Medical Marijuana, Traffic Fatalities, and Alcohol Consumption

by

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Introduction

- On November 6, 2012 Massachusetts became the 18th state to legalize the use of marijuana with the approval of a doctor
- More than a dozen state legislatures, including those of Illinois, New York, and Pennsylvania have recently considered medical marijuana bills
- If these bills are eventually signed into law, the majority of the United States population will live in states that permit the use of medical marijuana
- Despite the fact that 18 states have passed medical marijuana laws (MMLs), surprisingly little is known about their effects

- Using data collected from back issues of *High Times*, we begin by examining the relationship between legalization and the price of marijuana

- Next, using data from the Fatality Analysis Reporting System (FARS), we examine the relationship between MMLs and traffic fatalities

- By distinguishing between accidents that involved alcohol and those that did not, we contribute to the long-standing debate on whether marijuana and alcohol are substitutes or complements

- Finally, we examine the relationship between MMLs and direct measures of alcohol consumption

Background

- An introduction to MMLs
- Which states have passed a MML?
- Previous studies on:
  - substance use and driving
  - the relationship between marijuana and alcohol

An Introduction to MMLs

- MMLs remove state-level criminal penalties for the cultivation, possession, and use of medical marijuana
- Physicians are immune from prosecution for recommending medical marijuana to their patients
- Marijuana can be grown by patients or obtained from cooperatives/dispensaries
- Patients allowed to designate a “caregiver.” Most MMLs allow caregivers to grow plants and supply them to patients and cooperatives/dispensaries.

Marijuana Use and Driving

- Laboratory studies have shown that THC, the active component of marijuana, impairs distance perception and reduces concentration, reaction times, and eye-hand coordination (Kelly et al. 2004; Sewell et al. 2009)

- However, simulator and driving-course studies provide little evidence that marijuana use leads to increased collision frequency (Kelly et al. 2004; Sewell et al. 2009)

- Drivers under the influence of THC tend go at slower speeds and overestimate the extent to which they are impaired (Ronen et al. 2008; Sewell et al. 2009)

- Evidence “from the field” is mixed (Kelly et al. 2004; Sewell et al. 2009). Some studies find that marijuana use increases the probability of being in an accident, while others do not.

Alcohol Use and Driving

- Laboratory studies have shown that alcohol use reduces concentration, eye-hand coordination and reaction times (Kelly et al. 2004; Sewell et al. 2009)

- Simulator studies provide strong evidence that alcohol use leads to increased collision frequency (Kelly et al. 2004; Sewell et al. 2009)

- Drivers under the influence of alcohol tend to go at faster speeds and underestimate the extent to which they are impaired (Ronen et al. 2008; Sewell et al. 2009)

- Evidence “from the field” is unequivocal: alcohol and driving do not mix (Kelly et al. 2004; Sewell et al. 2009)

- Two studies used a regression discontinuity approach to examine the relationship between the MLDA and marijuana use. Using data from the NSDUH, Crost and Guerrero (2011) found that alcohol and marijuana are substitutes. Using data from the NLSY97, Yörük and Yörük (2011) found the opposite result.

- NLSY97 respondents are asked a series of questions with regard to marijuana use, including: "Since the date of last interview, have you used marijuana, even if only once, for example: grass or pot?" Respondents who answer this question in the affirmative are then immediately asked: "On how many days have you used marijuana in the last 30 days?"

- Yörük and Yörük (2011) appear to have inadvertently ignored the first of these two questions, in effect restricting their sample to respondents who had used marijuana at least once since they were last interviewed (Crost and Rees 2012).

MMLs and the Price of Marijuana

- The National Survey on Drug Use and Health (NSDUH) is the best source of information on marijuana consumption by adults living in the United States

- However, the NSDUH does not provide individual-level data with state identifiers to researchers, and did not publish state-level estimates of marijuana use prior to 1999

- Because 5 states (including California, Oregon and Washington) legalized medical marijuana during the period 1996-1999, we turn to back issues of *High Times* magazine in order to gauge the impact of legalization on the marijuana market

- Begun in 1975, *High Times* is published monthly and covers topics ranging from marijuana cultivation to politics. Each issue also contains a section entitled “Trans High Market Quotations” in which readers provide marijuana prices from across the country. In addition to price, a typical entry includes information about where the marijuana was purchased, its strain and its quality.

Estimating Equation

Following Jacobson (2004), we classified 8,271 marijuana purchases by quality and calculated the median per-ounce price by state and year. We estimated the following regression using data for the period 1990-2011:

$$ln(\text{Price High-Quality Marijuana})_{st} = \beta_0 + \boldsymbol{\beta_1 X_{st}} + \beta_2 MML_{st} + v_s + w_t + \varepsilon_{st},$$

where *s* indexes states, *t* indexes years, v_s is a set of state fixed effects, and w_t is a set of year fixed effects. The vector $\boldsymbol{X_{st}}$ includes: mean age in state *s* and year *t*, the unemployment rate, per capita income, the decriminalization of marijuana, and the beer tax. Standard errors are corrected for clustering at the state level. During the period 1990-2011, 16 states and the District of Columbia legalized medical marijuana.

