Medical Marijuana Laws, Traffic Fatalities, and Alcohol Consumption

D. Mark Anderson
Department of Agricultural Economics and Economics
Montana State University
dwight.anderson@montana.edu

Daniel I. Rees
Department of Economics
University of Colorado Denver
daniel.rees@ucdenver.edu

Benjamin Hansen
Department of Economics
University of Oregon
bchansen@uoregon.edu

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To date, 16 states have passed medical marijuana laws, yet very little is known about their effects. Using state-level data, we examine the relationship between medical marijuana laws and a variety of outcomes. Legalization of medical marijuana is associated with increased use of marijuana among adults, but not among minors. In addition, legalization is associated with nearly a 9 percent decrease in traffic fatalities, most likely as a result of its impact on alcohol consumption by young adults. Our estimates provide strong evidence that marijuana and alcohol are substitutes.

1. INTRODUCTION

Medical marijuana laws (hereafter MMLs) remove state-level penalties for using, possessing and cultivating medical marijuana. Patients are required to obtain approval or certification from a doctor, and doctors who recommend marijuana to their patients are immune from prosecution. MMLs allow patients to designate caregivers who can buy or grow marijuana on their behalf.

On July 1, 2011 Delaware became the 16th state, along with the District of Columbia, to enact a MML. Six more state legislatures, including those of New York and Illinois, have recently considered medical marijuana bills. If these bills are eventually signed into law, approximately 40 percent of the United States population will live in states that permit the use of medical marijuana.

Opponents of medical marijuana tend to focus on the "social issues" surrounding substance use. Critics argue that marijuana is addictive, serves as a gateway drug, has little medicinal value, and leads to criminal activity (Adams 2008; Blankstein 2010). Another often-raised argument against legalization is that it encourages the recreational use of marijuana, especially by teenagers (Brady et al. 2011; O'Keefe and Earleywine 2011). Proponents contend that marijuana is both efficacious and safe, and can be used to treat the side effects of chemotherapy as well as the symptoms of AIDS, multiple sclerosis, epilepsy, glaucoma and other serious illnesses. They cite clinical research showing that marijuana relieves chronic pain, nausea, muscle spasms and appetite loss (Eddy 2010; Marmor 1998; Watson et al. 2000), and note that neither the link between medical marijuana and youth consumption, nor that between medical marijuana and criminal activity, has been substantiated (Belville 2011; Corry et al. 2009; Hoeffel 2011; Lamoureux 2011).

This study begins by examining marijuana use in three states that passed a MML in the mid-2000s. Drawing on data collected by the National Survey on Drug Use and Health (NSDUH), we find that the passage of a MML was associated with increased marijuana use by adults in Montana and Rhode Island, but not by adults in Vermont where, as of June 2011, only 349 patients were registered. We find no evidence to support the hypothesis that MMLs are related to the use of marijuana by minors.

Next, we turn our attention to MMLs and traffic fatalities, the primary relationship of interest. In the United States, traffic fatalities are the leading cause of death among Americans ages 5 through 34 (Centers for Disease Control and Prevention 2010). To our knowledge, there has been no previous examination of this relationship. Data on traffic fatalities at the state level are obtained from the Fatality Analysis Reporting System (FARS) for the years 1990-2009. Thirteen states enacted a MML during this period. FARS includes the time of day the traffic fatality occurred, the day of the week it occurred, and whether alcohol was involved. Using this information, we contribute to the long-standing debate on whether marijuana and alcohol are substitutes or complements.

Specifically, we find that traffic fatalities fall by nearly 9 percent after the legalization of medical marijuana. However, the effect of MMLs on traffic fatalities involving alcohol appears to be larger, and is estimated with more precision, than the effect of MMLs on traffic fatalities that did not involve alcohol. Likewise, we find that the estimated effects of MMLs on fatalities at night and on weekends (when alcohol consumption rises) are larger, and are more precise, than the estimated effects of MMLs on fatalities during the day and on weekdays.

Finally, the relationship between MMLs and more direct measures of alcohol consumption is examined. Using data from the Behavioral Risk Factor Surveillance System

(BRFSS), we find that MMLs are associated with decreases in the number of drinks consumed, especially among 20- through 29-year-olds, suggesting that alcohol is the mechanism by which traffic fatalities are reduced. Using data from the Beer Institute, we find that beer sales fall after a MML comes into effect, suggesting that marijuana substitutes for beer, the most popular alcoholic beverage among young adults.

2. BACKGROUND

2.1. A brief history of medical marijuana

Marijuana was introduced in the United States in the early-1600s by Jamestown settlers who used the plant in hemp production; hemp cultivation remained a prominent industry until the mid-1800s (Deitch 2003). During the census of 1850, the United States recorded over 8,000 cannabis plantations of at least 2,000 acres (U.K. Cannabis Campaign 2011). Throughout this period, marijuana was commonly used by physicians and pharmacists to treat a broad spectrum of ailments (Pacula et al. 2002). From 1850 to 1942, marijuana was included in the *United States Pharmacopoeia*, the official list of recognized medicinal drugs (Bilz 1992).

In 1913, California passed the first marijuana prohibition law aimed at recreational use (Gieringer 1999); by 1936, the remaining 47 states had followed suit (Eddy 2010). In 1937, The Marihuana Tax Act effectively discontinued the use of marijuana for medicinal purposes (Bilz 1992), and marijuana was classified as a Schedule I drug in 1970.[1] According to the Controlled Substances Act (CSA), a Schedule I drug must have a "high potential for abuse" and "no currently accepted medical use in treatment in the United States" (Eddy 2010).[2]

[1] The Marihuana Tax Act imposed a registration tax and required extensive record-keeping, increasing the cost of prescribing marijuana as compared to other drugs (Bilz 1992).

[2] In addition to marijuana, other current Schedule I substances include heroin, peyote, and psilocybin.

In 1996, California passed the Compassionate Use Act, which removed criminal penalties for using, possessing and cultivating medical marijuana. It also provided immunity from prosecution to physicians who recommended the use of medical marijuana to their patients. Before 1996, a number of states allowed doctors to prescribe marijuana, but this had little practical effect because of federal restrictions.[3] Since 1996, 15 other states and the District of Columbia have joined California in legalizing the use of medical marijuana (see Table 1), although it is still classified as a Schedule I drug by the Federal government.[4]

2.2. Studies on substance use and driving

Laboratory studies have shown that cannabis use impairs driving-related functions such as distance perception, reaction time, and hand-eye coordination (Kelly et al. 2004; Sewell et al. 2009). However, neither simulator nor driving-course studies provide consistent evidence that these impairments to driving-related functions lead to an increased risk of collision (Kelly et al. 2004; Sewell et al. 2009). Drivers under the influence of tetrahydrocannabinol (THC), the primary psychoactive substance in marijuana, reduce their velocity, avoid risky maneuvers, and increase their "following distances," suggesting compensatory behavior (Kelly et al. 2004; Sewell et al. 2009). In addition, there appears to be an important learning-by-doing component

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[3] Federal regulations prohibit doctors from writing prescriptions for marijuana. In addition, even if a doctor were to illegally prescribe marijuana, it would be against federal law for pharmacies to distribute it. Doctors in states that have legalized medical marijuana avoid violating federal law by *recommending* marijuana to their patients rather than *prescribing* its use. Because it is illegal for pharmacies to distribute marijuana, cannabis products intended for medicinal use are typically obtained from cooperatives or dispensaries (Eddy 2010).

[4] Information on when MMLs were passed was obtained from a recent Congressional Research Services Report by Eddy (2010). Prior to the Obama administration, federal agents raided medical marijuana distributors who violated federal laws even if they complied with state statutes. In 2009, Attorney General Holder stated that the administration would discontinue raids on medical marijuana dispensaries (Johnston and Lewis 2009). Since 2009, the search and seizure rates have slowed; however, they have not ceased altogether (CNN 2011; Hamilton 2011; L.A. Now 2011).

to driving under the influence of marijuana: experienced users show substantially less functional impairment than infrequent users (Sutton 1983).

Like marijuana, alcohol impairs driving-related functions such as reaction time and hand-eye coordination (Kelly et al. 2004; Sewell et al. 2009). Moreover, unequivocal evidence from simulator and driving-course studies illustrates alcohol consumption leads to an increased risk of collision (Kelly et al. 2004; Sewell et al. 2009). Even at low doses, drivers under the influence of alcohol tend to underestimate the degree to which they are impaired (MacDonald et al. 2008; Marczinski et al. 2008; Robbe and O'Hanlon 1993; Sewell et al. 2009), drive at faster speeds, and take more risks (Burian et al. 2002; Ronen et al. 2008; Sewell et al. 2009). When used in conjunction with marijuana, alcohol appears to have an "additive or even multiplicative" effect on driving-related functions (Sewell et al. 2009, p. 186), although there is evidence that chronic marijuana users are less impaired by alcohol than infrequent users (Jones and Stone 1970; Marks and MacAvoy 1989; Wright and Terry 2002).[5]

2.3. The relationship between marijuana and alcohol consumption

Although THC has not been linked to an increased risk of collision in simulator and driving-course studies, MMLs could impact traffic fatalities through alcohol. A consensus, however, has not been reached with regard to the relationship between marijuana and alcohol consumption. A number of studies have found evidence of complementarity between marijuana and alcohol (Pacula 1998; Farrelly et al. 1999; Williams et al. 2004; Yörük and Yörük 2011). Other studies lend support to the hypothesis that marijuana and alcohol are substitutes. For

[5] A large body of research in epidemiology attempts to assess the effects of substance use based on observed THC and alcohol levels in the blood of drivers who have been in accidents. For marijuana, the results have been mixed. In contrast, these studies have consistently shown that the likelihood of an accident increases with BAC levels (Sewell et al. 2009). However, it should be noted that this research generally suffers from the problems inherent to non-random assignment.

instance, Chaloupka and Laixuthai (1997) and Saffer and Chaloupka (1999) found that marijuana decriminalization led to decreased alcohol consumption, while DiNardo and Lemieux (2001) found that increases in the minimum legal drinking age were positively associated with the use of marijuana.[6]

Two recent studies used a regression discontinuity approach to examine the effect of the minimum legal drinking age on marijuana use, but came to different conclusions. Crost and Guerrero (2011) concluded that alcohol and marijuana were substitutes, while Yörük and Yörük (2011) concluded that they were complements. However, according to Yörük and Yörük (2011), approximately 75 percent of NLSY97 respondents between the ages of 19 and 22 smoked marijuana in the past month. This figure is inconsistent with evidence on marijuana use by young adults available from other studies.[7]

3. MEDICAL MARIJUNA LAWS AND MARIJUANA USE

Medical marijuana dispensaries are ubiquitous in some parts of Denver, Los Angeles, Seattle, and Detroit; in Colorado and Montana, more than two percent of the population is a registered medical marijuana patient.[8] However, it is not necessarily the case that MMLs have

[6] Ideally, to address whether alcohol and marijuana are substitutes or complements, we would estimate the impact of MMLs on the price of marijuana. Unfortunately, a state-level panel on marijuana prices for the period 1990-2009 does not currently exist.

[7] For instance, using data from the 2001-2002 National Epidemiologic Survey on Alcohol and Related Conditions, Compton et al. (2004) found that approximately 11 percent of 18- through 29 year-olds smoked marijuana in the past year; Pacula (1998) found that approximately 20 percent of respondents in the NLSY79 admitted to marijuana use in the past month; and DeSimone and Farrelly (2003) reported that approximately 16 percent of 18- through 29-year-old respondents in the National Household Surveys on Drug Abuse used marijuana in the past year.

