagnostic test



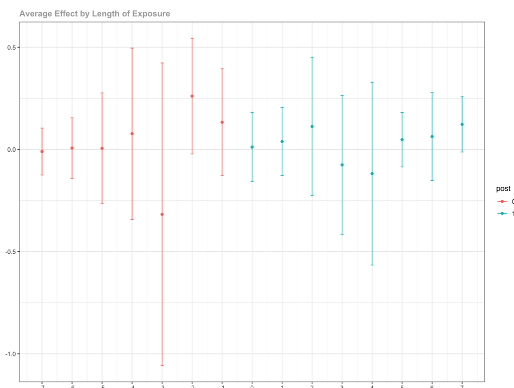
(a) Total fatalities



(b) Total fatalities event study

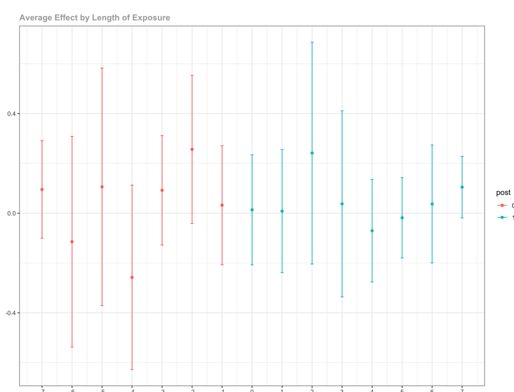


(c) Fatalities, BAC > 0



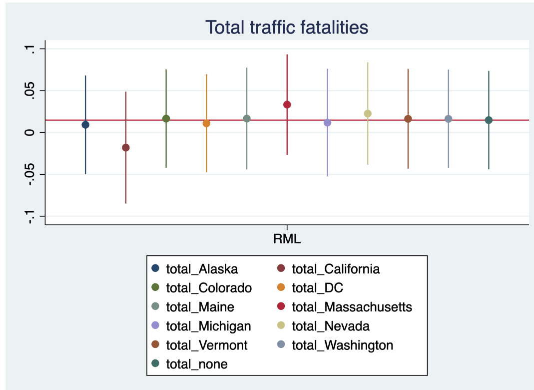
(d) Fatalities, BAC > 0 event study

(e) Fatalities, BAC > 0.1

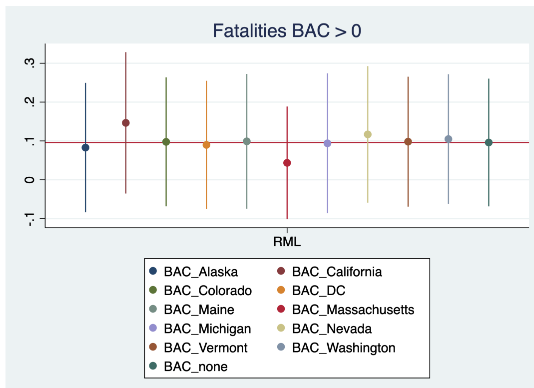


(f) Fatalities, BAC > 0.1 event study

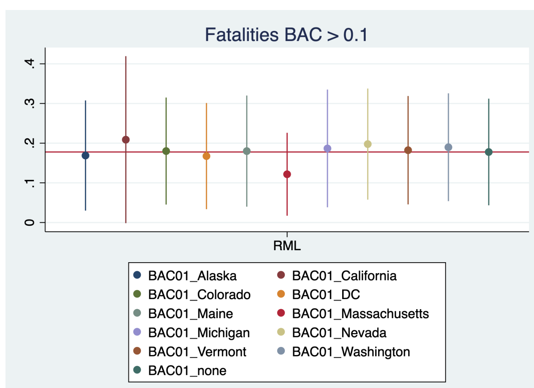
Figure 5: Group-time average treatment effects by Callaway and Sant'Anna (2018)



