Medical Marijuana Laws, Traffic Fatalities, and Alcohol Consumption

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To date, 17 states have passed medical marijuana laws, yet very little is known about their effects. The current study examines the relationship between the legalization of medical marijuana and traffic fatalities, the leading cause of death among Americans ages 5 through 34. 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, a pattern of results consistent with the hypothesis that marijuana and alcohol are substitutes. Because alternative mechanisms cannot be ruled out, the negative relationship between legalization 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.

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 obtain marijuana on their behalf.

On June 1, 2012 Connecticut became the 17th state, along with the District of Columbia, to enact a MML. 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 Americans 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. They argue that marijuana is addictive, serves as a gateway drug, has little medicinal value, and leads to criminal activity (Adams 2008; Blankstein 2010). Proponents argue 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 the use of other substances, nor the link between medical marijuana and criminal activity, has been substantiated (Belville 2011; Corry et al. 2009; Hoeffel 2011; Lamoureux 2011).

This study begins by exploring the effect of MMLs on the market for marijuana using price data collected from back issues of *High Times*, the leading cannabis-related magazine in the United States. Our results are consistent with anecdotal evidence that MMLs have led to a substantial increase in the supply of high-grade marijuana (Montgomery 2010). In contrast, the impact of MMLs on the market for low-quality marijuana appears to be modest.

Next, we turn our attention to MMLs and traffic fatalities, the primary relationship of interest. 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 1990-2010. Fourteen states and the District of Columbia 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.

The first full year after coming into effect, the legalization of medical marijuana is associated with an 8 to 11 percent decrease in traffic fatalities. However, the effect of MMLs on traffic fatalities involving alcohol is larger and estimated with more precision than the effect of MMLs on traffic fatalities that do not involve alcohol. In addition, 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 individual-level data from the Behavioral Risk Factor Surveillance System (BRFSS) for the period 1993-2010, we find that MMLs are associated with decreases in the probability of having consumed alcohol in the past month, binge drinking and the number of drinks consumed.

We conclude that alcohol is the likely mechanism through which the legalization of medical marijuana reduces traffic fatalities. However, this conclusion does not necessarily imply that driving under the influence of marijuana is safer than driving under the influence of alcohol. Alcohol is often consumed in restaurants and bars, while many states prohibit the use of medical marijuana in public. If marijuana consumption typically takes place at home or other private locations, then legalization could reduce traffic fatalities simply because marijuana users are less likely to drive while impaired.

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).

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.[2] Since 1996, 16 other states and the District of Columbia have joined California in legalizing the use of medical marijuana (Table 1), although it is still classified as a Schedule I drug by the Federal government.[3]

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) perhaps because drivers under the influence of tetrahydrocannabinol

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[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] 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.

[3] Information on when MMLs were passed was obtained from a recent Congressional Research Services Report by Eddy (2010). Although the New Jersey medical marijuana law came into effect on October 1, 2010, implementation has been delayed (Brittain 2012). Coding New Jersey as a non-medical marijuana state in 2010 has no appreciable impact on the results presented below.

(THC), the primary psychoactive substance in marijuana, engage in compensatory behaviors such as reducing their velocity, avoiding risky maneuvers, and increasing their "following distances" (Kelly et al. 2004; Sewell et al. 2009).

Like marijuana, alcohol impairs driving-related functions such as reaction time and hand-eye coordination (Kelly et al. 2004; Sewell et al. 2009). Moreover, simulator and driving-course studies provide unequivocal evidence 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). 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 chronic marijuana users may be less impaired by alcohol than infrequent users (Jones and Stone 1970; Marks and MacAvoy 1989; Wright and Terry 2002).[4]

2.3. The relationship between marijuana and alcohol

Although THC has not been linked to an increased risk of collision in simulator and driving-course studies, MMLs could impact traffic fatalities through the consumption of alcohol. While a number of studies have found evidence of complementarity between marijuana and alcohol (Pacula 1998; Farrelly et al. 1999; Williams et al. 2004), others lend support to the hypothesis that marijuana and alcohol are substitutes. For instance, Chaloupka and Laixuthai

[4] 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, while the likelihood of an accident occurring clearly increases with BAC levels (Sewell et al. 2009).