[8] Appendix Table 1 presents registry information by state. According to city and corporate records, Denver has more marijuana dispensaries than liquor stores or Starbucks coffee shops (Osher 2010).

led to increased consumption of marijuana; formerly illicit users may have simply become card-carrying patients.

MMLs afford suppliers to the medicinal market some degree of protection against prosecution, and allow patients to buy medical marijuana without fear of being arrested or fined. Because it is prohibitively expensive for the government to ensure that all marijuana ostensibly grown for the medicinal market ends up in the hands of registered patients (especially in states that permit home cultivation), diversion to the illegal market likely occurs.[9] Moreover, the majority of MMLs allow patients to register based on medical conditions that cannot be objectively confirmed (e.g. chronic pain and nausea).[10] According to recent Arizona registry data, only 7 out of 11,186 applications for medical marijuana have been denied approval.[11]

Although reasons to expect MMLs to increase the consumption of marijuana exist, the evidence has consisted primarily of popular press reports and anecdotes.[12] In an effort to fill this

[9] With the exception of Washington D.C., all MMLs enacted during the period 1990-2009 allowed for home cultivation. Since 2009, Delaware and New Jersey have passed MMLs that do not permit home cultivation (Marijuana Policy Project 2011).

[10] Chronic pain appears to be the most common medical condition among medical marijuana patients (see Appendix Table 1). There is anecdotal evidence of "quick-in, quick-out mills," where physicians provide recommendations for a nominal fee (Cochran 2010; Sun 2010).

[11] It has been argued that MMLs increase recreational demand, especially among minors, through a destigmatization effect. Bachman et al. (1998) and Pacula et al. (2001) provide evidence that marijuana use increases when individuals view it as either socially acceptable or less harmful. Using data from the National Survey on Drug Use and Health for the period 1999-2008, de Silva and Torgler (2011) found that the passage of a MML was actually associated with an increased tendency to view marijuana use as risky. In addition, it is possible that MMLs encourage the recreational use of marijuana by increasing the probability of interacting with a person who uses it for medicinal purposes (Pacula et al. 2010).

[12] To our knowledge, only two previous studies have examined the relationship between MMLs and consumption of marijuana. Gorman and Huber (2007) used data on adult arrestees for the period 1995–2002 from Denver, Los Angeles, Portland, San Diego and San Jose. They found little evidence that marijuana consumption among arrestees increased as a result of legalization. Using data from the National Survey on Drug Use and Health for the period 2002-2008, Wall et al. (2011) found that rates of marijuana use among 12- through 17-year-olds were higher in states that had legalized medical marijuana than in states that had not, but noted that "in the years prior to MML passage, there was already a higher prevalence of use and lower perceptions of risk" in states that had legalized medical marijuana.

gap, we draw on data from the National Survey on Drug Use and Health (NSDUH) to examine marijuana use in three states that passed MMLs in the mid-2000s.

Funded by the Substance Abuse and Mental Health Services Administration (an agency of the U.S. Department of Health and Human Services), the NSDUH is an annual, nationally representative survey of individuals ages 12 and older. The NSDUH is the best source of information on substance use among adults living in the United States, but does not typically provide individual-level data with state identifiers to researchers.[13] Because the design of the NSDUH changed in 1999 (and because data on substance use are not available after 2009), we focus on three states that legalized medical marijuana in the mid-2000s: Montana, Rhode Island, and Vermont.

Specifically, we adopt a difference-in-differences estimation strategy, using neighboring states as controls. Table 2 shows marijuana use in the past 30 days, by age group, for Montana and its neighboring states. The "Before MML" period is 1999-2003, and the "After MML" period is 2005-2009 (Montana's MML came into effect on November 2, 2004).

Marijuana use among Montana residents (ages 12 and over) increased by 1.7 percentage points from the pre-legalization to the post-legalization period. However, because marijuana use in neighboring states increased by 0.8 percentage points, the difference-in-differences estimate is 0.9 percentage points.[14]

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[13] Our attempts at obtaining individual-level NSDUH data with state identifiers were politely rebuffed. Monitoring the Future and the Youth Risk Behavior Surveys are important sources of data for researchers interested in the determinants of marijuana use, but they do not contain information on adults.

[14] Although the NSDUH does not provide individual-level data with state identifiers, they do provide the sample sizes upon which the state-level rates of substance use are based. We used these sample sizes and the weighted rates to calculate approximate standard errors.

Table 2 provides no evidence that Montana's MML encouraged minors to smoke marijuana. In contrast, Montana's MML is associated with a 3.3 percentage point increase in marijuana use among 18- through 25-year-olds (or a 19 percent increase from the pre-legalization mean). The law is also associated with a 0.6 percentage point increase among older adults, but this estimate is not statistically significant.

The medical marijuana industry is thriving in Montana. Currently, more than 27,000 patients are registered, representing almost 3 percent of the state population. In contrast, Rhode Island legalized medical marijuana on June 3, 2006, and five years later approximately 3,000 patients were registered; Vermont legalized medical marijuana on July 1, 2004, and more than six years later roughly 350 patients were registered.[15] Did marijuana use by the residents of Rhode Island and Vermont increase after medical marijuana became legal? In an effort to answer this question, we again turn to state-level data from the NSDUH and a difference-in-differences estimation strategy.

The results are presented in Tables 3 and 4. There was a substantial increase in adult marijuana use after Rhode Island's MML came into effect. For instance, marijuana use among 18- through 25-year-olds increased by 3.5 percentage points from the pre-legalization period to the post-legalization period, while the use of marijuana among 18- through 25-year-olds in neighboring states (Connecticut and Massachusetts) decreased. There was a 1.4 percentage point increase in marijuana use among Vermont residents (ages 12 and over) after legalization, but because marijuana use increased by 0.7 percentage points in neighboring states, the difference-in-differences estimate is a statistically insignificant 0.7 percentage points. There is no evidence that marijuana use among minors increased after legalization in Rhode Island or Vermont.

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[15] It is likely that registry numbers are so low in Vermont because their state law did not allow for dispensaries until May 2011 (Marijuana Policy Project 2011).

4. MEDICAL MARIJUNA LAWS AND TRAFFIC FATALITIES

4.1. Data on traffic fatalities

As noted above, we use data from the Fatal Accident Report System (FARS) for the period 1990-2009 to examine the relationship between MMLs and traffic fatalities. These data are collected by the National Highway Traffic Safety Administration, and represent an annual census of all fatal injuries suffered in motor vehicle accidents in the United States. This information is obtained from a variety of sources: 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. These sources contain descriptions on the circumstances of each crash and the persons and vehicles involved.

Table 5 presents descriptive statistics and definitions for our outcome measures. $\textit{Fatalities Total}_{st}$ is equal to the number of traffic fatalities per 100,000 licensed drivers in state *s* and year *t*.[16] The variables $\textit{Fatalities (BAC} > 0)_{st}$ and $\textit{Fatalities (BAC} \geq 0.10)_{st}$ allow us to examine the effects of MMLs by alcohol involvement. $\textit{Fatalities (BAC} > 0)_{st}$ is equal to the number of fatal crashes per 100,000 licensed drivers in state *s* and year *t* where at least one driver involved had a positive blood alcohol content level. $\textit{Fatalities (BAC} \geq 0.10)_{st}$ is defined analogously, but at least one driver had to have a blood alcohol content level greater than or

[16] According to Eisenberg (2003), this variable is measured with little to no error. Information on the number of licensed drivers by state was obtained from *Highway Statistics*, published annually by the U.S. Department of Transportation. Due to missing values, licensed drivers in Indiana and Texas were imputed for 2009. We experimented with scaling traffic fatalities by the number of miles driven in state s and year *t* rather than by the population of licensed drivers. These estimates, which are similar in terms of magnitude and precision to those presented below, are available upon request.

equal to 0.10. *Fatalities (No Alcohol)$_{st}$* is equal to the number of fatal crashes per 100,000 licensed drivers where alcohol involvement was not reported.[17]

The information in FARS with regard to alcohol involvement is likely measured with error (Eisenberg 2003), and the possibility exists that some states collected information on BAC levels more diligently than others.[18] Fortunately, the inclusion of state fixed effects eliminates the influence of time-invariant differences in data collection and reporting. Focusing on nighttime and weekend fatal crashes can provide additional insight into the role of alcohol and help address the measurement error issue. As noted by Dee (1999), a substantial proportion of fatal crashes on weekends and at night involve alcohol.

State-level traffic fatality rates were calculated by sex and age using population data from the National Cancer Institute.[19] According to state registry data, 75 percent of patients in Arizona, and 68 percent of patients in Colorado, are male. There is also evidence that many medical marijuana patients are below the age of 40. Forty-eight percent of registered patients in Montana, and 42 percent of registered patients in Arizona, are between the ages of 18 and 40; the average age of registered patients in Colorado is 41.[20] To the extent that registered patients

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[17] The numerator for *Fatalities (No Alcohol)$_{st}$* was determined from two sources in the FARS. First, all drivers involved had to have either registered a BAC = 0 or, if BAC information was missing, the police had to report that alcohol was not involved. We also experimented with defining *Fatalities (No Alcohol)$_{st}$* based solely on the available BAC information. When this alternative definition was used, the results were similar to those reported below.

[18] Eisenberg (2003) provides an in-depth discussion of measurement error in alcohol-related fatalities in the FARS data.

[19] These data are available at: http://seer.cancer.gov/popdata/index.html.

[20] Links to state registry data are available at: http://norml.org/index.cfm?Group_ID=3391.

below the age of 40 are more likely to use medical marijuana recreationally, one might expect heterogeneous effects by age.[21]

4.2. The empirical model

A standard difference-in-differences (DD) regression is used to evaluate the impact of MMLs on traffic fatalities. This approach allows us to exploit the panel nature of our data by estimating a model that includes both state and year fixed effects. Specifically, the baseline estimating equation is:

$$(1) \qquad \ln(\mathit{Fatalities\ Total}_{st}) = \beta_0 + \beta_1 MML_{st} + \boldsymbol{X_{st}\beta_2} + v_s + w_t + \varepsilon_{st},$$

where *s* indexes states and *t* indexes years.[22] The variable MML_{st} indicates whether a MML was in effect in state *s* and year *t*, and β_1, the coefficient of interest, represents the marginal effect of legalizing medical marijuana. In alternative specifications we replace $\mathit{Fatalities\ Total}_{st}$ with the remaining dependent variables listed in Table 5.

The vector $\boldsymbol{X_{st}}$ is composed of the controls described in Table 6, and v_s and w_t are state and year fixed effects, respectively. Previous studies provide evidence that a variety of state-level policies can impact traffic fatalities. For instance, graduated driver licensing regulations

[21] Figures 1-4 show pre- and post-legalization trends in traffic fatalities by age group. The solid line represents the average traffic fatality rate across treatment states (those that legalized medical marijuana). The dashed line represents the average traffic fatality rate across control states (those that did not legalize medical marijuana). Year 0 on the horizontal axis represents the year in which legalization took place. Control states were randomly assigned a year of legalization between 1999 and 2009. Among minors and older adults (40 years of age and above), the pre- and post-legalization trends are similar. In contrast, there is evidence that legalization led to a sizable reduction in the traffic fatality rate among young adults (20- through 39 year-olds).