MMLs and the Price of High-Quality Marijuana

	(1)	(2)	(3)	(4)
MML	-0.304***	-0.103*		
	(0.037)	(0.058)		
Year of Law Change			-0.117*	-0.059
			(0.061)	(0.069)
1 Year After			-0.156***	-0.082
			(0.044)	(0.070)
2 Years After			-0.203***	-0.110
			(0.074)	(0.082)
3 Years After			-0.211***	-0.128
			(0.062)	(0.084)
4 Years After			-0.387***	-0.283**
			(0.123)	(0.115)
5+ Years After			-0.439***	-0.257**
			(0.048)	(0.116)
N	920	920	920	920
R^2	0.224	0.310	0.241	0.315
State and Year FEs	yes	yes	yes	yes
State Trends	no	yes	no	yes

MMLs and the Price of Low-Quality Marijuana

	(1)	(2)	(3)	(4)
MML	-0.096	-0.075		
	(0.105)	(0.150)		
Year of Law Change			-0.035	-0.056
			(0.154)	(0.193)
1 Year After			-0.250*	-0.182
			(0.146)	(0.176)
2 Years After			-0.058	-0.016
			(0.176)	(0.190)
3 Years After			-0.244***	-0.114
			(0.098)	(0.141)
4 Years After			0.032	0.046
			(0.403)	(0.373)
5+ Years After			-0.038	0.271
			(0.073)	(0.335)
N	483	483	483	483
R^2	0.720	0.748	0.723	0.751
State and Year FEs	yes	yes	yes	yes
State Trends	no	yes	no	yes

MMLs and Traffic Fatalities

- Regression estimates of the relationship between MMLs and traffic fatalities using data from FARS

- MMLs could be positively related to traffic fatalities because marijuana use impairs reactions, distance perception and eye-hand coordination

- There is evidence that alcohol and marijuana are substitutes. If they are in fact substitutes, then MMLs could be negatively related to traffic fatalities because:
  - It is more dangerous to drive drunk than under the influence of marijuana
  - Alcohol is often consumed in public (bars, parties, restaurants). In contrast, many states prohibit the use of medical marijuana in public.

The FARS Data

- Our primary data source is the Fatality Analysis Reporting System (FARS), collected by the National Highway Traffic Safety Administration

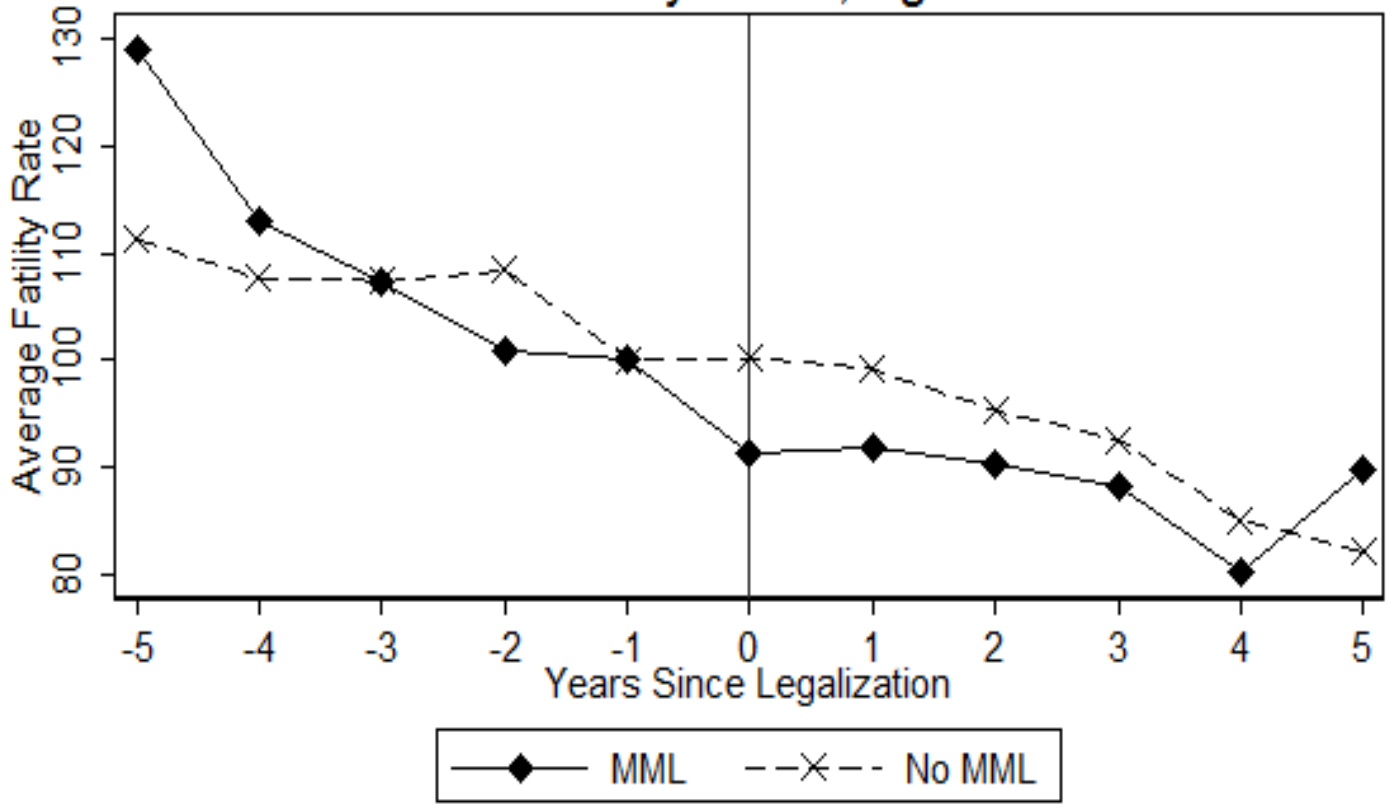
- The data are at the state-level and cover the years 1990-2010. During this period, 14 states and the District of Columbia legalized medical marijuana.