(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.

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 (2012) analyzed data from the National Survey on Drug Use and Health (NSDUH). They found that marijuana use decreased sharply at 21 years of age, evidence consistent with substitutability between alcohol and marijuana. In contrast, Yörük and Yörük (2011), who drew on data from the National Longitudinal Survey of Youth 1997 (NLSY97), concluded that alcohol and marijuana were complements. However, these authors appear to have inadvertently conditioned on having used marijuana at least once since the last interview. When Crost and Rees (forthcoming) applied Yörük and Yörük's (2011) research design to the NLSY97 data without conditioning on having used marijuana since the last interview, they found no evidence that alcohol and marijuana were complements.

3. MEDICAL MARIJUNA LAWS AND THE MARIJUANA MARKET

MMLs should, in theory, increase both the supply of marijuana and the demand for marijuana, unambiguously leading to an increase in consumption (Pacula et al. 2010). They afford suppliers some protection against prosecution, and allow patients to buy medical marijuana without fear of being arrested or fined, lowering the full cost of obtaining marijuana.[5]

[5] The majority of MMLs allow patients to register based on medical conditions that cannot be objectively confirmed (e.g. chronic pain and nausea). In fact, chronic pain is the most common medical condition among patients seeking treatment (Appendix Table 1). According to recent Arizona registry data, only 7 out of 11,186 applications for medical marijuana have been denied approval. Sun (2010) described "quick-in, quick-out mills," where physicians provide recommendations for a nominal fee. Cochran (2010) reported on doctors who provide medical marijuana recommendations to patients via brief web interviews on Skype.

Because it is prohibitively expensive for the government to ensure that all medicinal marijuana ends up in the hands of registered patients (especially in states that permit home cultivation), diversion to non-patients almost certainly occurs.[6]

The 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.[7] 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.

We collected price information from *High Times* for the period 1990 through 2011. Jacobson (2004), who collected information on the price of marijuana from *High Times* for the

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[6] Aside from Washington D.C. and New Jersey, all MMLs enacted during the period 1990-2010 allowed for home cultivation, and 8 out of 15 allowed patients or caregivers to cultivate collectively (Appendix Table 2). A recent investigation concluded that thousands of pounds of medical marijuana grown in Colorado are diverted annually to the recreational market (Wirfs-Brock et al. 2010). See also Thurstone et al. (2011) who interviewed 80 adolescents (15 through 19 years of age) undergoing outpatient substance abuse treatment in Denver. Thirty-nine of the 80 reported having obtained marijuana from someone with a medical marijuana license. Florio (2011) described the story of 4 8th-graders in Montana who received marijuana-laced cookies from a registered medical marijuana patient.

[7] Using these estimates, 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. Using NSDUH data for the years 2002 through 2009, Harper et al. (2012) found that legalization was associated with a small *reduction* in the rate of marijuana use among 12- through 17-year-olds. Using data for the period 1995–2002 from Denver, Los Angeles, Portland, San Diego and San Jose, Gorman and Huber Jr. (2007) found little evidence that marijuana consumption increased among adult arrestees as a result of legalization.

period 1975 through 2000, distinguished between high-quality (a category that included Californian and Hawaiian "sensimilla") and low-quality marijuana (a category that included commercial grade Colombian and Mexican "weed").[8] Following Jacobson (2004), we classified marijuana purchases by quality, and calculated the median per-ounce price by state and year.[9] Table 2A presents estimates of the following equation:

$$(1) \qquad \ln(\textit{Price High-Quality Marijuana}_{st}) = \beta_0 + \beta_1 MML_{st} + \boldsymbol{X_{st}\beta_2} + v_s + w_t + \varepsilon_{st},$$

where s indexes states and t indexes years. The variable MML_{st} indicates whether medical marijuana was legal in state s and year t, and β_1 represents the estimated relationship between legalization and the per-ounce price of high-quality marijuana. The vector $\boldsymbol{X_{st}}$ includes controls for the mean age in state s and year t, the unemployment rate, per capita income, whether the state had a marijuana decriminalization law in place, and the beer tax. State fixed effects,

[8] Plant variety (i.e., strain), which part of the plan is used, method of storage, and cultivation techniques are all important determinants of quality/potency (McLaren et al. 2008). In recent decades there has been a marked trend towards indoor cultivation and higher potency in the United States (McLaren et al. 2008). Jacobson (2004) argued that, ideally, prices would be deflated by a measure of potency. Unfortunately, information on potency is not available in the *High Times* data.