[22] Dee (2001) used a similar specification to examine the relationship between 0.08 BAC laws and traffic fatalities. See also Dee and Sela (2003) and Lovenheim and Steefel (2011).

and stricter seatbelt laws are associated with fewer traffic fatalities (Cohen and Einav 2003; Dee et al. 2005; Freeman 2007; Carpenter and Stehr 2008). Other studies have examined the effects of speed limits (Ledolter and Chan 1996; Farmer et al. 1999; Greenstone 2002; Dee and Sela 2003), BAC laws (Dee 2001; Eisenberg 2003), and Zero Tolerance Laws (Carpenter 2004; Liang and Huang 2008; Grant 2010). The relationship between beer taxes and traffic fatalities has also received attention from economists (Chaloupka et al. 1991; Ruhm 1996; Dee 1999; Young and Likens 2000; Young and Bielinska-Kwapisz 2006).[23] In addition to these polices, we include an indicator for marijuana decriminalization, the state unemployment rate, and real per capita income.[24] Finally, following Eisenberg (2003), we control for the vehicle miles driven per licensed driver in the state.[25]

4.3. The estimated relationship between MMLs and traffic fatalities

Table 7 presents OLS estimates of the relationship between MMLs and traffic fatalities. The regressions are weighted by the population of licensed drivers in state *s* and year *t*, and the standard errors are corrected for clustering at the state-level (Bertrand et al. 2004).

In the first column, we present the most basic specification. Without controls and fixed effects, the legalization of medical marijuana is associated with a 22 percent decrease in the

[23] Information on graduated driver licensing laws and seatbelt requirements is available from Dee et al. (2005), Cohen and Einav (2003), and the Insurance Institute for Highway Safety (iihs.org). The FARS accident files were used to construct the variable *Speed 70*.

[24] Data on decriminalization laws are from Model (1993) and Scott (2010). The possession and use of marijuana is not legal in decriminalized states, but expected penalties and fines are lower than those in states without such legislation. For our sample period, however, the decriminalization variable only captures one policy change; Nevada decriminalized the use of marijuana in 2001. The majority of decriminalization laws were passed prior to 1990. The unemployment and income data are from the Bureau of Labor Statistics and the Bureau of Economic Analysis, respectively.

[25] Due to missing data, the number of miles driven in Arizona was imputed for 2009.

traffic fatality rate ($e^{-0.248} - 1 = -0.220$). When state and year fixed effects are included, legalization is associated with a 9.7 percent decrease in the fatality rate. Adding the state-level controls decreases the magnitude of the estimated relationship between MMLs and traffic fatalities still further. Legalization is associated with a 7.9 percent decrease in the traffic fatality rate.[26]

The final specification of Table 7 includes state-specific linear time trends.[27] These are intended to control for the influence of difficult-to-measure factors at the state level, such as sentiment towards marijuana use, that trend smoothly over time. When state-specific trends are added, the legalization of medical marijuana is still associated with an 8.7 percent decrease in the fatality rate.

Next, we replace $\textit{Fatalities Total}_{st}$ with $\textit{Fatalities (No Alcohol)}_{st}$, $\textit{Fatalities } (BAC > 0)_{st}$ and $\textit{Fatalities } (BAC \geq 0.10)_{st}$. The results are consistent with the hypothesis that MMLs are related to traffic fatalities through alcohol consumption (Table 8). The estimate of β_1 is negative when fatalities not involving alcohol are considered, but it is relatively small and statistically indistinguishable from zero. In contrast, the legalization of medical marijuana is associated with an almost 12 percent decrease in any-BAC fatal crashes per 100,000 licensed drivers, and an almost 14 percent decrease in high-BAC fatal crashes per 100,000 licensed drivers.

Table 9 shows pre- and post-legalization trends in fatal crashes involving alcohol. In the years preceding legalization, $\textit{Fatalities } (BAC > 0)_{st}$ and $\textit{Fatalities } (BAC \geq 0.10)_{st}$ appear stable,

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[26] Controlling for economic conditions and policies (such as whether a primary seatbelt law was in effect or whether a state had a 0.08 BAC law) has very little impact on our estimate of β_1. In contrast, using miles driven as an additional control reduces the estimated relationship between legalization and fatalities from -0.108 to -0.082. We recognize that legalization of medical marijuana could have a direct impact on miles driven, but follow previous research on traffic fatalities by including it as a control variable (Dills 2010; Eisenberg 2003; Young and Likens 2000).

[27] In other words, it includes an interaction between the state dummies and a trend variable equal to 1 in 1990, 2 in 1991, 3 in 1993, and so forth. State-specific linear time trends are included in all subsequent specifications.

suggesting that neither marijuana nor alcohol consumption rose in anticipation of legalization. However, 1-2 years after coming into effect, MMLs are associated with a (statistically insignificant) 11.0 percent decrease in any-BAC fatal crashes per 100,000 licensed drivers, and a 13.5 percent decrease in high-BAC fatal crashes per 100,000 licensed drivers. MMLs are associated with even larger reductions in fatal crashes involving alcohol 2-3 years and 3+ years post-legalization. For instance, MMLs are associated with a 15.0 percent decrease in any-BAC fatal crashes, and an almost 20 percent reduction in high-BAC fatal crashes, after 3 or more years.

This pattern of results is consistent with state registry data from Colorado, Montana, and Rhode Island showing that patient numbers increased slowly in the years immediately after legalization, but ramped up quickly thereafter. For instance, Montana legalized medical marijuana in November 2004. Two years later, only 287 patients were registered; five years later, more than 7,000 patients were registered; and six years later, 27,292 patients were registered.[28]

Table 10 provides additional evidence that MMLs decrease traffic fatalities by reducing alcohol consumption. The first two columns of Table 10 show the relationship between MMLs and traffic fatalities occurring on weekdays as compared to the weekend, when the consumption of alcohol rises (Haines et al. 2003). Legalization is associated with a 7.8 percent decrease in the weekday traffic fatality rate; in comparison, it is associated with a 9.5 percent decrease in the

[28] Patient numbers appear to be growing rapidly in Arizona, which passed the Arizona Medical Marijuana Act on November 2, 2010. Three thousand six hundred and ninety-six patient applications had been approved as of May 24, 2011; 11,133 patient applications had been approved by August 29, 2011.

weekend traffic fatality rate. The former estimate is not significant at conventional levels, while the latter is significant at the 0.05 level.[29]

The last two columns of Table 10 show the relationship between MMLs and traffic fatalities occurring during the day as compared to at night, when fatal crashes are more likely to involve alcohol (Dee 1999). Legalization is associated with a 6.8 percent decrease in the daytime traffic fatality rate; in comparison, it is associated with a 10.1 percent decrease in the nighttime traffic fatality rate. The former estimate is not significant at conventional levels, but the latter is significant at the 0.10 level.[30]

Table 11 presents estimates of the relationship between MMLs and traffic fatalities by age. In column 1, the estimate of β_1 is negative, but is small in magnitude and statistically insignificant. This is consistent with the evidence from Montana and Rhode Island suggesting that MMLs have little impact on the use of marijuana by minors. Legalization is associated with a 19 percent decrease in the fatality rate of 20- through 29 year-olds, a 16.8 percent decrease in the fatality rate of 30- through 39-year-olds, and an 11.5 percent decrease in the fatality rate of 40- through 49-year-olds. Although registry data indicate that many medical marijuana patients are over the age of 49, there is little evidence that MMLs are associated with fatalities among 50- through 59-year-olds or fatalities among individuals 60 years of age and older.[31] This result is consistent with research showing that policies that have been effective at increasing younger driver safety are essentially irrelevant for older drivers (Morrisey and Grabowski 2005).

[29] It should be noted, however, that we cannot formally reject the hypothesis that these estimates are equal.

[30] It should be noted, however, that we cannot formally reject the hypothesis that these estimates are equal.

[31] According to state registry data, 37.8 percent and 32.3 percent of registered medical marijuana patients are over the age of 50 in Arizona and Montana, respectively.

Table 12 presents estimates of the relationship between MMLs and traffic fatalities by gender. They provide some evidence that MMLs have a greater impact on fatalities among males. Specifically, legalization is associated with a 12.5 percent decrease in the male traffic fatality rate as compared to a 9.2 percent decrease in the female fatality rate. This pattern of results is consistent with registry data that show the majority of medical marijuana patients are male.[32]

5. MEDICAL MARIJUNA LAWS, ALCOHOL CONSUMPTION AND SALES

5.1. Number of drinks per month and binge drinking

In this section, we use data from the Behavioral Risk Factor Surveillance System (BRFSS) to examine the effects of MMLs on direct measures of alcohol consumption. Administered by state health departments in collaboration with the Centers for Disease Control, the BRFSS is designed to measure "behavioral risk factors" for the adult population (18 years of age or older).

Approximately 350,000 individuals are surveyed by phone every year by the BRFSS. Among the questions asked are:

1. Have you had any beer, wine, wine coolers, cocktails, or liquor during the past month?
2. During the past month, how many days per week or per month did you drink any alcoholic beverages, on the average?
3. On days when you drink, about how many drinks do you drink on average?

[32] The hypothesis that these estimates are equal can be rejected at the 0.05 level. Appendix Tables 2A and 2B present estimates of β_1 by age and gender. The estimated effect of legalization on traffic fatalities is largest among 20- through 29-year-old males and 30- through 39-year-old females. There is evidence that legalization leads to reduced traffic fatalities among males over the age of 49.

Using the answers to these questions, we constructed *Number of Drinks*, equal to the mean number of drinks consumed among residents of state *s* in year *t*. In addition, the BRFSS asked, about binge drinking.[33] Using the answers to this question, we constructed *Binge Drinking*, equal to the proportion of respondents in state *s* and year *t* who engaged in binge drinking in the month prior to being interviewed.

The top panel of Table 13 presents estimates of the following equation for the period 1990-2009:

$$(2) \qquad \textit{Number of Drinks}_{st} = \pi_0 + \pi_1 MML_{st} + \boldsymbol{X_{st}\pi_2} + v_s + w_t + \Theta_s \cdot t + \varepsilon_{st},$$

where $\boldsymbol{X_{st}}$ is a modified vector of controls and state-specific linear trends are represented by $\Theta_s \cdot t$.[34] The bottom panel presents estimates of (2) replacing *Number of Drinks* with *Binge Drinking*.

The results are consistent with the hypothesis that marijuana and alcohol are substitutes. The legalization of medical marijuana is associated with a 9 percent reduction in the mean number of drinks consumed per month by males (1.51/16.08 = 0.09), a 12 percent reduction in the mean number of drinks consumed by females, and a 0.007 reduction in binge drinking by females.

Although the estimates of π_1 are negative for every age group, the estimated relationship between MMLs and drinking is strongest among 20- through 29-year-olds. Legalization is associated with a 25 percent reduction in the mean number of drinks consumed by 20 through

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[33] Specifically, the BRFSS asks, "Considering all types of alcoholic beverages, how many times during the past 30 days did you have X or more drinks on an occasion?", where X is five for male respondents and 4 for female respondents.

[34] The vector $\boldsymbol{X_{st}}$ includes the controls listed in Table 6 with the following exceptions: *Miles driven, GDL, Primary seatbelt, Secondary seatbelt,* and *Speed 70*. We also control for the relevant age- or sex-specific population.