- FARS is an annual census of all fatal injuries suffered in motor vehicle crashes in the United States

- The data are obtained from a variety of sources including police crash reports, driver licensing files, vehicle registration files, state highway department data, emergency medical services records, medical examiner reports, toxicology reports, and death certificates

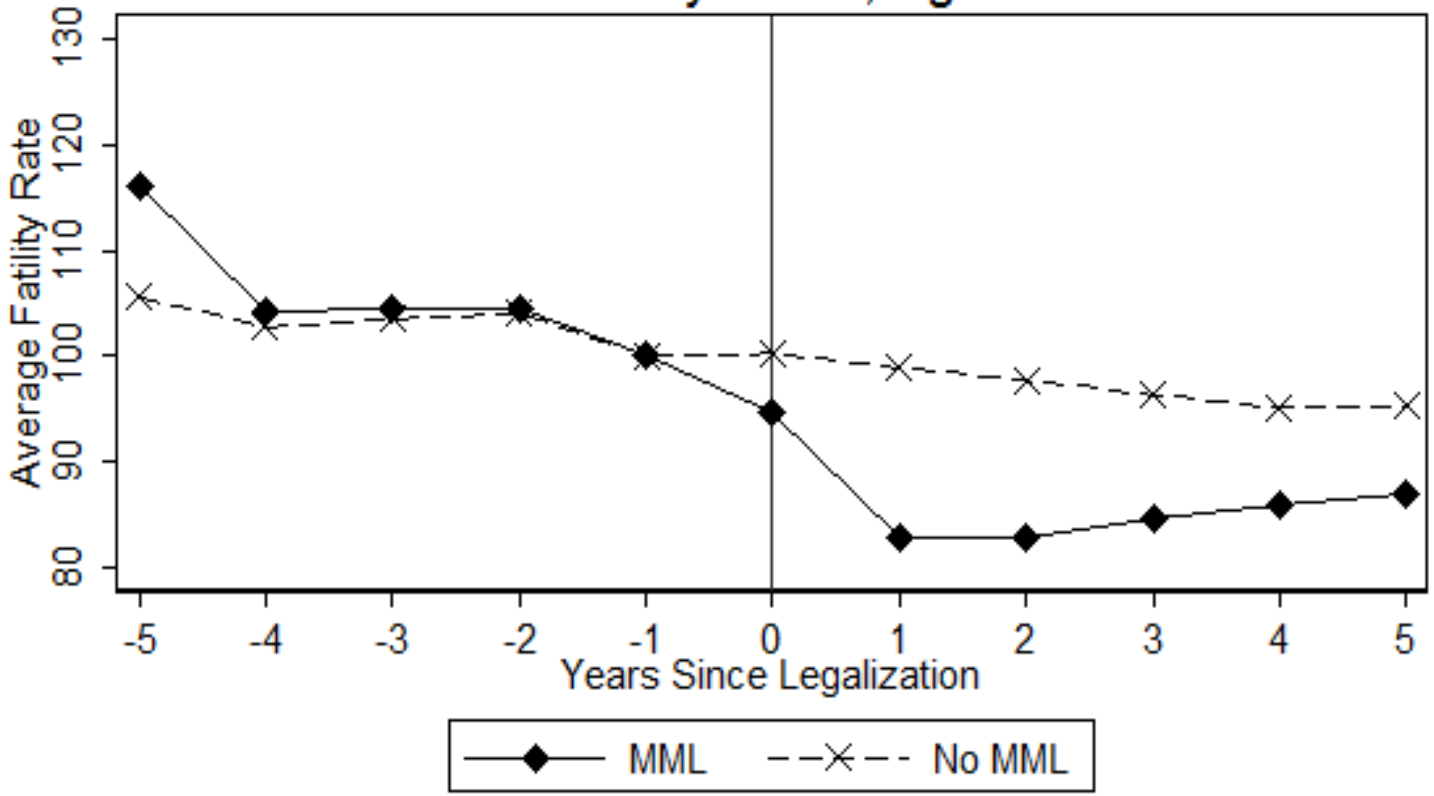
- They provide detailed information with regard to the circumstances of each crash and the persons/vehicles involved

