Recreational Marijuana Legalization on Traffic Fatalities: Early Evidence from FARS

Nhat Hoang Pham

UC Denver

December 13, 2021

Research Question

What is the effect of Recreational Marijuana Legalization (RML) on Traffic Fatalities at the state level?

Motivation- Why RML ?

1. Policy makers rely on evidence produced from medical marijuana laws (MMLs) research to inform them the effect of marijuana on public.
2. However, RMLs can be very different from MMLs : target population, RML states already had MML

Motivation- Why RML ?

1. Policy makers rely on evidence produced from medical marijuana laws (MMLs) research to inform them the effect of marijuana on public.
2. However, RMLs can be very different from MMLs : target population, RML states already had MML
3. RML is a recent phenomenon, the chance that this paper get published is much higher.

Literature Review

- Hansen, Benjamin, Keaton Miller, and Caroline Weber. 2020a. "Early Evidence on Recreational Marijuana Legalization and Traffic Fatalities." Economic Inquiry, 58(2): 547-568.

Literature Review

- Hansen, Benjamin, Keaton Miller, and Caroline Weber. 2020a. "Early Evidence on Recreational Marijuana Legalization and Traffic Fatalities." Economic Inquiry, 58(2): 547-568.
- Santaella-Tenorio, Julian, Katherine Wheeler-Martin, Charles J. DiMaggio, Alvaro Castillo-Carniglia, Katherine M. Keyes, Deborah Hasin, and Magdalena Cerdá. 2020. "Association of Recreational Cannabis Laws in Colorado and Washington State with Changes in Traffic Fatalities, 2005-2017." JAMA Internal Medicine, 180(8): 1061-1068.

Literature Review

- Hansen, Benjamin, Keaton Miller, and Caroline Weber. 2020a. "Early Evidence on Recreational Marijuana Legalization and Traffic Fatalities." Economic Inquiry, 58(2): 547-568.
- Santaella-Tenorio, Julian, Katherine Wheeler-Martin, Charles J. DiMaggio, Alvaro Castillo-Carniglia, Katherine M. Keyes, Deborah Hasin, and Magdalena Cerdá. 2020. "Association of Recreational Cannabis Laws in Colorado and Washington State with Changes in Traffic Fatalities, 2005-2017." JAMA Internal Medicine, 180(8): 1061-1068.
- 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.

Literature Review

- Hansen, Benjamin, Keaton Miller, and Caroline Weber. 2020a. "Early Evidence on Recreational Marijuana Legalization and Traffic Fatalities." Economic Inquiry, 58(2): 547-568.
- Santaella-Tenorio, Julian, Katherine Wheeler-Martin, Charles J. DiMaggio, Alvaro Castillo-Carniglia, Katherine M. Keyes, Deborah Hasin, and Magdalena Cerdá. 2020. "Association of Recreational Cannabis Laws in Colorado and Washington State with Changes in Traffic Fatalities, 2005-2017." JAMA Internal Medicine, 180(8): 1061-1068.
- 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.

Data at State-Year Level(2010-2019)

- FARS from 2010-2019 using accident, accident auxiliary, and person data files
- U.S census: population, median age, male/female population
- BEA: Income by state
- BLS: Unemployment Rate
- Highway statistics: Number of licensed driver, Vehicle miles driven
- National Highway Traffic Safety Administration and National Conference of State Legislatures: laws such as primary seat belts, texting ban etc.
- Use 10 states legalizing recreational marijuana before 2020