29-year-olds. Almost one fourth of the individuals killed in traffic accidents during the period 1990-2009 were between the ages of 20 and 29; more than one third of individuals killed in traffic accidents involving alcohol were between the ages of 20 and 29.[35]

5.2. Alcohol sales

Published annually by the Beer Institute, the *Brewers Almanac* is an alternative source of information on alcohol consumption. State-level data on per capita beer sales (in gallons) are available from the *Brewers Almanac* for the period 1990-2009. Data on wine and spirits sales (in gallons) are available for the period 1994-2009. Using these data, we estimate the following equation:

(3) $$\ln(Sales_{st}) = \partial_0 + \partial_1 MML_{st} + \boldsymbol{X_{st}}\boldsymbol{\partial_2} + v_s + w_t + \Theta_s \cdot t + \varepsilon_{st}.$$

where $\boldsymbol{X_{st}}$ is a modified vector of controls.[36] Again, the results are consistent with the hypothesis that marijuana and alcohol are substitutes (Table 14). The legalization of medical marijuana is associated with a 5.3 percent reduction in beer sales, the most popular beverage among 18- through 29-year-olds during the period under study (Jones 2008). Legalization is negatively

[35] Appendix Tables 3A and 3B present estimates of π_1 by age and gender. The estimated relationship between legalization and mean number of drinks is strongest among 20- through 29-year-old males. It is not significant among older males or among 18- through 19-year-old males.   There is evidence that legalization leads to reduced alcohol consumption by females between the ages of 20 and 49.

[36] The vector $\boldsymbol{X_{st}}$ includes the controls listed in Table 6 with the following exceptions: *Miles driven, GDL, Primary seatbelt, Secondary seatbelt, and Speed 70*.

related to wine and spirit sales, but the estimates are not statistically significant at conventional levels.[37]

6. CONCLUSION

To date, 16 states and the District of Columbia have legalized medical marijuana. Others are likely to follow. A recent Gallup poll found that 70 percent of Americans are in favor of "making marijuana legally available for doctors to prescribe in order to reduce pain and suffering" (Mendes 2010).

Despite intense public interest, medical marijuana laws have received little attention from researchers. In fact, next to nothing is known about their impact on outcomes of interest to policymakers, social scientists, advocates, and opponents.

The current study draws on data from a variety of sources to explore the effects of legalizing medical marijuana. Using data from the National Survey on Drug Use and Health (NSDUH), we find that the use of marijuana by adults in Montana and Rhode Island increased after medical marijuana was legalized. Although opponents of legalization argue that it encourages recreational use among teenagers (Brady et al. 2011; O'Keefe and Earleywine 2011), we find no evidence that the use of marijuana by minors increased.

Using data from the Fatality Analysis Reporting System (FARS) for the period 1990-2009, we find that traffic fatalities fall by nearly 9 percent after the legalization of medical marijuana, an effect comparable in magnitude to those found by economists using the FARS data

[37] These results help explain why The California Beer & Beverage Distributors donated $10,000 to Public Safety First, a committee organized to oppose a recent California initiative legalizing marijuana (Grim 2010).

to examine policies such as the minimum legal drinking age.[38] Although registry data from Arizona and Montana suggest that more than half of medical marijuana patients are over the age of 40, the estimated relationship between legalization and traffic fatalities is strongest among young adults.

Why does legalizing medical marijuana reduce traffic fatalities? Alcohol consumption appears to play a key role. The legalization of medical marijuana is associated with a 6.4 percent decrease in fatal crashes that did not involve alcohol, but this estimate is not statistically significant at conventional levels. In comparison, the legalization of medical marijuana is associated with an almost 12 percent decrease in any-BAC fatal crashes per 100,000 licensed drivers, and an almost 14 percent decrease in high-BAC fatal crashes per 100,000 licensed drivers.

The negative relationship between legalization of medical marijuana and traffic fatalities involving alcohol is consistent with the hypothesis that marijuana and alcohol are substitutes. In order to explore this hypothesis further, we examine the relationship between medical marijuana laws and alcohol consumption using data from the Behavioral Risk Factor Surveillance System and *The Brewer's Almanac*. We find the legalization of medical marijuana is associated with a 25 percent decrease in the mean number of drinks consumed by 20- through 29-year-olds. In addition, we find that legalization is associated with a 5 percent drop in beer sales, the most popular alcoholic beverage among young adults (Jones 2008).

Evidence from simulator and driving course studies provides a simple explanation for why substituting marijuana for alcohol could lead to fewer traffic fatalities. These studies show

[38] For instance, Dee (1999) found that increasing the minimum legal drinking age to 21 reduces fatalities by approximately 9 percent; Carpenter and Stehr (2008) found that mandatory seatbelt laws decrease traffic fatalities among 14- through 18-year-olds by approximately 8 percent.

that alcohol consumption leads to an increased risk of collision (Kelly et al. 2004; Sewell et al. 2009). Even at low doses, drivers under the influence of alcohol tend to underestimate the degree to which they are impaired (MacDonald et al. 2008; Marczinski et al. 2008; Robbe and O'Hanlon 1993; Sewell et al. 2009), drive at faster speeds, and take more risks (Burian et al. 2002; Ronen et al. 2008; Sewell et al. 2009). In contrast, simulator and driving course studies provide only limited evidence that driving under the influence of marijuana leads to an increased risk of collision, perhaps as a result of compensatory driver behavior (Kelly et al. 2004; Sewell et al. 2009).

However, because other mechanisms cannot be ruled out, the negative relationship between medical marijuana laws and alcohol-related traffic fatalities does not necessarily imply that driving under the influence of marijuana is safer than driving under the influence of alcohol. For instance, it is possible that legalizing medical marijuana reduces traffic fatalities though its effect on substance use in public. Alcohol is often consumed in restaurants and bars, while many states prohibit the use of medical marijuana in public.[39] Even where it is not explicitly prohibited, anecdotal evidence suggests public use of medical marijuana can be controversial.[40] If marijuana consumption typically takes place at home, then designating a driver for the trip back from a restaurant or bar becomes unnecessary, and legalization could reduce traffic fatalities even if driving under the influence of marijuana is every bit as dangerous as driving under the influence of alcohol.

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[39] For instance, in Colorado "the medical use of marijuana in plain view of, or in a place open to, the general public" is prohibited; in Connecticut, the smoking of marijuana is prohibited in "any public place"; in Oregon engaging "in the medical use of marijuana in a public place" is prohibited; and in Washington, it is a misdemeanor "to use or display medical marijuana in a manner or place which is open to the view of the general public." Although Montana law prohibits the use of medical marijuana in parks, schools, public beaches and correctional facilities, it does not explicitly prohibit its use in other public places.

[40] See, for instance, Whitnell (2008), Adams (2010), Moore (2010), and Ricker (2010).

Finally, an important caveat deserves mention. Our classification of states into those that allow the use of medical marijuana and those that prohibit its use does not capture potentially important factors such as whether formal registration with the state is compulsory or voluntary, what types of ailments are covered, and whether an official dispensary system is in place. While measuring these differences and their impact is beyond the scope of this study, future research could explore the nuances of these laws.

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7. REFERENCES

Adams, Jill. 2008. "Medical Marijuana Inspires Strong Opinions, But What Does Science Say?" *Chicago Tribune*. 18 August. Available at: http://www.chicagotribune.com/health/la-he-marijuana-adams18-2008aug18,0,2023647.story.

Adams, Tom. 2010. "Oregon Man Tests Whether Medical Marijuana Users Can Carry it in Public." KLEWTV.COM, March 16. Available at: http://www.klewtv.com/news/87968832.html.

Bachman, Jerald; Johnston, Lloyd and Patrick O'Malley. 1998. "Explaining Recent Increases in Students' Marijuana Use: Impacts of Perceived Risks and Disapproval, 1976 through 1996." *American Journal of Public Health* 88: 887-892.

Belville, Russ. 2011. "Oregon's Workplaces Safest Ever, Despite 40,000 Medical Marijuana Patients." *Examiner*. 6 June. Available at: http://www.examiner.com/medical-marijuana-dispensaries-in-portland/oregon-s-workplaces-safest-ever-despite-40-000-medical-marijuana-patients.

Bertrand, Marianne; Duflo, Esther and Sendhil Mullainathan. 2004. "How Much Should We Trust Differences-in-Differences Estimates? *Quarterly Journal of Economics* 119: 249-

276.

Bilz, Gregg. 1992. "The Medical Use of Marijuana: The Politics of Medicine." *Hamline Journal of Public Law and Policy* 13: 117-135.

Blankstein, Andrew. 2010. "LAPD Investigates Third Shooting at a Medical Marijuana Dispensary." *Los Angeles Times.* 1 July. Available at: http://articles.latimes.com/2010/jul/01/local/la-me-pot-shooting-20100701.

Brady, Cherrie; Needham, Laura and Susan Smith. 2011. "'Nightmare' of Medical Marijuana Threatens Kids." *Billings Gazette.* 22 February. Available at: http://billingsgazette.com/news/opinion/guest/article_36f52b60-0e0a-54f8-a86c-a7acde6ec904.html.

Burian, Scott; Liguori, Anthony and John Robinson. 2002. "Effects of Alcohol on Risk-Taking During Simulated Driving." *Human Psychopharmacology* 17: 141-150.

Carpenter, Christopher. 2004. "How do Zero Tolerance Drunk Driving Laws Work?" *Journal of Health Economics* 23: 61-83.

Carpenter, Christopher and Mark Stehr. 2008. "The Effects of Mandatory Seatbelt Laws on Seatbelt Use, Motor Vehicle Fatalities, and Crash-Related Injuries among Youths." *Journal of Health Economics* 27: 642-662.

Centers for Disease Control and Prevention. 2010. Web-based Injury Statistics Query and Reporting System. Atlanta, GA: U.S. Department of Health and Human Services, CDC. Available at: http://www.cdc.gov/injury/wisqars.

Chaloupka, Frank; Saffer, Henry and Michael Grossman. 1991. "Alcohol Control Policies and Motor Vehicle Fatalities." NBER Working Paper No. 3831.

Chaloupka, Frank and Adit Laixuthai. 1997. "Do Youths Substitute Alcohol and Marijuana? Some Econometric Evidence." *Eastern Economic Journal* 23: 253-275.

CNN. 2011. "Montana Medical Marijuana Stores Raided; Advocates Cry Foul." *CNN News*. 16 March. Available at: http://articles.cnn.com/2011-03-16/justice/montana.marijuana.raids_1_medical-marijuana-steph-sherer-americans-for-safe-access?_s=PM:CRIME.

Cochran, Diane. 2010. "Medical Marijuana Card OK'd After 8 Minutes, 6 Questions." *Billings Gazette.* 21 August. Available at: http://billingsgazette.com/news/local/article_873a0ad2-adaf-11df-8799-001cc4c002e0.html.

Cohen, Alma and Liran Einav. 2003. "The Effects of Mandatory Seat Belt Laws on Driving Behavior and Traffic Fatalities." *Review of Economics and Statistics* 85: 828-843.

Compton, Wilson M.; Grant, Bridget; Colliver, James; Glantz, Meyer and Frederick S. Stinson. 2004. "Prevalence of Marijuana Use Disorders in the United States: 1991-1992 and 2001-2002." *JAMA* 291: 2114-2121.

Corry, Jessica; Davis, Lauren; Corry, Jr., Robert and Bob Hoban. 2009. "Setting the Facts Straight on Medical Marijuana Statistics." *Denver Post*, 19 December. Available at: http://www.denverpost.com/headlines/ci_14027740.