Figure 1. Pre-and Post-Legalization Trends in Traffic Fatality Rates, Ages 15-19



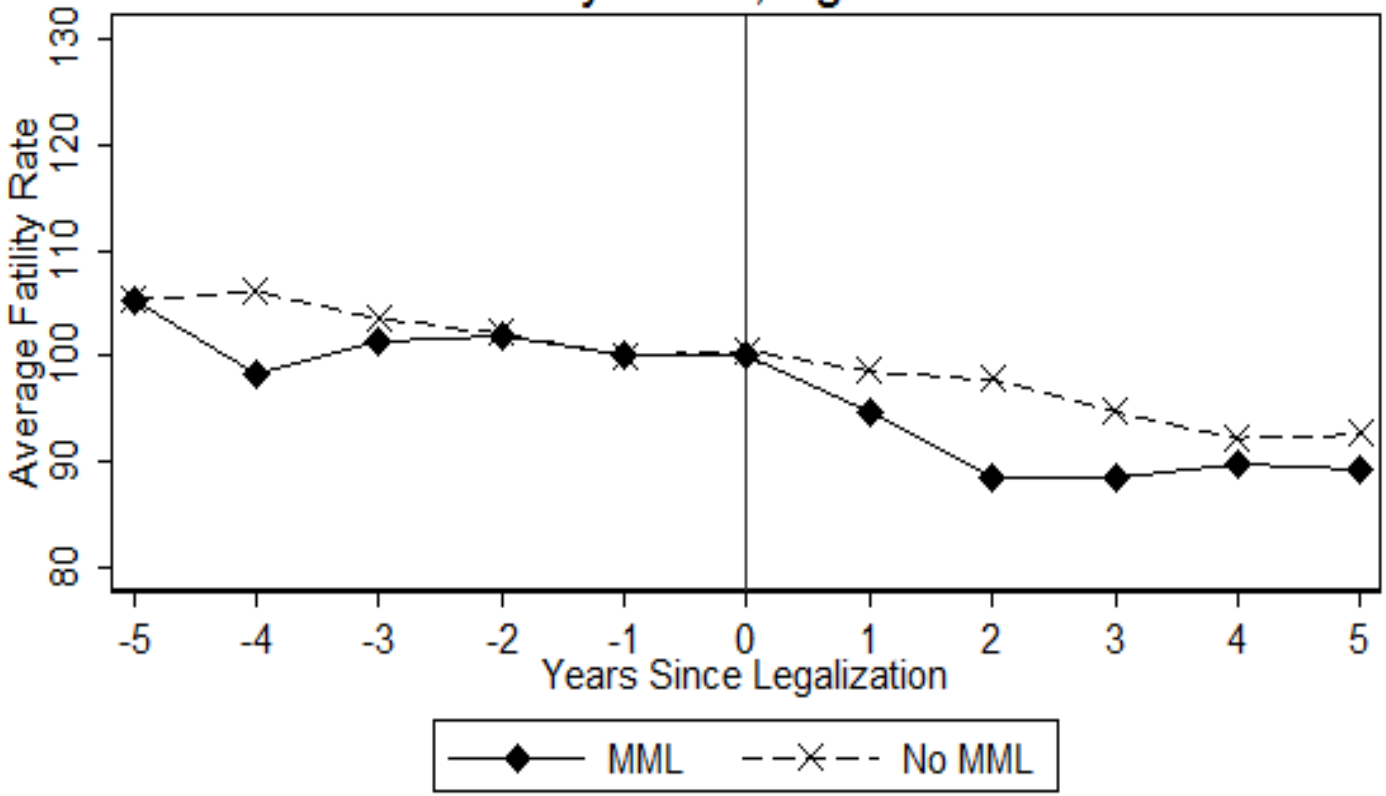
Based on FARS data for the period 1990-2010. On the horizontal axis, *0* represents the year in which medical marijuana was legalized. It was randomly assigned to states that did not legalize medical marijuana during the period under study. Fatality rates are expressed relative to year *-1* and are weighted by the relevant population in state *s* and year *t*.