Summary Statistics

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**

Summary Statistics

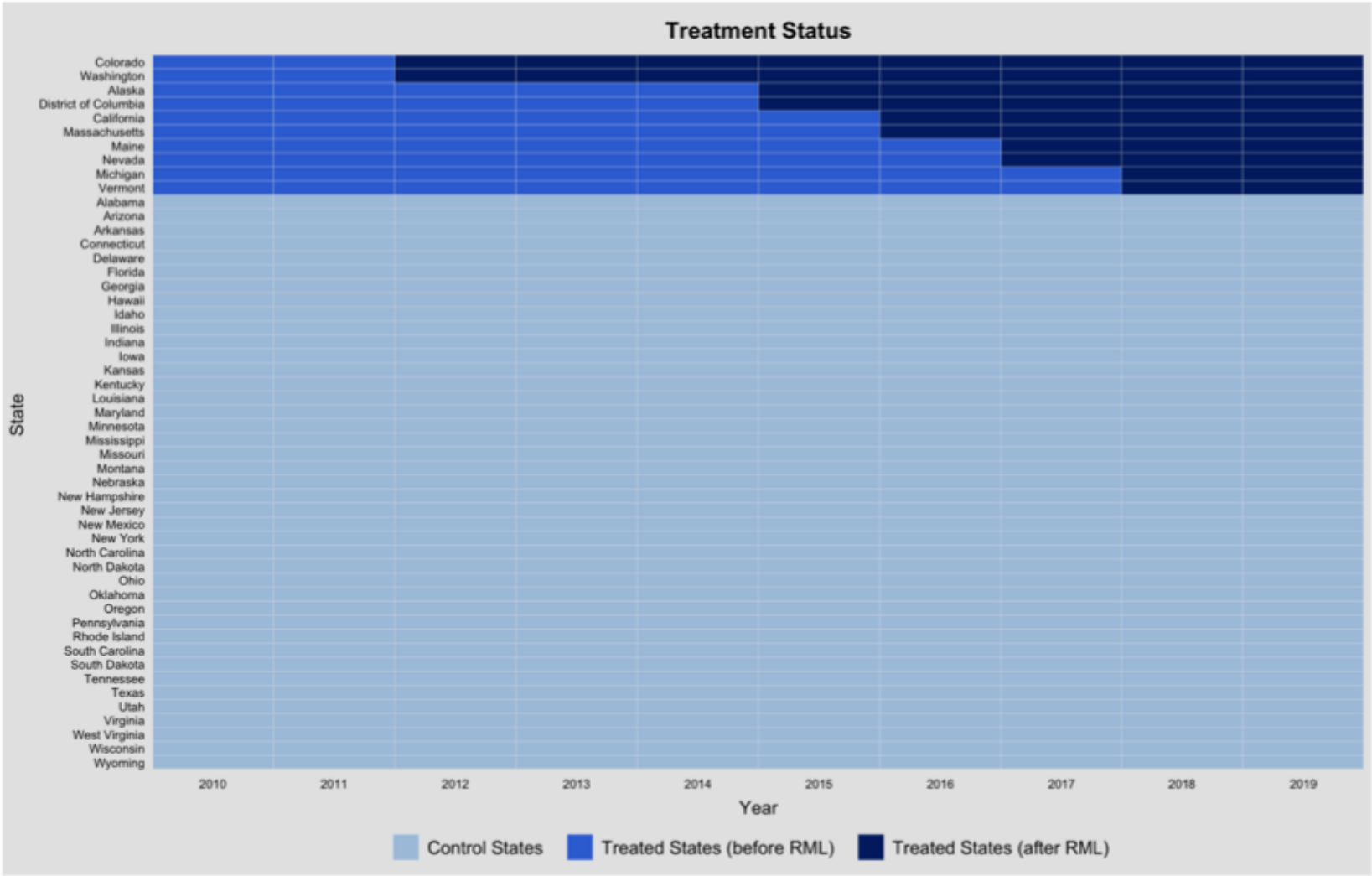


Figure 2: Treatment Status Panel View

Summary statistics

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.