Crost, Benjamin and Santiago Guerrero. 2011. "The Effect of Alcohol Availability on Marijuana Use: Evidence from the Minimum Legal Drinking Age." Working Paper, University of Colorado Denver.

de Silva, Niko and Benno Torgler. 2011. "Smoke Signals and Mixed Messages: Medical Marijuana & Drug Policy Signalling Effects." CREMA Working Paper No. 2011 – 18. Available at: http://ideas.repec.org/p/cra/wpaper/2011-18.html.

Dee, Thomas. 1999. "State Alcohol Policies, Teen Drinking and Traffic Fatalities." *Journal of Public Economics* 72: 289-315.

Dee, Thomas. 2001. "Does Setting Limits Save Lives? The Case of 0.08 BAC Laws." *Journal of Policy Analysis and Management* 20: 111-128.

Dee, Thomas and Rebecca Sela. 2003. "The Fatality Effects of Highway Speed Limits by Gender and Age." *Economics Letters* 79: 401-408.

Dee, Thomas; Grabowski, David and Michael Morrisey. 2005. "Graduated Driver Licensing and Teen Traffic Fatalities." *Journal of Health Economics* 24: 571-589.

Deitch, Robert. 2003. *Hemp – American History Revisited.* New York, NY: Algora Publishing.

DeSimone, Jeff and Matthew Farrelly. 2003. "Price and Enforcement Effects on Cocaine and Marijuana Demand." *Economic Inquiry* 41: 98-115.

Dills, Angela. 2010. "Social Host Liability for Minors and Underage Drunk-Driving Accidents." *Journal of Health Economics* 29: 241-249.

DiNardo, John and Thomas Lemieux. 2001. "Alcohol, Marijuana, and American Youth: The Unintended Consequences of Government Regulation." *Journal of Health Economics* 20: 991-1010.

Eddy, Mark. 2010. "Medical Marijuana: Review and Analysis of Federal and State Policies." Congressional Research Service Report for Congress. Available at: http://www.fas.org/sgp/crs/misc/RL33211.pdf.

Eisenberg, Daniel. 2003. "Evaluating the Effectiveness of Policies Related to Drunk Driving." *Journal of Policy Analysis and Management* 22: 249-274.

Farmer, Charles; Retting, Richard and Adrian Lund. "Changes in Motor Vehicle Occupant Fatalities After Repeal of the National Maximum Speed Limit." *Accident Analysis and Prevention* 31: 537-543.

Farrelly, Matthew; Bray, Jeremy; Zarkin, Gary; Wendling, Brett and Rosalie Pacula. 1999. "The Effects of Prices and Policies on the Demand for Marijuana: Evidence from the National Household Surveys on Drug Abuse." NBER Working Paper No. 6940.

Freeman, Donald. 2007. "Drunk Driving Legislation and Traffic Fatalities: New Evidence on BAC 08 Laws." *Contemporary Economic Policy* 25: 293-308.

Gieringer, Dale.1999. "The Forgotten Origins of Cannabis Prohibition in California." *Contemporary Drug Problems* 26: 237-288.

Gorman, Dennis M. and J. Charles Huber Jr. 2007. "Do Medical Cannabis Laws Encourage Cannabis Use?" *International Journal of Drug Policy* 18:160-167.

Grant, Darren. 2010. "Dead on Arrival: Zero Tolerance Laws Don't Work." *Economic Inquiry* 48: 756-770.

Greenstone, Michael. 2002. "A Reexamination of Resource Allocation Responses to the 65-mph Speed Limit." *Economic Inquiry* 40: 271-278.

Grim, Ryan. 2010. "California Pot Initiative Opposed By Beer Industry." *The Huffington Post*. 21 September. Available at: http://www.huffingtonpost.com/2010/09/21/this-buds-not-for-you-bee_n_732901.html.

Hamilton, Keegan. 2011. "Spokane Marijuana Dispensaries Raided; Feds Say New State Law Won't Stop Crackdown." *Seattle Weekly*. 29 April. Available at: http://blogs.seattleweekly.com/dailyweekly/2011/04/spokane_marijuana_dispensaries.php

Haines, Pamela; Hama, Mary; Guilkey, David and Barry M. Popkin. 2003. "Weekend Eating in the United States is Linked with Greater Energy, Fat, and Alcohol Intake." *Obesity Research* 11: 945–949.

Hoeffel, John. 2011. "Rand Study Finds *Less* Crime Near Pot Dispensaries." *Los Angeles Times*, 21 September. Available at: http://articles.latimes.com/2011/sep/21/local/la-me-0928-marijuana-dispensaries-20110921.

Johnston, David and Neil Lewis. 2009. "Obama Administration to Stop Raids on Medical

Marijuana Dispensers." *New York Times*. 18 March. Available at: http://www.nytimes.com/2009/03/19/us/19holder.html.

Jones, Jeffrey M. 2008. "Beer Back to Double-Digit Lead Over Wine as Favored Drink." *Gallup*. 25 July. Available at: http://www.gallup.com/poll/109066/beer-back-doubledigit-lead-over-wine-favored-drink.aspx

Jones, Reese and George Stone. 1970. "Psychological Studies of Marijuana and Alcohol in Man." *Psychopharmacologia* 18: 108-117.

Kelly, Erin; Darke, Shane and Joanne Ross. 2004. "A Review of Drug Use and Driving: Epidemiology, Impairment, Risk Factors and Risk Perceptions." *Drug and Alcohol Review* 23: 319-344.

L.A. Now. 2011. "2 West Hollywood Medical Marijuana Dispensaries Raided by Federal Agents." *Los Angeles Times*. 15 March. Available at: http://latimesblogs.latimes.com/lanow/2011/03/west-hollywood-medical-marijuana-raid.html.

Lamoureux, Shannon. 2011. "State Medical Marijuana Laws Have Not Increased Teen Marijuana Use." Colorado Dispensary Services, 3 July. Available at: http://www.cdscenters.com/blog/2011/07/03/state-medical-marijuana-laws-have-not-increased-teen-marijuana-use/.

Ledolter, Johannes and K.S. Chan. 1996. "Evaluating the Impact of the 65 mph Maximum Speed Limit on Iowa Rural Interstates." *American Statistician* 50: 79-85.

Liang, Lan and Jidong Huang. 2008. "Go Out or Stay In? The Effects of Zero Tolerance Laws on Alcohol Use and Drinking and Driving Patterns among College Students." *Health Economics* 17: 1261-1275.

Lovenheim, Michael and Daniel Steefel. 2011. "Do Blue Laws Save Lives? The Effect of Sunday Alcohol Sales Bans on Fatal Vehicle Accidents." *Journal of Policy Analysis and Management* 30: 798-820.

MacDonald, Scott; Mann, Robert; Chipman, Mary; Pakula, Basia; Erickson, Pat; Hathaway, Andrew and Peter MacIntyre. 2008. "Driving Behavior Under the Influence of Cannabis or Cocaine." *Traffic Injury Prevention* 9: 190-194.

Marczinski, Cecile; Harrison, Emily and Mark Fillmore. 2008. "Effects of Alcohol on Simulated Driving and Perceived Driving Impairment in Binge Drinkers." *Alcoholism: Clinical and Experimental Research* 32: 1329-1337.

Marijuana Policy Project. 2011. "Key Aspects of State and D.C. Medical Marijuana Laws." Available at: http://www.mpp.org/legislation/state-by-state-medical-marijuana-laws.html.

Marks, David and Michael MacAvoy. 1989. "Divided Attention Performance in Cannabis Users and Non-Users Following Alcohol and Cannabis Separately and in Combination." *Psychopharmacology* 99: 397-401.

Marmor, Jane. 1998. "Medical Marijuana." *Western Journal of Medicine* 168: 540-543.

Mendes, Elizabeth. 2010. "New High of 46% of Americans Support Legalizing Marijuana." *Gallup*, October 28. Available at: http://www.gallup.com/poll/144086/New-High-Americans-Support-Legalizing-Marijuana.aspx.

Model, Karyn. 1993. "The Effect of Marijuana Decriminalization on Hospital Emergency Room Drug Episodes: 1975-1978." *Journal of the American Statistical Association* 88: 737-747.

Moore, Michael. 2010. "Lighting Up: Rules Vague on Using Medical Marijuana in Public." The Missoulian. June 1. Available at: http://missoulian.com/news/local/article_540ae92c-6d38-11df-9db9-001cc4c03286.html.

Morrisey, Michael and David Grabowski. 2005. "State Motor Vehicle Laws and Older Drivers." *Health Economics* 14: 407-419.

O'Keefe, Karen and Mitch Earleywine. 2011. "Marijuana Use by Young People: The Impact of State Medical Marijuana Laws." Marijuana Policy Project Report. Available at: http://www.mpp.org/assets/pdfs/library/Teen-Use-FINAL.pdf.

Osher, Christopher. 2010. "As Dispensaries Pop Up, Denver May Be Pot Capital, U.S.A." *Denver Post*. 3 January. Available at: http://www.denverpost.com/ci_14112792.

Pacula, Rosalie. 1998. "Does Increasing the Beer Tax Reduce Marijuana Consumption?" *Journal of Health Economics* 17: 557-585.

Pacula, Rosalie; Grossman, Michael; Chaloupka, Frank; O'Malley, Patrick; Johnston, Lloyd and Matthew Farrelly. 2001. "Marijuana and Youth." In Jonathan Gruber, ed., *Risky Behavior among Youths: An Economic Analysis.* Chicago, IL: University of Chicago Press.

Pacula, Rosalie; Chriqui, Jamie; Reichmann, Deborah and Yvonne Terry-McElrath. 2002. "State Medical Marijuana Laws: Understanding the Laws and their Limitations." *Journal of Public Health Policy* 23: 413-439.

Pacula, Rosalie; Kilmer, Beau; Grossman, Michael and Frank Chaloupka. 2010. "Risks and Prices: The Role of User Sanctions in Marijuana Markets." *B.E. Journal of Economic Analysis and Policy (Contributions)* 10: 1-36.

Ricker, Amanda. 2010. "Bozeman Medical Marijuana Ordinance Takes Effect." *Bozeman Daily Chronicle*, August 25. Available at: http://www.bozemandailychronicle.com/news/article_f6394d6c-afda-11df-ba34-001cc4c002e0.html

Robbe, Hindrick and James O'Hanlon. 1993. "Marijuana and Actual Driving Performance." Washington, D.C.: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Ronen, Adi; Gershon, Pnina; Drobiner, Hana; Rabinovich, Alex; Bar-Hamburger, Rachel; Mechoulam, Raphael; Cassuto, Yair and David Shinar. 2008. "Effects of THC on Driving Performance, Physiological State and Subjective Feelings Relative to Alcohol." *Accident Analysis and Prevention* 40: 926-934.

Ruhm, Christopher.1996. "Alcohol Policies and Highway Vehicle Fatalities." *Journal of Health Economics* 15: 435-454.

Saffer, Henry and Frank Chaloupka. 1999. "The Demand for Illicit Drugs." *Economic Inquiry* 37: 401-411.

Scott, Emilee Mooney. 2010. "Marijuana Decriminalization." Office of Legislative Research Report. Available at: http://www.cga.ct.gov/2010/rpt/2010-R-0204.htm.