[9] A total of 8,271 purchases were coded. Of these, 7,029 were classified as high-quality and 1,242 were classified as low-quality. Prior to 2004, information on the seller was occasionally included in the Trans High Market Quotations section of *High Times*. Although dispensaries were never mentioned, they are a relatively recent phenomenon. The number of dispensaries in California expanded rapidly after 2004 (Jacobson 2011), and the number of dispensaries in Colorado and Montana expanded rapidly after 2008 (Smith 2011; Smith 2012). We compared *High Times* price data from 2011-2012 with price data posted on the internet by 84 dispensaries located in 7 states. In 4 out of the 7 states (California, Michigan, Nevada and Washington) prices charged by dispensaries were statistically indistinguishable from the prices provided by *High Times* readers. In Arizona, Colorado and Oregon, prices charged by dispensaries were significantly lower than prices provided by *High Times* readers; however, these differences were generally not large in magnitude. The greatest difference was in Colorado, where dispensaries, on average, charged 24.4 percent less per ounce ($72.8) than the prices provided by *High Times* readers. In Arizona, dispensaries, on average, charged 10.3 percent less per ounce ($36.6) than the prices provided by *High Times* readers; in Oregon, dispensaries, on average, charged 14.9 percent less per ounce ($37.2) than the prices provided by *High Times* readers. Dispensary price data are available at: www.legalmarijuanadispensary.com.

represented by v_s, control for time-invariant unobservables at the state level; year fixed effects, represented by w_t, control for common shocks to the price of high-quality marijuana.[10]

The baseline estimate, in column (1) of Table 2A, suggests that the supply response to legalization is larger than the demand response. Specifically, legalization is associated with a 26.2 percent ($e^{-0.304} - 1 = -0.262$) decrease in the price of high-quality marijuana. When we include state-specific linear time trends, intended to control for omitted variables at the state level that evolve at a constant rate, legalization is associated with a 9.8 percent decrease in the price of high-quality marijuana.

Lagging the MML indicator provides evidence that the effect of legalization on the price of high-quality marijuana is not immediate. Controlling for state-specific linear time trends, the estimated coefficients of the MML indicator lagged 1-3 years are negative, but not statistically significant. There is a statistically significant 24.6 percent reduction in the price of high-quality marijuana the fourth full year after legalization. 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.[11] Adding leads to the model with state-

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[10] Standard errors are corrected for clustering at the state level (Bertrand et al. 2004). Descriptive statistics are presented in Appendix Table 3. Mean age in state *s* and year *t* was calculated using Census data. Data on beer taxes are from the *Brewers Almanac*, an annual publication produced by the Beer Institute. The unemployment and income data are from the Bureau of Labor Statistics and the Bureau of Economic Analysis, respectively. Data on decriminalization laws are from Model (1993) and Scott (2010). During the period under study, the decriminalization indicator only captures two policy changes: Nevada and Massachusetts decriminalized the use of marijuana in 2001 and 2010, respectively. The majority of decriminalization laws were passed prior to 1990. Following Jacobson (2004), the estimates presented in Tables 2A and 2B are unweighted. When the regressions are weighted by the number of observations used to calculate median price and state-specific linear time trends are included on the right-hand side, estimates of the relationship between legalization and price are smaller and less precise. Nevertheless, they continue to show that legalization is associated with a statistically significant reduction in the price of high-quality marijuana after 4 years. When the regressions are weighted by the number of observations used to calculate median price but state-specific linear time trends are not included on the right-hand side, estimates of relationship between legalization and price are almost identical to those reported in Tables 2A and 2B.

[11] Appendix Table 1 presents registry information by state. Montana legalized medical marijuana in November 2004. Two years later, only 287 patients were registered; seven years later, 30,036 patients were registered. The

specific linear time trends produces no evidence that legalization was systematically preceded by changes in tastes or policies related to the market for high-quality marijuana.