15

Summary statistics

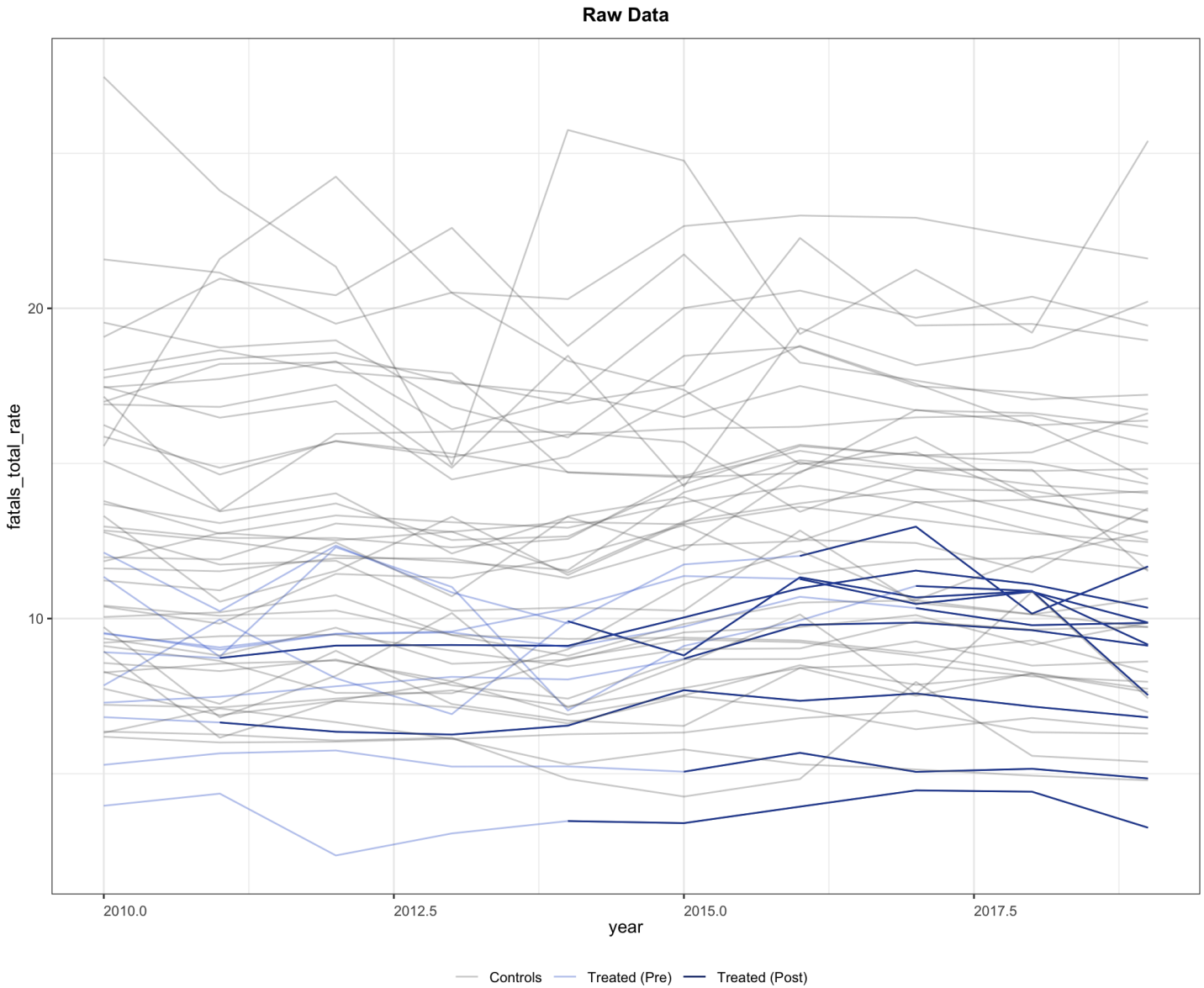
Table 3: **Independent Variables for the Fatality Analysis Reporting System Analysis**

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 ze
RMD[a]	0.03	0.17	Equals one if a state had a actual opening recreational marijuana dispensary in a given year an
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 othe
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.

Raw data- Trend in total fatalities



Regression Model

$$ln(traffic\_fatalities_{st}) = \beta_0 + \beta_1 MML_{st} + \beta_2 RML_{st} + X_{st}\beta_3 + \mu_s + \eta_t + \epsilon_{st}$$

β_2 is a coefficient of interest.

Result

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.

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

Result

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

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

Result

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

Result

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

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

Result

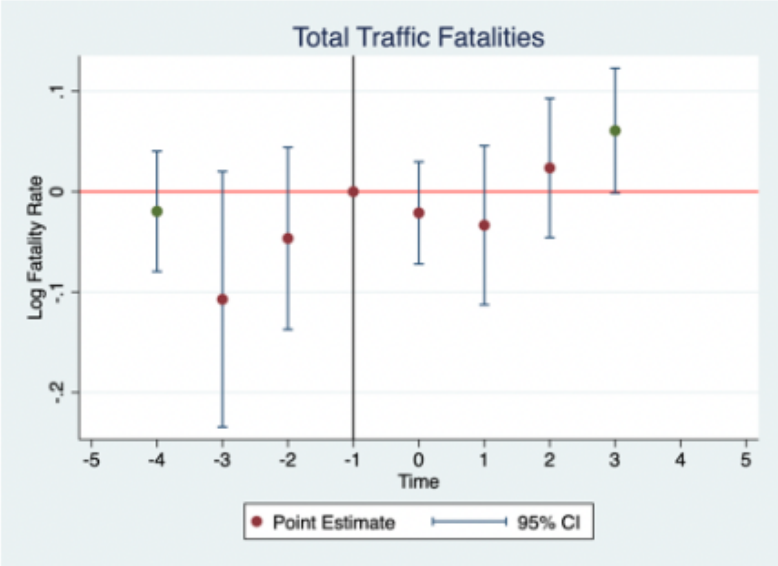
Table 8: **Recreational Marijuana Laws and Traffic Fatalities: The Role of Alcohol, Using Fractional Values**