Sewell, R. Andrew; Poling, James and Mehmet Sofuoglu. 2009. "The Effect of Cannabis Compared with Alcohol on Driving." *American Journal on Addictions* 18:185-193.

Sun, Lena. 2010. "Dispensing Medical Pot a Challenge for Doctors." *San Francisco Chronicle.* 6 May. Available at: http://articles.sfgate.com/2010-05-06/news/20887811_1_medical- marijuana-doctors-recommend.

Sutton, Lawrence. 1983. "The Effects of Alcohol, Marihuana and their Combination on Driving Ability." *Journal of Studies on Alcohol* 44: 438-445.

U.K. Cannabis Campaign. 2011. "A Chronology of Cannabis." Available at: http://www.ccguide.org/chronol.php.

U.S. Department of Transportation 2010. *Traffic Safety Facts 2009*. Available at: http://www-nrd.nhtsa.dot.gov/Pubs/811402EE.pdf.

Watson, Stanley; Benson, Jr., John and Janet Joy. 2000. "Marijuana and Medicine: Assessing the Science Base." *Archives of General Psychiatry* 57: 547-552.

Whitnell, Tim. 2008. "Human Rights Tribunal of Ontario to Decide Medical Marijuana Case. Sports Bar Owner Pitted against Former Customer." *The Burlington Post*, February 10. Available at: http://www.insidehalton.com/news/article/477905--human-rights-tribunal-of-ontario-to-decide-medical-marijuana-case.

Wall, Melanie, M., Ernest Poh, Magdelena Cerdá M, Katherine M. Keyes, Sandro Galea S, and Deborah S. Hasin. 2011. "Adolescent Marijuana Use from 2002 to 2008: Higher in States with Medical Marijuana Laws, Cause Still Unclear." *Annals of Epidemiology*, Vol. 21, No. 9, pp. 714-716.

Williams, Jenny; Pacula, Rosalie; Chaloupka, Frank and Henry Wechsler. 2004. "Alcohol and Marijuana Use among College Students: Economic Complements or Substitutes?" *Health Economics* 13: 825-843.

Wright, Kay and Philip Terry. 2002. "Modulation of the Effects of Alcohol on Driving-Related Psychomotor Skills by Chronic Exposure to Cannabis." *Psychopharmacology* 160: 213-219.

Yörük, Bariş and Ceren Yörük. 2011. "The Impact of Minimum Legal Drinking Age Laws on Alcohol Consumption and Marijuana Use: Evidence from a Regression Discontinuity Design Using Exact Date of Birth." *Journal of Health Economics* 30: 740-753.

Young, Douglas and Thomas Likens. 2000. "Alcohol Regulation and Auto Fatalities." *International Review of Law and Economics* 20: 107-126.

Young, Douglas and Agnieszka Bielinska-Kwapisz. 2006. "Alcohol Prices, Consumption, and Traffic Fatalities." *Southern Economic Journal* 72: 690-703.

Table 1. Medical Marijuana Laws, 1990-2009

	Effective date
Alaska	March 4, 1999
California	November 6, 1996
Colorado	June 1, 2001
Hawaii	December 28, 2000
Maine	December 22, 1999
Michigan	December 4, 2008
Montana	November 2, 2004
Nevada	October 1, 2001
New Mexico	July 1, 2007
Oregon	December 3, 1998
Rhode Island	January 3, 2006
Vermont	July 1, 2004
Washington	November 3, 1998

Notes: Arizona, D.C., Delaware, and New Jersey have passed medical marijuana laws since 2009. Source: Eddy (2010).

Table 2. Difference-in-Differences Estimates of the Effect of Montana's MML on Marijuana Use

	(1) *Past Month Usage MT*	(2) *Past Month Usage ID, ND, SD and WY*	(1) – (2)
<u>All ages</u>			
Before MML	0.069	0.046	0.023***
	(0.004)	(0.002)	(0.004)
After MML	0.086	0.054	0.032***
	(0.004)	(0.002)	(0.004)
Within-state difference	0.017**	0.008***	**0.009***
(row 2 – row 1)	(0.006)	(0.002)	**(0.005)**
<u>Ages 12 to 17</u>			
Before MML	0.109	0.073	0.036***
	(0.008)	(0.003)	(0.008)
After MML	0.094	0.064	0.031***
	(0.007)	(0.003)	(0.007)
Within-state difference	-0.015	-0.010**	**-0.005**
(row 2 – row 1)	(0.011)	(0.005)	**(0.011)**
<u>Ages 18 to 25</u>			
Before MML	0.178	0.127	0.051***
	(0.010)	(0.004)	(0.010)
After MML	0.224	0.139	0.084***
	(0.011)	(0.004)	(0.010)
Within-state difference	0.045**	0.012**	**0.033****
(row 2 – row 1)	(0.014)	(0.006)	**(0.014)**
<u>Ages 26 and older</u>			
Before MML	0.044	0.025	0.019***
	(0.005)	(0.002)	(0.005)
After MML	0.062	0.036	0.026***
	(0.006)	(0.002)	(0.006)
Within-state difference	0.017**	0.011***	**0.006**
(row 2 – row 1)	(0.008)	(0.003)	**(0.008)**

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Based on state-level estimates from the National Surveys on Drug Use and Health (NSDUH), provided by the Substance Abuse and Mental Health Services Administration (SAMHSA). Standard errors (in parentheses) are approximated using weighted means and raw sample sizes provided by the NSDUH. The "Before MML" period is 1999-2003; the "After MML" period is 2005-2009 (Montana's MML came into effect on November 2, 2004).

Table 3. Difference-in-Differences Estimates of the Effect of Rhode Island's MML on Marijuana Use

	(1) *Past Month Usage RI*	(2) *Past Month Usage CT and MA*	(1) – (2)
All ages			
Before MML	0.083	0.074	0.009**
	(0.004)	(0.002)	(0.004)
After MML	0.106	0.072	0.034***
	(0.006)	(0.003)	(0.006)
Within-state difference	0.023***	-0.002	**0.025*****
(row 2 – row 1)	(0.007)	(0.004)	**(0.008)**
Ages 12 to 17			
Before MML	0.107	0.103	0.004
	(0.007)	(0.005)	(0.008)
After MML	0.093	0.082	0.011
	(0.010)	(0.007)	(0.012)
Within-state difference	-0.013	-0.021**	**0.008**
(row 2 – row 1)	(0.012)	(0.008)	**(0.014)**
Ages 18 to 25			
Before MML	0.257	0.236	0.021*
	(0.010)	(0.007)	(0.011)
After MML	0.293	0.218	0.075***
	(0.016)	(0.009)	(0.018)
Within-state difference	0.035**	-0.019	**0.054*****
(row 2 – row 1)	(0.018)	(0.012)	**(0.021)**
Ages 26 and older			
Before MML	0.050	0.045	0.005
	(0.005)	(0.003)	(0.006)
After MML	0.073	0.046	0.027***
	(0.009)	(0.005)	(0.009)
Within-state difference	0.022**	0.001	**0.022****
(row 2 – row 1)	(0.009)	(0.006)	**(0.011)**

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Based on state-level estimates from the National Surveys on Drug Use and Health (NSDUH), provided by the Substance Abuse and Mental Health Services Administration (SAMHSA). Standard errors (in parentheses) are approximated using weighted means and raw sample sizes provided by the NSDUH. The "Before MML" period is 1999-2005; the "After MML" period is 2007-2009 (Rhode Island's MML came into effect on January 3, 2006).

Table 4. Difference-in-Differences Estimates of the Effect of Vermont's MML on Marijuana Use

	(1) *Past Month Usage* *VT*	(2) *Past Month Usage* *MA, NH and NY*	(1) – (2)
<u>All ages</u>			
Before MML	0.087	0.068	0.019***
	(0.004)	(0.002)	(0.004)
After MML	0.101	0.075	0.026***
	(0.005)	(0.002)	(0.004)
Within-state difference	0.014**	0.007***	**0.007**
(row 2 – row 1)	(0.006)	(0.002)	**(0.005)**
<u>Ages 12 to 17</u>			
Before MML	0.122	0.092	0.031***
	(0.008)	(0.003)	(0.008)
After MML	0.103	0.082	0.021***
	(0.008)	(0.003)	(0.008)
Within-state difference	-0.019*	-0.009**	**-0.010**
(row 2 – row 1)	(0.012)	(0.004)	**(0.011)**
<u>Ages 18 to 25</u>			
Before MML	0.268	0.210	0.058***
	(0.011)	(0.004)	(0.011)
After MML	0.293	0.224	0.069***
	(0.012)	(0.004)	(0.012)
Within-state difference	0.025	0.014**	**0.011**
(row 2 – row 1)	(0.016)	(0.006)	**(0.016)**
<u>Ages 26 and older</u>			
Before MML	0.053	0.042	0.011*
	(0.006)	(0.002)	(0.006)
After MML	0.069	0.049	0.021***
	(0.007)	(0.002)	(0.006)
Within-state difference	0.016*	0.007**	**0.010**
(row 2 – row 1)	(0.009)	(0.003)	**(0.008)**

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Based on state-level estimates from the National Surveys on Drug Use and Health (NSDUH), provided by the Substance Abuse and Mental Health Services Administration (SAMHSA). Standard errors (in parentheses) are approximated using weighted means and raw sample sizes provided by the NSDUH. The "Before MML" period is 1999-2003; the "After MML" period is 2005-2009 (Vermont's MML came into effect on July 1, 2004).

Table 5. Descriptive Statistics for FARS Analysis (Dependent Variables)

Variable	Mean (SD)	Description
Fatalities Total	21.95 (7.09)	Number of fatalities per 100,000 licensed drivers
Fatalities (BAC > 0)	5.28 (2.16)	Number of any-BAC (>0.00) fatal crashes per 100,000 licensed drivers
Fatalities (BAC ≥ 0.10)	4.17 (1.79)	Number of high-BAC (≥0.10) fatal crashes per 100,000 licensed drivers
Fatalities (No Alcohol)	13.15 (4.25)	Number of fatal crashes with no indication of alcohol use per 100,000 licensed drivers
Variable	**Mean (SD)**	**Denominator**
Fatalities, 15-19 year-olds	25.20 (9.53)	per 100,000 15- through 19-year-olds
Fatalities, 20-29 year-olds	23.96 (8.37)	per 100,000 20- through 29-year-olds
Fatalities, 30-39 year-olds	15.63 (6.48)	per 100,000 30- through 39-year-olds
Fatalities, 40-49 year-olds	14.15 (5.63)	per 100,000 40- through 49-year-olds
Fatalities, 50-59 year-olds	13.36 (4.94)	per 100,000 50- through 59-year-olds
Fatalities, *60 plus*	17.68 (5.23)	per 100,000 60-year-olds and above
Fatalities males	20.78 (7.12)	per 100,000 males
Fatalities females	9.18 (3.27)	per 100,000 females
Fatalities weekends	9.38 (3.20)	per 100,000 licensed drivers
Fatalities weekdays	12.52 (4.02)	per 100,000 licensed drivers
Fatalities nighttime	11.17 (3.68)	per 100,000 licensed drivers
Fatalities daytime	10.60 (3.64)	per 100,000 licensed drivers

Note: Weighted means based on the FARS state-level panel for 1990-2009.