(a) Total fatalities



(b) Fatalities, BAC > 0



(c) Fatalities, BAC > 0.1

Figure 6: Leave-one-out analysis

Note. total_ Alaska means dropping Alaska out of the sample, similarly for other total_*, and BAC_*, and BAC01_*

8.4 Non DID methods

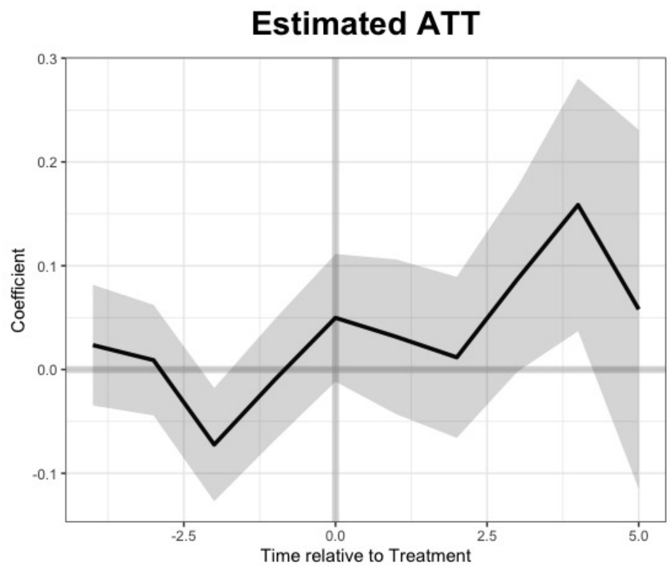


Figure 7: Generalized Synthetic Control

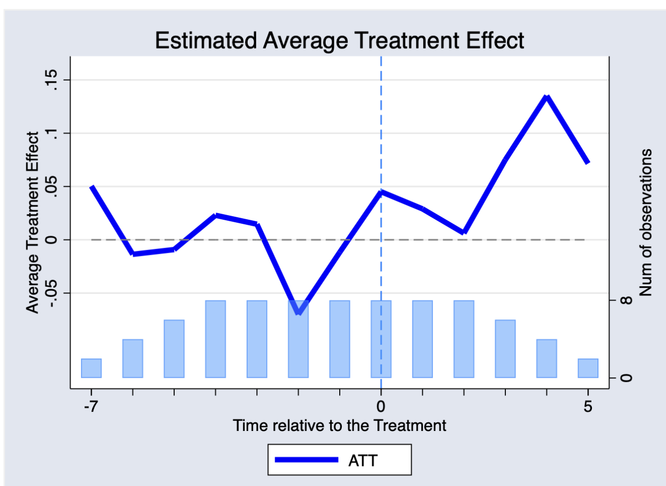


Figure 8: Counterfactual estimators

9 References

American Civil Liberties Union. 2013. "The War on Marijuana in Black and White: Billions of Dollars Wasted on Racially Charged Arrests," Available at: `https://www.aclu.org/sites/default/files/field_document/1114413-mj-report-rfs-rel1.pdf`

Agan, Amanda, and Sonja Starr. 2018. "Ban the Box, Criminal Records, and Racial Discrimination: A Field Experiment." *The Quarterly Journal of Economics, 133(1)*: 191-235.

Agan, Amanda Y., Jennifer L. Doleac, and Anna Harvey. 2021. "Misdemeanor Prosecution." NBER Working Paper No. w28600.

Anderson, D. Mark, Benjamin Hansen, and Daniel I Rees. 2013. "Medical Marijuana Laws, Traffic Fatalities, and Alcohol Consumption." *Journal of Law and Economics, 56(2)*: 333-369.

Anderson, D. Mark, and Daniel I. Rees. 2021. "The Public Health Effects of Legalizing Marijuana". NBER Working Paper No. w28647.

Angélica Meinhofer, Allison E. Witman, Jesse M. Hinde, Kosali Simon, 2021. "Marijuana liberalization policies and perinatal health," Journal of Health Economics, vol 80.