	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

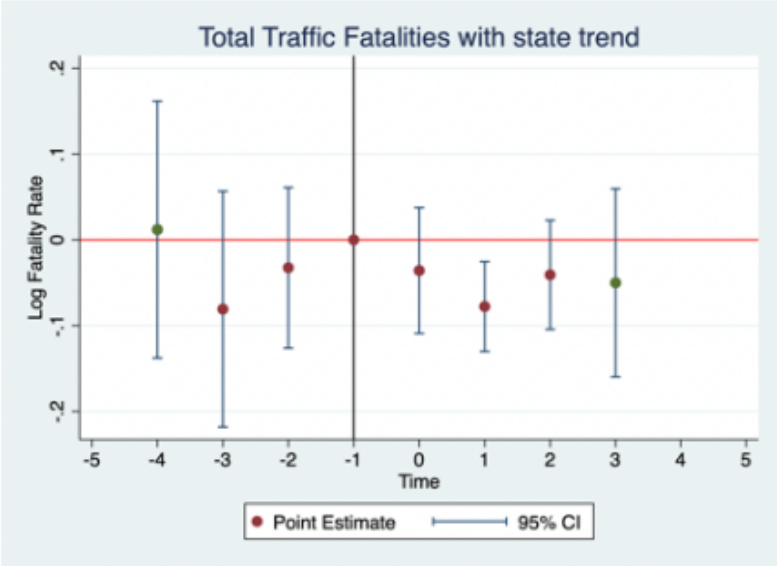
Note. The dependent variables are equal to the natural log of fatalities per 100,000 people.Regressions are weighted using state populations. Year fixed effects, state fixed effects, state covariates are included in all specifications. Standard errors, clustering at the state level, in parentheses. N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