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Table 6. Descriptive Statistics for FARS Analysis (Independent Variables)

Variable	Mean (SD)	Description
MML[a]	0.122 (0.325)	= 1 if a state had a medical marijuana law in a given year, = 0 otherwise
Unemployment	5.65 (1.64)	State unemployment rate
Income	10.26 (0.16)	Natural logarithm of state real income per capita (2000 dollars)
Miles driven	14.12 (2.05)	Vehicle miles driven per licensed driver (thousands of miles)
Decriminalized[a]	0.316 (0.465)	= 1 if a state had a marijuana decriminalization law in a given year, = 0 otherwise
GDL[a]	0.501 (0.493)	= 1 if a state had a graduated driver licensing law with an intermediate phase in a given year, = 0 otherwise
Primary seatbelt[a]	0.430 (0.490)	= 1 if a state had a primary seatbelt law in a given year, = 0 otherwise
Secondary seatbelt[a]	0.547 (0.492)	= 1 if a state had a secondary seatbelt law in a given year, = 0 otherwise
BAC 0.08[a]	0.566 (0.487)	= 1 if a state had a .08 BAC law in a given year, = 0 otherwise
ALR[a]	0.723 (0.444)	= 1 if a state had an administrative license revocation law in a given year, = 0 otherwise
Zero Tolerance[a]	0.752 (0.424)	= 1 if a state had a “Zero Tolerance” drunk driving law in a given year, = 0 otherwise
Beer tax	0.252 (0.215)	Real beer tax (2000 dollars)
Speed 70	0.456 (0.498)	= 1 if a state had a speed limit of 70 mph or greater in a given year, = 0 otherwise

[a]Takes on fractional values during the years in which laws changed.

Note: Weighted by the number of licensed drivers in state *s* and year *t*.

Table 7. Traffic Fatalities and Medical Marijuana Laws: Baseline Results

	(1)	(2)	(3)	(4)
	Fatalities Total	*Fatalities Total*	*Fatalities Total*	*Fatalities Total*
MML	-0.248***	-0.102***	-0.082***	-0.091*
	(0.062)	(0.021)	(0.020)	(0.047)
N	1020	1020	1020	1020
R^2	0.061	0.950	0.964	0.975
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Covariates	No	No	Yes	Yes
State-specific trends	No	No	No	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Each column represents the results from a separate regression. The dependent variable is equal to the natural log of total fatalities per 100,000 licensed drivers; the covariates are listed in Table 6. Regressions are weighted using number of licensed drivers in state *s* and year *t*. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 8. Traffic Fatalities and Medical Marijuana Laws: The Role of Alcohol

	(1) *Fatalities (No Alcohol)*	(2) *Fatalities (BAC > 0)*	(3) *Fatalities (BAC ≥ 0.10)*
MML	-0.066	-0.127*	-0.150*
	(0.045)	(0.069)	(0.080)
N	1020	1019	1019
R^2	0.960	0.888	0.890
Year FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
Covariates	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Each column represents the results from a separate regression. The dependent variable is equal to the natural log of estimated fatal crashes per 100,000 licensed drivers; the covariates are listed in Table 6. Regressions are weighted using number of licensed drivers in state *s* and year *t*. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 9. Traffic Fatalities and Medical Marijuana Laws: The Timing of Laws

	(1) *Fatalities (BAC > 0)*	(2) *Fatalities (BAC ≥ 0.10)*
2-3 years before MML	0.009	-0.001
	(0.036)	(0.044)
1-2 years before MML	0.025	0.017
	(0.058)	(0.056)
0-1 year before MML	-0.036	-0.073
	(0.059)	(0.058)
Year of law change	-0.004	-0.033
	(0.055)	(0.060)
0-1 year after MML	-0.084	-0.119
	(0.078)	(0.090)
1-2 years after MML	-0.117	-0.145*
	(0.073)	(0.079)
2-3 years after MML	-0.228**	-0.282***
	(0.086)	(0.096)
3+ years after MML	-0.162*	-0.221**
	(0.088)	(0.094)
p-value: joint significance of lags	0.060*	0.044**
N	1019	1019
R^2	0.889	0.891
Year FE	Yes	Yes
State FE	Yes	Yes
Covariates	Yes	Yes
State-specific trends	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Each column represents the results from a separate regression. The dependent variable is equal to the natural log of estimated fatal crashes per 100,000 licensed drivers; the covariates are listed in Table 6. The omitted category is 3+ years before MML. Regressions are weighted using the number of licensed drivers in state *s* and year *t*. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 10. Traffic Fatalities and Medical Marijuana Laws by Day and Time

	(1) *Fatalities weekdays*	(2) *Fatalities weekend*	(3) *Fatalities day*	(4) *Fatalities night*
MML	-0.081	-0.100**	-0.070	-0.106*
	(0.053)	(0.043)	(0.046)	(0.054)
N	1020	1020	1020	1020
R^2	0.964	0.956	0.964	0.960
Year FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Each column represents the results from a separate regression. The dependent variable is equal to the natural log of fatalities per 100,000 licensed drivers; the covariates are listed in Table 6. Regressions are weighted using number of licensed drivers in state *s* and year *t*. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 11. Traffic Fatalities and Medical Marijuana Laws by Age

	(1) *Fatalities 15-19*	(2) *Fatalities 20-29*	(3) *Fatalities 30-39*	(4) *Fatalities 40-49*	(5) *Fatalities 50-59*	(6) *Fatalities 60 plus*
MML	-0.041	-0.211***	-0.184**	-0.122**	-0.040	-0.064
	(0.067)	(0.053)	(0.079)	(0.053)	(0.038)	(0.044)
N	1020	1020	1020	1020	1020	1020
R^2	0.912	0.942	0.942	0.940	0.895	0.915
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

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; the covariates are listed in Table 6. Regressions are weighted using the relevant state-by-age populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 12. Traffic Fatalities and Medical Marijuana Laws by Sex

	(1) *Fatalities males*	(2) *Fatalities females*
MML	-0.133**	-0.097*
	(0.052)	(0.054)
N	1020	1020
R^2	0.975	0.959
Year FE	Yes	Yes
State FE	Yes	Yes
Covariates	Yes	Yes
State-specific trends	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

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; the covariates are listed in Table 6. Regressions are weighted using the relevant state-by-sex populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 13. Number of Drinks, Binge Drinking and Medical Marijuana Laws: Evidence from the BRFSS

	(1) Males	(2) Females	(3) 18-19 yr.-olds	(4) 20-29 yr.-olds	(5) 30-39 yr.-olds	(6) 40-49 yr.-olds	(7) 50-59 yr.-olds	(8) 60 + yr.-olds
Number of Drinks								
MML	-1.51*	-0.65***	-1.39	-3.79***	-0.51	-0.71	-0.42	-0.27
	(0.77)	(0.23)	(1.08)	(1.42)	(0.77)	(0.63)	(0.46)	(0.50)
Mean # Drinks, MML = 0	16.08	5.463	10.68	15.03	11.06	10.66	9.66	7.101
N	852	852	852	852	852	852	852	852
R^2	0.768	0.898	0.353	0.638	0.645	0.708	0.786	0.885
Binge Drinking								
MML	-0.002	-0.007*	-0.000	-0.010	0.002	-0.010	0.001	-0.003
	(0.009)	(0.004)	(0.027)	(0.016)	(0.009)	(0.009)	(0.005)	(0.003)
Mean Incidence of Binge Drinking, MML = 0	0.220	0.079	0.208	0.280	0.186	0.139	0.094	0.037
N	855	855	855	855	855	855	855	855
R^2	0.834	0.895	0.528	0.825	0.795	0.815	0.778	0.774
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Each column represents the results from a separate regression. The dependent variables are the mean number of drinks consumed in the past 30 days and the rate of binge drinking in the past 30 days in state *s* and year *t*, and are based on information collected from the Behavioral Risk Factor Surveillance System (BRFSS) for the period 1990-2009. Controls include the state unemployment rate, per capita income, the relevant population size (e.g., the number of males in state *s* and year *t*), the state beer tax, and indicators for marijuana decriminalization, BAC 0.08, administrative license revocation, and Zero Tolerance. Regressions are weighted using sample sizes from the BRFSS. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 14. Per Capita Alcohol Sales and Medical Marijuana Laws

	(1) *State-level per capita beer sales (1990-2009)*	(2) *State-level per capita wine sales (1994-2009)*	(3) *State-level per capita spirits sales (1994-2009)*
MML	-0.054***	-0.012	-0.002
	(0.018)	(0.014)	(0.012)
N	1020	816	816
R^2	0.983	0.990	0.990
Year FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
State covariates	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: The dependent variable is equal to the natural log of per capita sales (measured in gallons) and is based on data from the *Brewers Almanac*, published by the Beer Institute. 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 Zero Tolerance. Regressions are weighted using state populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Appendix Table 1. Registry Information by State, 2011

	Number of registered patients	Chronic pain (%)	Male (%)	Average age	18-40 years of age (%)
Alaska	380[a]	…	…	…	…
Arizona	11,133	86	75	…	42
California	1,250,000[b]	…	…	…	…
Colorado	127,816	94	68	41	…
Hawaii	8,000[c]	…	…	…	…
Maine	796	…	…	…	…
Michigan	105,458	…	…	…	…
Montana	26,492	86	…	41	48
New Mexico	3,981	24	…	…	…
Oregon	49,220	65	…	…	…
Rhode Island	3,073	20	…	…	…
Vermont	349[d]	…	…	…	…
Washington	100,000[e]	…	…	…	…

[a]Based on a communication between NORML and the Alaska Bureau of Vital Statistics.
[b]Estimated by NORML.
[c]Estimated by the Drug Policy Forum of Hawaii.
[d]Based on a communication between NORML and the Vermont Criminal Information Center.
[e]Estimated by NORML.

Notes: Unless otherwise indicated, the information in this table was obtained from official state registry data. Links to state registry data are available at: http://norml.org/index.cfm?Group_ID=3391.

Appendix Table 2A. Traffic Fatalities and Medical Marijuana Laws by Age and Gender (Males)

	(1) *Fatalities 15-19*	(2) *Fatalities 20-29*	(3) *Fatalities 30-39*	(4) *Fatalities 40-49*	(5) *Fatalities 50-59*	(6) *Fatalities 60 plus*
MML	-0.073	-0.217***	-0.153*	-0.119**	-0.058*	-0.101**
	(0.059)	(0.062)	(0.081)	(0.058)	(0.031)	(0.043)
N	1019	1019	1020	1020	1018	1020
R^2	0.881	0.925	0.918	0.910	0.862	0.884
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

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; the covariates are listed in Table 6. Regressions are weighted using the relevant state-by-age populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Appendix Table 2B. Traffic Fatalities and Medical Marijuana Laws by Age and Gender (Females)

	(1) *Fatalities 15-19*	(2) *Fatalities 20-29*	(3) *Fatalities 30-39*	(4) *Fatalities 40-49*	(5) *Fatalities 50-59*	(6) *Fatalities 60 plus*
MML	0.036	-0.181***	-0.252***	-0.107*	-0.011	-0.007
	(0.088)	(0.036)	(0.088)	(0.059)	(0.080)	(0.057)
N	1011	1020	1010	1016	1006	1020
R^2	0.821	0.861	0.867	0.844	0.784	0.826
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

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; the covariates are listed in Table 6. Regressions are weighted using the relevant state-by-age populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Appendix Table 3A. Number of Drinks, Binge Drinking and Medical Marijuana Laws: Evidence from the BRFSS (Males)

	(1) 18-19 yr.-olds	(2) 20-29 yr.-olds	(3) 30-39 yr.-olds	(4) 40-49 yr.-olds	(5) 50-59 yr.-olds	(6) 60 + yr.-olds
Number of Drinks						
MML	-2.80	-4.90**	-0.42	-0.73	-0.54	-0.35
	(1.93)	(1.97)	(1.02)	(0.98)	(0.84)	(0.91)
Mean # Drinks, MML = 0	14.99	22.67	16.60	15.54	14.43	11.41
N	852	852	852	852	852	852
R^2	0.310	0.533	0.557	0.591	0.644	0.804
Binge Drinking						
MML	-0.013	-0.005	0.007	-0.011	0.006	-0.007
	(0.038)	(0.017)	(0.013)	(0.016)	(0.008)	(0.006)
Mean Incidence of Binge Drinking, MML = 0	0.270	0.388	0.274	0.205	0.147	0.066
N	855	855	855	855	855	855
R^2	0.475	0.753	0.724	0.708	0.662	0.672
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

Notes: Each column represents the results from a separate regression. The dependent variables are the mean number of drinks consumed in the past 30 days and the rate of binge drinking in the past 30 days in state *s* and year *t*, and are based on information collected from the Behavioral Risk Factor Surveillance System (BRFSS) for the period 1990-2009. Controls include the state unemployment rate, per capita income, the relevant population size (e.g., the number of males in state *s* and year *t*), the state beer tax, and indicators for marijuana decriminalization, BAC 0.08, administrative license revocation, and Zero Tolerance. Regressions are weighted using sample sizes from the BRFSS. Standard errors, corrected for clustering at the state level, are in parentheses.