Figure 2. Pre-and Post-Legalization Trends in Traffic Fatality Rates, Ages 20-39



Based on FARS data for the period 1990-2010. On the horizontal axis, *0* represents the year in which medical marijuana was legalized. It was randomly assigned to states that did not legalize medical marijuana during the period under study. Fatality rates are expressed relative to year *-1* and are weighted by the relevant population in state *s* and year *t*.

Figure 3. Pre-and Post-Legalization Trends in Traffic Fatality Rates, Ages 40 and Older



Based on FARS data for the period 1990-2010. On the horizontal axis, *0* represents the year in which medical marijuana was legalized. It was randomly assigned to states that did not legalize medical marijuana during the period under study. Fatality rates are expressed relative to year *-1* and are weighted by the relevant population in state *s* and year *t*.

Estimating Equation

$$ln(Fatality\ Rate)_{st} = \beta_0 + \boldsymbol{\beta_1 X_{st}} + \beta_2 MML_{st} + v_s + w_t + \varepsilon_{st},$$

where s indexes states, t indexes years, $\boldsymbol{X_{st}}$ is a vector of controls, v_s is a set of state fixed effects, and w_t is a set of year fixed effects. Standard errors are corrected for clustering at the state level and regressions are weighted using the population of state s in year t.

MMLs and Traffic Fatalities per 100,000 Population

	(1)	(2)	(3)	(4)
MML	-0.110***	-0.098		
	(0.030)	(0.065)		
Year of Law Change			-0.049**	-0.026
			(0.023)	(0.029)
1 Year After			-0.115****	-0.087*
			(0.036)	(0.051)
2 Years After			-0.125***	-0.095
			(0.059)	(0.080)
3 Years After			-0.137***	-0.107
			(0.051)	(0.071)
4 Years After			-0.138***	-0.108*
			(0.038)	(0.063)
5+ Years After			-0.102***	-0.042
			(0.026)	(0.062)
N	1071	1071	1071	1071
R^2	0.969	0.979	0.979	0.979
State and Year FEs	yes	yes	yes	yes
State Trends	no	yes	no	yes

MMLs and Traffic Fatalities: The Role of Alcohol

	Fatalities No Alcohol	*Fatalities BAC > 0*	*Fatalities BAC >.10*	*Fatalities BAC > .10*
MML	-0.075	-0.141*	-0.168**	
	(0.062)	(0.077)	(0.082)	
Year of Law Change				-0.041
				(0.051)
1 Year After				-0.124
				(0.086)
2 Years After				-0.117
				(0.081)
3 Years After				-0.292***
				(0.100)
4 Years After				-0.256**
				(0.105)
5+ Years After				-0.197**
				(0.090)
N	1071	1071	1071	1071
R^2	0.964	0.905	0.906	0.906
State and Year FEs	yes	yes	yes	yes
State Trends	yes	yes	yes	yes

MMLs and Traffic Fatalities by Sex and Age Group

			Males		Females	
	Males	Females	20-29	30-39	20-29	30-39
MML	-0.114*	-0.072	-0.189**	-0.158*	-0.159***	-0.221*
	(0.065)	(0.073)	(0.080)	(0.089)	(0.058)	(0.127)
N	1071	1071	1071	1071	1071	1071
R^2	0.974	0.960	0.924	0.920	0.861	0.833
State and Year FEs	yes	yes	yes	yes	yes	yes
State Trends	yes	yes	yes	yes	yes	yes

Notes: Each column represents the results from a separate regression. The dependent variable is equal to the natural log of fatalities per 100,000 population and the covariates are listed in Table 4. Regressions are weighted using the relevant state-by-age populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Collective Cultivation

- Roughly half of the states that have legalized medical marijuana permit collective cultivation, also known as “group growing”

- However, several states have attempted to dampen the supply response to legalization by limiting caregivers to one patient or prohibiting home cultivation altogether. In these states, possession limits are easier to enforce and illegal suppliers are easier to identify (Selecky 2008).