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

Result- Event study

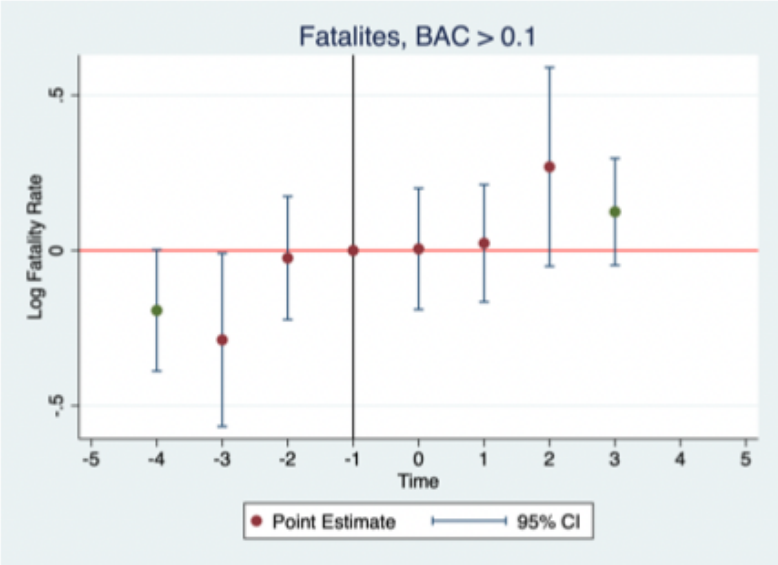


(a) Total fatalities

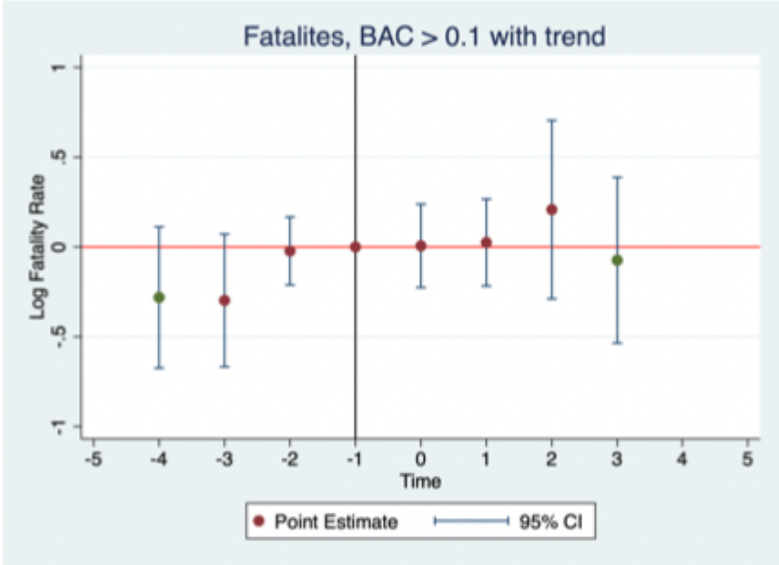


(b) Total fatalities with trend

Result- Event study



(g) Fatalities, BAC > 0.1



(h) Fatalities, BAC > 0.1 with trend

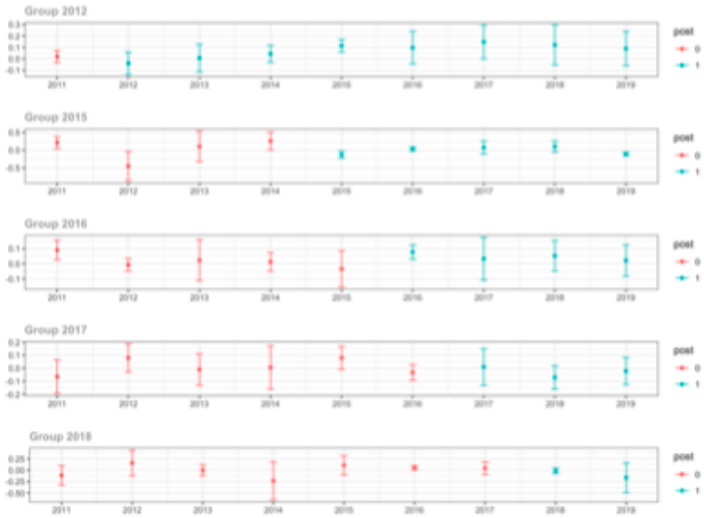
TWFE concern?

1. Goodman-Bacon(2021) shows that regular TWFE using early-adopting states as a counterfactual for later-adopting states will bias our estimates.
2. Sun and Abraham(2020) claims that the evaluation of pre-treatment trends in event studies — as a test of common trends —unreliable
3. In Andrew Baker blog, using recent econometric work on issues with TWFE staggered DiD designs to re-evaluate the effect of MMLs on opioid overdose mortality , he concluded "...it is unlikely that the adoption of medical marijuana laws and their timing was as-if random.Without real randomization we should be reluctant to make causal claims from staggered adoption alone. "

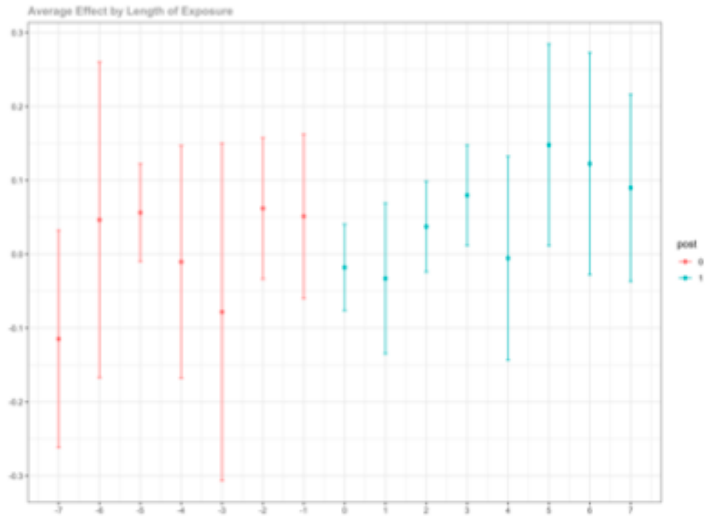
Robustness checks - Bacon decomposition

	type	weight	avg_est
1	Earlier vs Later Treated	0.04018	0.11131
2	Later vs Earlier Treated	0.03664	0.04588
3	Treated vs Untreated	0.92318	0.21960