Estimates of the relationship between legalization and the price of low-quality marijuana are presented in Table 2B. The majority of these estimates are negative. However, with two exceptions, they are statistically insignificant. Given that much of the medicinal crop is grown indoors under ultraviolet lights, and that high-potency and high-quality strains such as “Northern Lights” and “Super Silver Haze” are favored by medical marijuana cultivators, this imprecision is not surprising.

4. MEDICAL MARIJUNA LAWS AND TRAFFIC FATALITIES

The estimates discussed above suggest that legalization leads to a substantial decrease in the price of high-quality marijuana and, presumably, a correspondingly-large increase in consumption.[12] In this section, we test whether the impact of legalization extends to traffic fatalities.

4.1. Data on traffic fatalities

As noted above, we use data from the Fatal Accident Report System (FARS) for the period 1990-2010 to examine the relationship between MMLs and traffic fatalities. These data

number of registered patients in Colorado increased from 5,051 in January 2009 to 128,698 in June 2011. Patient numbers also appear to be growing rapidly in Arizona, which passed the Arizona Medical Marijuana Act on November 2, 2010. Eleven thousand one hundred and thirty-three patient applications had been approved as of August 29, 2011; 40,463 patient applications had been approved by June 30, 2012.

[12] If we assume, conservatively, that legalization has a negligible impact on demand, then the change in marijuana consumption is equal to the elasticity of demand multiplied by the percent change in price. Only a handful of papers have estimated the price elasticity of demand for marijuana. Using data on UCLA undergraduates, Nisbet and Vakil (1972) estimated a price elasticity of demand between -1.01 and -1.51; using data from Monitoring the Future on high school seniors, Pacula et al. (2001) estimated a 30-day participation elasticity between -0.002 and -0.69; using data from the Harvard College Alcohol Study, Williams et al. (2004) estimated a 30-day participation elasticity of -0.24.

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. Information on the circumstances of each crash and the persons and vehicles involved is 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.

Table 3 presents descriptive statistics and definitions for our outcome measures. $\textit{Fatalities Total}_{st}$ is equal to the number of traffic fatalities per 100,000 population of state *s* in year *t*.[13] The variables $\textit{Fatalities (BAC} > 0)_{st}$ and $\textit{Fatalities (BAC} \geq 0.10)_{st}$ allow us to examine the effects of legalization by alcohol involvement. $\textit{Fatalities (BAC} > 0)_{st}$ is equal to the number of traffic fatalities per 100,000 population resulting from accidents in which at least one driver had a positive blood alcohol concentration. $\textit{Fatalities (BAC} \geq 0.10)_{st}$ is defined analogously, but at least one driver had to have a blood alcohol concentration greater than or equal to 0.10. $\textit{Fatalities (No Alcohol)}_{st}$ is equal to the number of fatalities per 100,000 population in which alcohol involvement was not reported.[14] 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.[15] Focusing on nighttime and weekend fatal crashes can provide

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[13] Population data come from the National Cancer Institute and are available at: http://seer.cancer.gov/popdata/index.html. According to Eisenberg (2003), traffic fatalities in FARS are measured with little to no error. We experimented with scaling traffic fatalities by the population of licensed drivers and by the number of miles driven in state *s* and year *t* rather than by the state population. These estimates, which are similar in terms of magnitude and precision to those presented below, are available upon request.

[14] The numerator for $\textit{Fatalities (No Alcohol)}_{st}$ 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.

[15] We also experimented with calculating the alcohol-related fatality rates based on the imputed BAC levels available in the FARS data. These estimates, which are similar in terms of magnitude and precision to those

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.

According to state registry data, 75 percent of patients in Arizona, and 69 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 40.[16] To the extent that registered patients below the age of 40 are more likely to use medical marijuana recreationally, heterogeneous effects across the age distribution might be expected.

Figures 1-3 compare pre- and post-legalization traffic fatality trends by age group. The solid line represents the average traffic fatality rate for the treated states (those that legalized medical marijuana). The dashed line represents the average fatality rate for the 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 1996 and 2010.