Collective Cultivation Permitted	Collective Cultivation Prohibited
California	Alaska
Colorado	District of Columbia
Michigan	Hawaii
Montana	Maine
Oregon	New Jersey
Rhode Island	New Mexico
Washington	Vermont

MMLs and Traffic Fatalities: The Role of Collective Cultivation

	Fatality Rate	*Fatalities BAC > 0*	*Fatalities BAC >.10*
Collective Cultivation Permitted			
MML	-0.115	-0.150*	-0.171*
	(0.072)	(0.087)	(0.094)
Collective Cultivation Prohibited			
MML	-0.016	-0.076	-0.144**
	(0.052)	(0.072)	(0.066)
N	1071	1071	1071
R^2	0.979	0.905	0.906
State and Year FEs	yes	yes	yes
State Trends	yes	yes	yes

MMLs and Drinking

- Since 1993, the Behavioral Risk Factor Surveillance System (BRFSS) has been administered to residents of all 50 states
- It is designed to measure "behavioral risk factors" for the adult population (18 years of age or older)
- Telephone survey, now conducted using computer-assisted telephone interviewing technology
- Hundreds of thousands of individuals are surveyed every year. Asked about drinking behavior (number of drinks in the past month, and binge drinking in the past month)
- We estimate the following equation:

$$Alcohol\ Consumption_{ist} = \beta_0 + \boldsymbol{\beta_1 X_{ist}} + \beta_2 MML_{ist} + v_s + w_t + \Theta_s \cdot t + \varepsilon_{ist}$$

MMLs and Alcohol Consumption: Evidence from the BRFSS, 1993-2010

	All BRFSS Respondents	18-19	20-29	30-39	40-49	50-59
Drank	-0.019* (0.010) [3884082]	-0.051** (0.020) [54296]	-0.031* (0.017) [378058]	-0.022 (0.014) [614541]	-0.017 (0.012) [739094]	-0.016* (0.009) [760147]
15 + Drinks	-0.010* (0.006) [3884082]	-0.022* (0.011) [54296]	-0.015 (0.011) [378058]	-0.015** (0.008) [614541]	-0.009 (0.006) [739094]	-0.014** (0.005) [760147]
30 + Drinks	-0.009* (0.005) [3884082]	-0.017* (0.008) [54296]	-0.018* (0.009) [378058]	-0.008 (0.007) [614541]	-0.010* (0.006) [739094]	-0.009** (0.004) [760147]
60+ Drinks	-0.004 (0.003) [3884082]	-0.008 (0.007) [54296]	-0.011** (0.005) [378058]	-0.003 (0.005) [614541]	-0.005 (0.003) [739094]	-0.003 (0.003) [760147]
Binge Drank	-0.007* (0.003) [3928524]	-0.018* (0.009) [55426]	-0.012 (0.010) [383970]	-0.007 (0.006) [621722]	-0.013** (0.005) [746947]	-0.007* (0.004) [767567]
2+ Binges	-0.004* (0.002) [3928524]	-0.010 (0.011) [55426]	-0.012* (0.007) [383970]	-0.002 (0.004) [621722]	-0.006* (0.003) [746947]	-0.005 (0.003) [767567]

- Among 20- through 29-year-olds, legalization is associated with a 5.3 percent (.031/.589) reduction in the probability of having consumed alcohol in the past month, a 19.6 percent (.011/.056) reduction in the probability of having consumed 60+ drinks, and a 10.6 percent (2.40/22.71) reduction in the number of drinks consumed (conditional on having had at least one drink)

- During the period 1990-2010, almost one fourth of individuals killed in traffic accidents, and more than one third of individuals killed in traffic accidents involving alcohol, were between the ages of 20 and 29

- Among 18- and 19-year-olds, legalization is associated with a 9.4 percent (.018/.192) reduction in the probability of binge drinking in the past month

- Among 20- through 29-year-olds, legalization is associated with a 7.4 percent (.012/.163) reduction in the probability of binge drinking at least twice in the past month

- Using data on 19- through 22-year-olds and a regression discontinuity design, Carpenter and Dobkin (2009) found that reaching the minimum legal drinking age was associated with a 21 percent increase in the number of days on which alcohol is consumed and a 15 percent increase in traffic fatalities

- The implied elasticity from these estimates is 0.71 (i.e., 0.15/0.21)

- Restricting our sample to 19- through 22-year-olds, we find that the legalization of medical marijuana is associated with a 15.0 percent decrease in the number of drinks consumed (p-value = 0.17) and a 12.2 percent decrease in traffic fatalities (p-value = 0.16)

- The implied elasticity from these estimates is 0.81 (i.e., 0.122/0.150)

MMLs and Alcohol Sales

- The Beer Institute annually publishes data on alcohol sales in the *Brewers Almanac*

- State-level data on per capita beer (1990-2010), wine (1994-2010) and spirits (1994-2010) sales in gallons
  - Data represent shipments from brewers to wholesalers and are the "best available proxy for consumption"

- We estimate the following equation:

$$ln(\text{per-capita sales})_{st} = \beta_0 + \boldsymbol{\beta_1 X_{st}} + \beta_2 MML_{st} + v_s + w_t + \Theta_s \cdot t + \varepsilon_{st},$$

where *s* indexes states, *t* indexes years, $\boldsymbol{X_{st}}$ is a vector of controls, v_s is a set of state fixed effects, w_t is a set of year fixed effects, and $\Theta_s \cdot t$ represents state-specific linear time trends