Result- Event study by Callaway- Sant'Anna(2018)

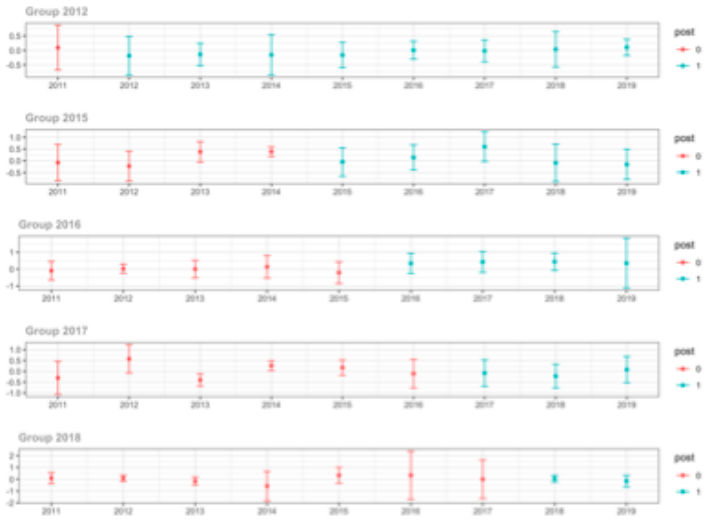


(a) Total fatalities

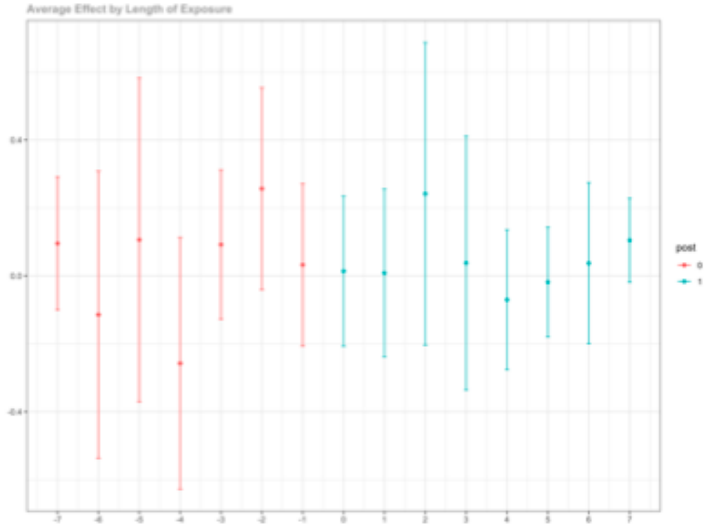


(b) Total fatalities event study

Result- Event study by Callaway- Sant'Anna(2018)



(e) Fatalities, BAC > 0.1



(f) Fatalities, BAC > 0.1 event study

Robustness checks- Selective Migration

Can't examine the composition of migration.

Table 10: 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

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

Robustness checks - Using RMD and MMD

Table 11: 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

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

Robustness checks - Different definition of fatalities rate

Table 12: Recreational Marijuana and Total Traffic Fatalities by different definitions