Aydelotte, Jayson D., Lawrence H. Brown, Kevin M. Luftman, Alexandra L. Mardock, Pedro G. R. Teixeira, Ben Coopwood, and Carlos V. R. Brown. 2017. "Crash Fatality Rates After Recreational Marijuana Legalization in Washington and Colorado." *American Journal of Public Health, 107(8)*: 1329- 1331.

Beer Institute. 1990–2010. Brewers Almanac. Washington, D.C.: Beer Institute.

Callaway, Brantly, and Pedro H.C. Sant'Anna. 2021. "Difference-in-Differences with Multiple Time Periods." Forthcoming, Journal of Econometrics.

Dobbie, Will, Jacob Goldin, and Crystal S. Yang. 2018. "The Effects of Pretrial Detention on Conviction, Future Crime, and Employment: Evidence from Randomly Assigned Judges." *American Economic Review, 108(2)*: 201-40.

Fandos, Nicolas. 2021. "In a Milestone, Schumer Will Propose Federal Decriminalization of Marijuana." New York Times , Accessed on December 14 at https://www.nytimes.com/2021/07/14/us/politics/marijuana-legalization-schumer.html?action=click&module=Top%20Stories&pgtype=Homepage

Goodman-Bacon, Andrew. 2021. "Difference-in-Differences with Variation in Treatment Timing." Forthcoming, *Journal of Econometrics.*

Hansen, Benjamin and Miller, Keaton and Weber, Caroline, Early Evidence on Recreational Marijuana Legalization and Traffic Fatalities (April 2020). *Economic Inquiry, Vol. 58, Issue 2, pp. 547-568*, 2020, Available at SSRN: https://ssrn.com/abstract=3596383orhttp://dx.doi.org/10.1111/ecin.12751

Liu, Licheng and Wang, Ye and Xu, Yiqing, A Practical Guide to Counterfactual Estimators for Causal Inference with Time-Series Cross-Sectional Data (July 12, 2021). Available at SSRN: https://ssrn.com/abstract=3555463orhttp://dx.doi.org/10.2139/ssrn.3555463

Mueller-Smith, Michael, and Kevin T. Schnepel. 2021. "Diversion in the Criminal Justice System." *The Review of Economic Studies, 88(2)*: 883-936.

National Academies of Sciences, Engineering, and Medicine. 2017. *The Health Effects of Cannabis and Cannabinoids: The Current State ofEvidence and Recommendations for Research.* Washington, D.C.: National Academies Press.

National Conference of State Legislatures NCSL . United States, 2001. Web Archive. Retrieved from the Library of Congress, <www.loc.gov/item/lcwaN0006936/>.

National Highway Traffic Safety Administration. 2010.*Drug per se Laws: A Review of Their Use in the States.* Traffic Tech: Technology Transfer Series No. 393. Washington, D.C.: U.S. Department of Transportation.http://www.nhtsa.gove/staticfiles/traffic_tech/tt393.pdf.

Pager, Devah. 2003. "The Mark of a Criminal Record." *American Journal of Sociology, 108(5)*: 937-975.

Santaella-Tenorio, Julian, Christine M. Mauro, Melanie M. Wall, June H. Kim, Magdalena Cerdá, Katherine M. Keyes, Deborah S. Hasin, Sandro Galea, and Silvia S. Martins. 2017. "US Traffic Fatalities, 1985–2014, and Their Relationship to Medical Marijuana Laws." *American Journal of Public Health, 107(2)*: 336–342.

Sabia, Joseph and Dave, Dhaval and Dave, Dhaval and Alotaibi, Fawaz and Rees, Daniel I., Is Recreational Marijuana a Gateway to Harder Drug Use and Crime? (July 2021). Available at SSRN:https://ssrn.com/abstract=3889145orhttp://dx.doi.org/10.2139/ssrn.3889145

Sun, Liyang, and Sarah Abraham. 2020. "Estimating Dynamic Treatment Effects in Event Studies with Heterogeneous Treatment Effects." Forthcoming, *Journal of Econometrics.*