MMLs and Per-Capita Alcohol Sales

	Ln(Beer Sales)	*Ln(Wine Sales)*	*Ln(Spirits Sales)*
MML	-0.049**	-0.008	0.002
	(0.022)	(0.239)	(0.011)
N	1071	867	867
R^2	0.981	0.990	0.990
F-Statistic for MML	4.8	0.36	0.03
State and Year FEs	yes	yes	yes
State Trends	yes	yes	yes

Notes: The dependent variable is equal to the natural log of per-capita sales in state *s* and year *t* (measured in gallons) and is based on data from the *Brewers Almanac*. Beer sales data are for the period 1990-2010. Wine and spirits sales data are for the period 1994-2010. Controls include the state unemployment rate, per capita income, the state beer tax, and indicators for marijuana decriminalization, BAC 0.08, administrative license revocation, and whether a zero tolerance drunk driving law was in place. Regressions are weighted using state populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Per-Capita Beer Sales and Traffic Fatalities

	Fatality Rate	*Fatalities BAC > 0*	*Fatalities BAC >0.10*
Ln(Beer Sales)	1.68***	2.40***	3.16***
	(0.484)	(0.764)	(0.841)
N	1071	1071	1071
R^2	0.976	0.900	0.897
State and Year FEs	yes	yes	yes
State Trends	yes	yes	yes

Notes: The natural log of per-capita beer sales is instrumented with the MML indicator. Controls include the state unemployment rate, per capita income, the state beer tax, and indicators for marijuana decriminalization, BAC 0.08, administrative license revocation, and whether a zero tolerance drunk driving law was in place. Regressions are weighted using state populations. Standard errors, corrected for clustering at the state level, are in parentheses.

- We find that a 10 percent increase in per-capita beer sales is associated with a 17 percent increase in total fatalities

- In comparison, using alcohol excise taxes as instruments, Young and Bielinska-Kwapisz (2006) found that a 10 percent increase in per-capita ethanol consumption led to an 11 percent increase in traffic fatalities

- The difference between these estimates could reflect who, in effect, is being treated:
  - Our analysis of the BRFSS data suggests that the relationship between legalization and alcohol consumption is strongest among young adults (a group prone to heavy drinking and responsible for a disproportionate share of traffic fatalities)
  - There is evidence that light and moderate drinkers are more responsive to increases in the price of alcohol than heavy drinkers (Manning, Blumberg, and Moulton 1995)

Conclusions

- The first full year after coming into effect, legalization is associated with an 8 to 11 percent decrease in traffic fatalities
- The impact of legalization on traffic fatalities involving alcohol is larger and estimated with more precision than its impact on traffic fatalities that do not involve alcohol
- Legalization is also associated with sharp decreases in the price of marijuana and alcohol consumption, suggesting that marijuana and alcohol are substitutes

States with MMLs

(year MML came into effect)

Alaska (1999)

Arizona (2011)

California (1996)

Colorado (2001)

Connecticut (2012)

Delaware (2011)

District of Columbia (2010)

Hawaii (1999)

Maine (1999)

Massachusetts (2012)

Michigan (2008)

Montana (2004)

Nevada (2001)

New Mexico (2007)

New Jersey (2010)

Oregon (1998)

Rhode Island (2006)

Vermont (2004)

Washington (1998)