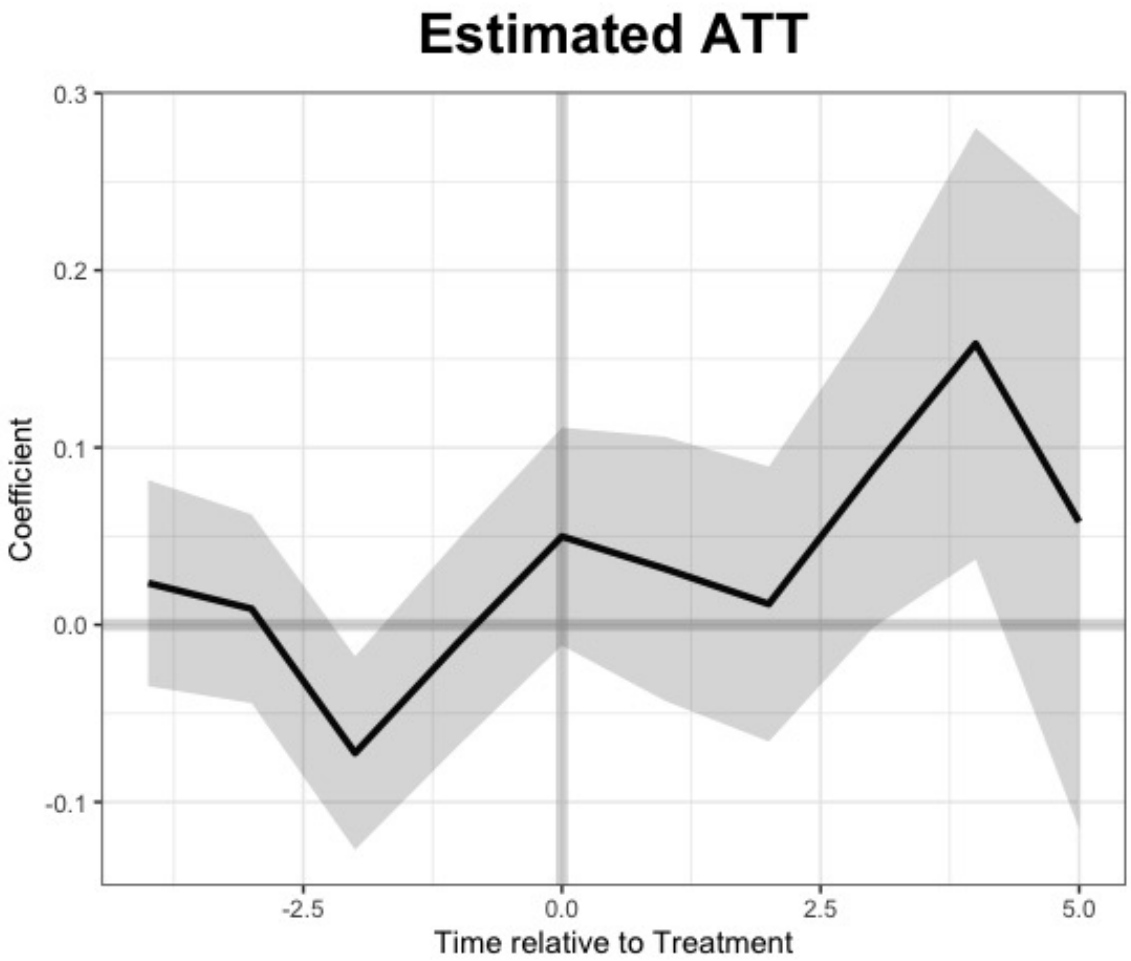
	Fatalities rate per licensed driver			Fatalities rate per 1000 driving miles		
	(1)	(2)	(3)	(4)	(5)	(6)
RML	0.030	0.024	0.004	0.027	0.021	0.004
	(0.038)	(0.035)	(0.024)	(0.039)	(0.037)	(0.025)
MML		-0.032	-0.002		-0.031	-0.002
		(0.032)	(0.015)		(0.029)	(0.014)
State-speific linear trend	No	No	Yes	No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