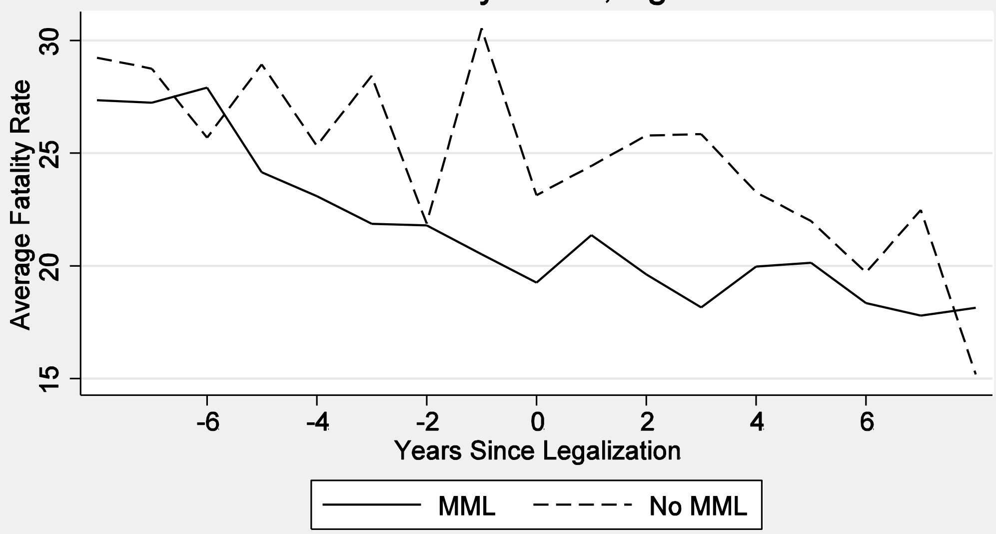
Appendix Table 3B. Number of Drinks, Binge Drinking and Medical Marijuana Laws: Evidence from the BRFSS (Females)

	(1) 18-19 yr.-olds	(2) 20-29 yr.-olds	(3) 30-39 yr.-olds	(4) 40-49 yr.-olds	(5) 50-59 yr.-olds	(6) 60 + yr.-olds
Number of Drinks						
MML	0.29	-1.55**	-0.58*	-0.74**	-0.28	-0.47
	(1.30)	(0.68)	(0.31)	(0.29)	(0.36)	(0.41)
Mean # Drinks, MML = 0	5.514	7.397	5.626	5.878	5.152	3.865
N	852	852	852	852	852	852
R^2	0.304	0.629	0.717	0.769	0.841	0.894
Binge Drinking						
MML	0.010	-0.016	-0.008	-0.010**	-0.003	-0.001
	(0.022)	(0.016)	(0.008)	(0.005)	(0.006)	(0.002)
Mean Incidence of Binge Drinking, MML = 0	0.137	0.172	0.099	0.074	0.043	0.015
N	855	855	855	855	855	855
R^2	0.423	0.792	0.777	0.835	0.804	0.755
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes	Yes	Yes

*Statistically significant at 10% level; **at 5% level; ***at 1% level.

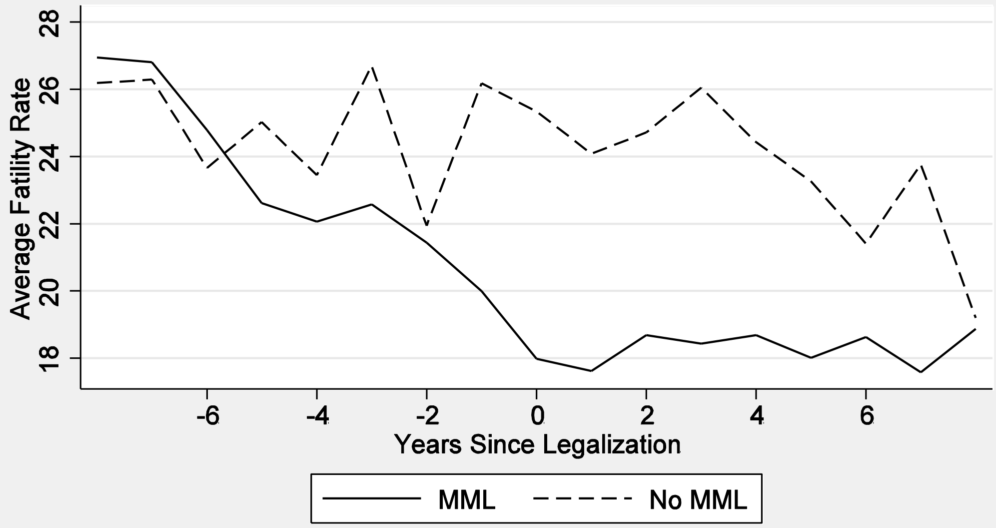
Notes: Each column represents the results from a separate regression. The dependent variables are the mean number of drinks consumed in the past 30 days and the rate of binge drinking in the past 30 days in state *s* and year *t*, and are based on information collected from the Behavioral Risk Factor Surveillance System (BRFSS) for the period 1990-2009. Controls include the state unemployment rate, per capita income, the relevant population size (e.g., the number of males in state *s* and year *t*), the state beer tax, and indicators for marijuana decriminalization, BAC 0.08, administrative license revocation, and Zero Tolerance. Regressions are weighted using sample sizes from the BRFSS. Standard errors, corrected for clustering at the state level, are in parentheses.

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



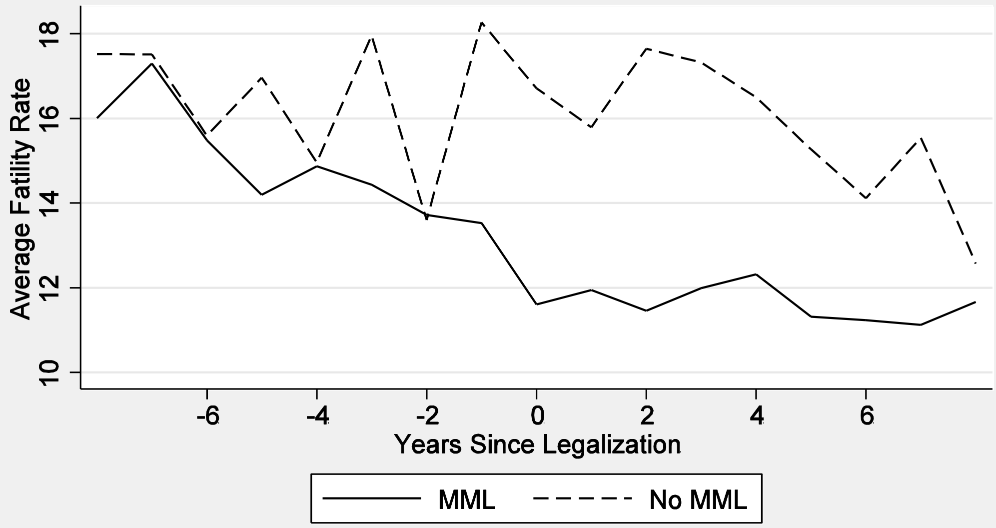
Fatality rates are weighted by the relevant population in state *s* and year *t*, but are otherwise unadjusted. On the horizontal axis, 0 represents the year in which medical marijuana was legalized. It was randomly assigned to states that did not legalize medical marijuana during the period under study (1990-2009).

Figure 2. Pre-and Post-Legalization Trends in Traffic Fatality Rates, Ages 20-29



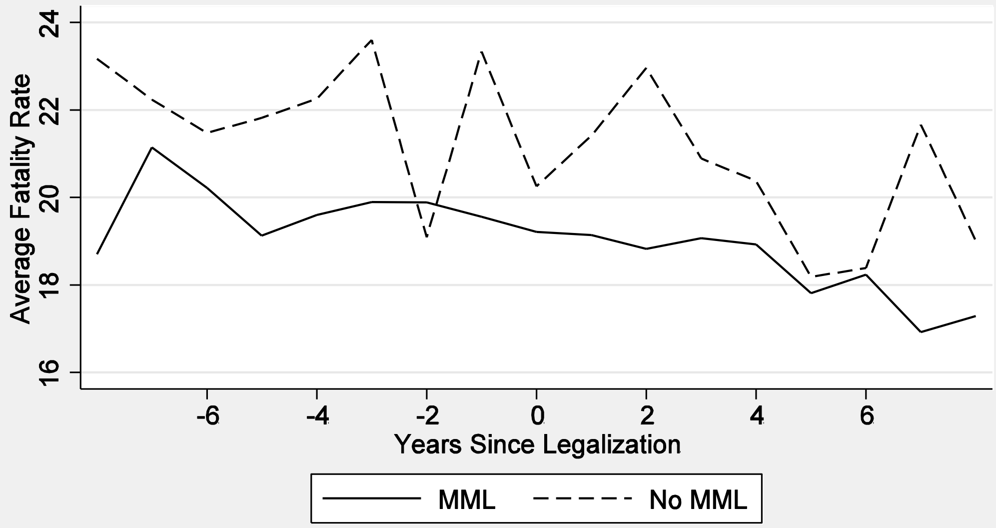
Fatality rates are weighted by the relevant population in state *s* and year *t*, but are otherwise unadjusted. On the horizontal axis, 0 represents the year in which medical marijuana was legalized. It was randomly assigned to states that did not legalize medical marijuana during the period under study (1990-2009).

Figure 3. Pre-and Post-Legalization Trends in
Traffic Fatality Rates, Ages 30-39



Fatality rates are weighted by the relevant population in state *s* and year *t*, but are otherwise unadjusted. 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 (1990-2009).

Figure 4. Pre-and Post-Legalization Trends
Traffic Fatality Rates, Ages 40 and above



Fatality rates are weighted by the relevant population in state *s* and year *t*, but are otherwise unadjusted. 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 (1990-2009).