Patients by State, 2011

Alaska: 380

Arizona: 11,133

California: *1,250,000*

Colorado: 127,816

Delaware: NA

District of Columbia: NA

Hawaii: *8,000*

Maine: 796

Michigan: 105,458

Montana: 26,492

Nevada:*860*

New Mexico: 3,981

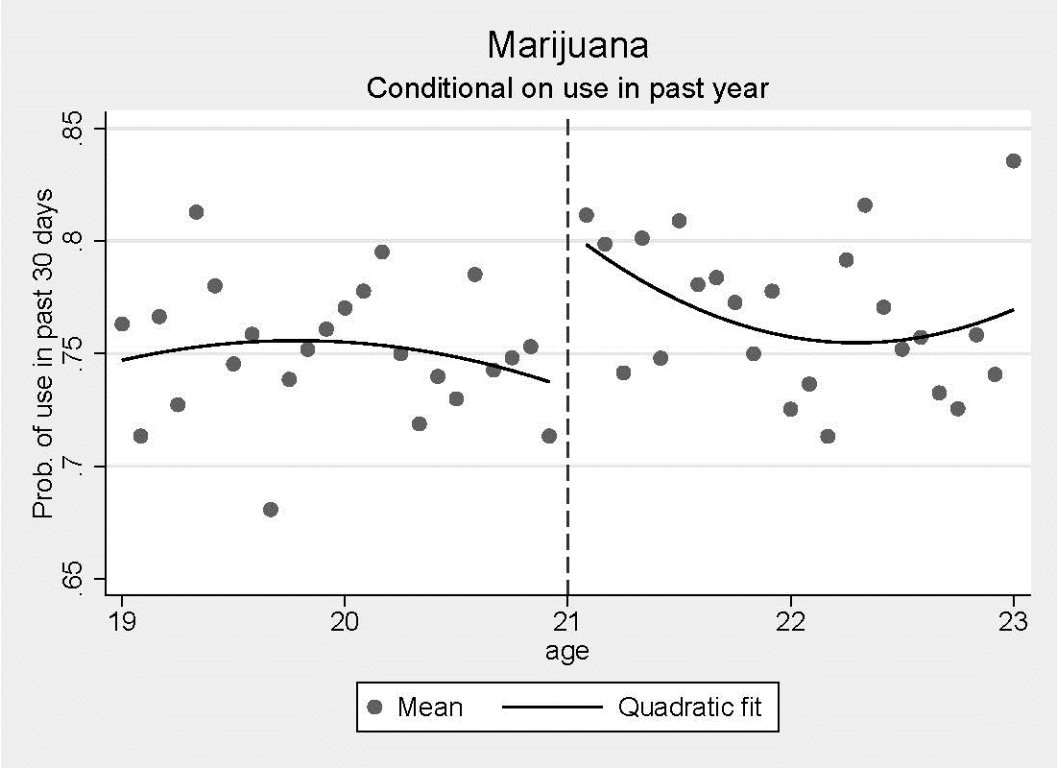
New Jersey: NA

Oregon: 49,220

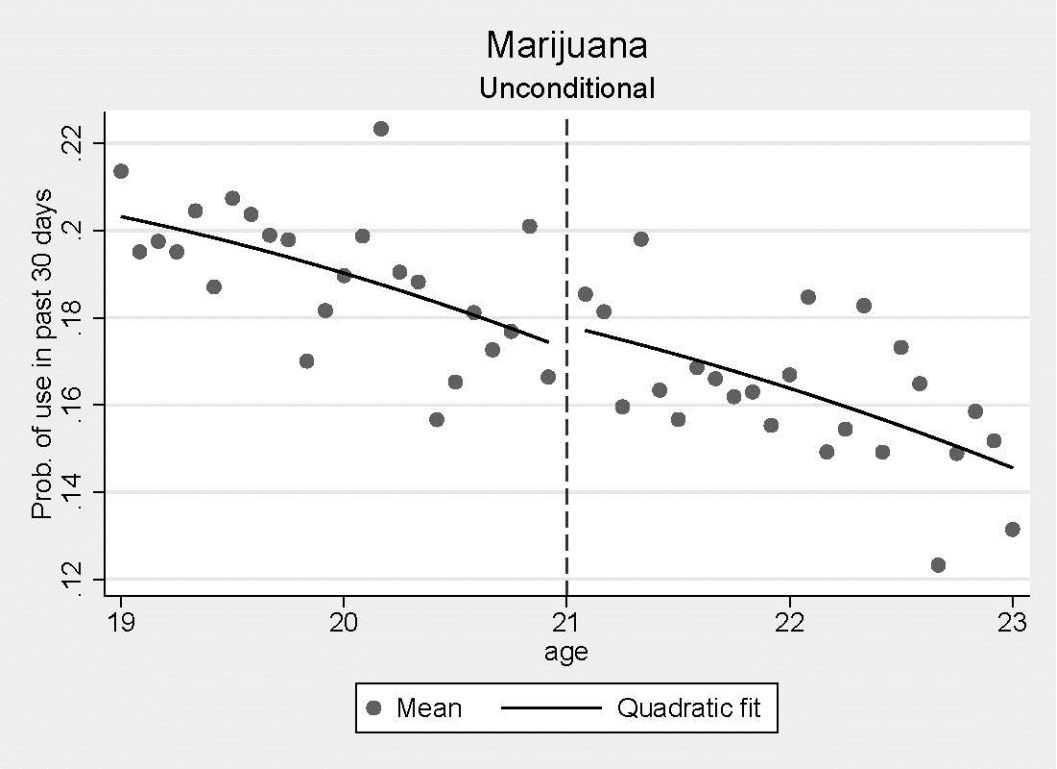
Rhode Island: 3,073

Vermont: 349

Washington: *100,000*



- Crost and Rees(2012) show that the Yörük and Yörük (2011) estimate is conditional on having used marijuana in the past year



- The unconditional estimate is small and statistically insignificant (Crost and Rees 2012)