Standard errors in parentheses

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

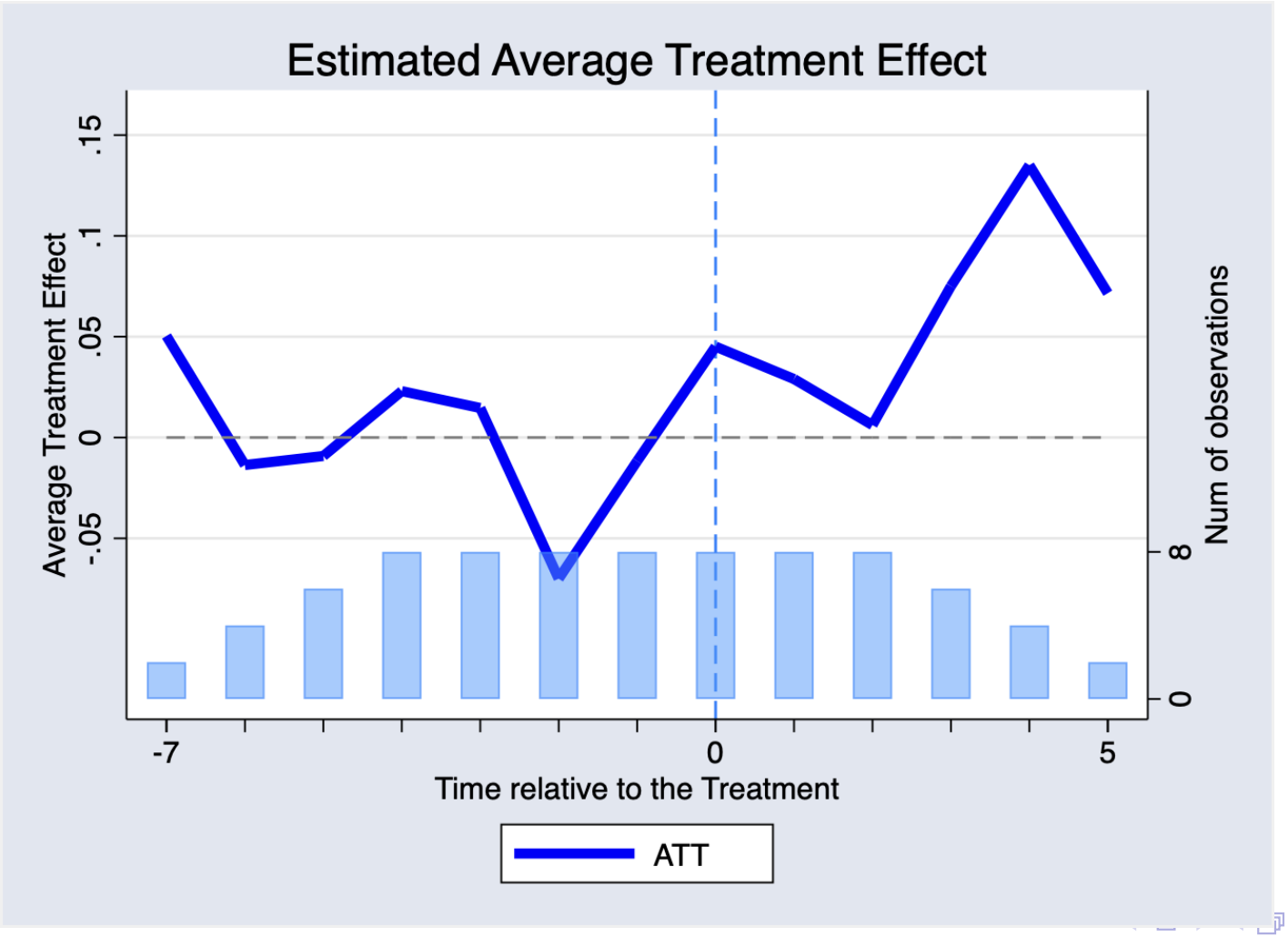
Robustness checks -Non DID model- Generalized Synthetic control by Yiqing Lu(2018)

Required lots of pre-treatment data, it removes Colorado and Washington.



Robustness checks -Non DID model- Counterfactual Estimator by Licheng Liu(2021)

Total traffic fatalities



Disscusion and Conclusion- Potential limitation

1. Can't check the composition of migration
2. Lack of post-legalization data, so can't fully investigate the dynamic effect of RMLs

Disscusion and Conclusion

1. Light evidence of positive effect on total traffic fatalities, strong evidence of large positive significant effect on alcohol-related traffic fatalities. $\Longrightarrow$ Marijuana may not be a substitute of alcohol, contrary to many MML studies.

Disscusion and Conclusion

1. Light evidence of positive effect on total traffic fatalities, strong evidence of large positive significant effect on alcohol-related traffic fatalities. $\Longrightarrow$ Marijuana may not be a substitute of alcohol, contrary to many MML studies.
2. Mechanism : selective migration, edible pot product, illegal-to-legal transformation.

Disscusion and Conclusion

1. Light evidence of positive effect on total traffic fatalities, strong evidence of large positive significant effect on alcohol-related traffic fatalities. $\Longrightarrow$ Marijuana may not be a substitute of alcohol, contrary to many MML studies.
2. Mechanism : selective migration, edible pot product, illegal-to-legal transformation.
3. Policy Implication: Combined with other studies, policy makers should be very careful when liberalizing the use of marijuana.

Disscusion and Conclusion

1. Light evidence of positive effect on total traffic fatalities, strong evidence of large positive significant effect on alcohol-related traffic fatalities. $\Longrightarrow$ Marijuana may not be a substitute of alcohol, contrary to many MML studies.
2. Mechanism : selective migration, edible pot product, illegal-to-legal transformation.
3. Policy Implication: Combined with other studies, policy makers should be very careful when liberalizing the use of marijuana.
4. Future research: studies with more post-legalization data, studies taking advantages of natural experiment rather than only depending on TWFE mode to provide a causal claim.