Among teenagers (ages 15 through 19), young adults (ages 20 through 39) and older adults (ages 40 and above), average traffic fatality rates in the treated states closely follow those in the control states through year -1. This finding is important because it suggests that legalization was not preceded by, for instance, new anti-drunk driving policies, increased spending on law enforcement, or highway improvements. In the years immediately after

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presented below, are available upon request. See Adams et al. (2012) for a discussion of the BAC imputation method.

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

legalization, average traffic fatality rates in MML states fall faster than average traffic fatality rates in the control states. This divergence is most pronounced among 20 through 39 year olds. Among teenagers and older adults, average traffic fatality rates in MML states converge with average traffic fatality rates in the control states 4 to 5 years after legalization.

4.2. The empirical model

To further explore the relationship between legalization and traffic fatalities, we estimate the following baseline equation:

$$(2) \qquad \ln(\mathit{Fatalities\ Total}_{st}) = \beta_0 + \beta_1 MML_{st} + \boldsymbol{X_{st}\beta_2} + v_s + w_t + \varepsilon_{st},$$

where s indexes states and t indexes years. The coefficient of interest, β_1, represents the effect of legalizing medical marijuana.[17] In alternative specifications we replace $\mathit{Fatalities\ Total}_{st}$ with the remaining outcomes listed in Table 3.

The vector $\boldsymbol{X_{st}}$ is composed of the controls described in Table 4, 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 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), administrative license revocation laws (Freeman 2007), BAC laws (Dee 2001; Eisenberg 2003; Young and Bielinska-Kwapisz 2006; Freeman 2007), Zero Tolerance Laws (Carpenter

[17] This specification is based on Dee (2001), who examined the relationship between BAC 0.08 laws and traffic fatalities.

2004; Liang and Huang 2008; Grant 2010), and cellphone bans (Kolko 2009). 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).[18] In addition to these polices, we include mean age in state *s* and year *t*, the unemployment rate, real per capita income, vehicle miles driven per licensed driver, and indicators for marijuana decriminalization and whether a drug per se law was in place.[19]

4.3. The relationship between MMLs and traffic fatalities

Table 5 presents OLS estimates of the relationship between MMLs and traffic fatalities. The regressions are weighted by the population of state *s* in year *t*, and the standard errors are corrected for clustering at the state level (Bertrand et al. 2004). The baseline estimate, in column (1), suggests that legalization leads to a 10.4 percent decrease in the fatality rate.[20] When we include state-specific linear time trends, the estimate of β_1 retains its magnitude but is no longer statistically significant at conventional levels (p-value = 0.139).

[18] 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). Information on administrative license revocation laws and BAC limits is available from Freeman (2007). The FARS accident files were used to construct the variable *Speed 70*. Data on beer taxes are from the *Brewers Almanac*, an annual publication produced by the Beer Institute. Data on whether texting while driving was banned and whether using a handheld cellphone while driving was banned are from www.handsfreeinfo.com.

[19] Mean age in state *s* and year *t* was calculated using U.S. Census data. Information on vehicle miles driven per licensed driver is from *Highway Statistics*, an annual publication produced by the U.S. Department of Transportation. 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). The unemployment and income data are from the Bureau of Labor Statistics and the Bureau of Economic Analysis, respectively. Data on decriminalization laws are from Model (1993) and Scott (2010). Data on drug per se laws, which prohibit the operation of a motor vehicle with drugs (or drug metabolites) in the system, are from the National Highway Traffic Safety Administration (2010).

[20] 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 only a small impact on our estimate of β_1. In fact, when the covariates listed in Table 5 are excluded from the regression, the estimated coefficient reported in the first column of Table 5 changes from -0.110 to -0.118.

In columns (3) through (5), we lag the MML indicator. The MML lags are jointly significant and are, without exception, negative. However, there is evidence that the impact of legalization eventually wanes. The first full year after coming into effect, legalization is associated with an 8 to 11 percent reduction in the fatality rate.[21] The estimated coefficients increase in absolute magnitude until the fourth full year after legalization, when there is a 10 to 13 percent reduction in the fatality rate. After 5 years, the reduction is between 4 and 10 percent and only significant when the state-specific linear time trends are omitted. In the final column of Table 5, we add a series of MML leads to the model. Consistent with the graphical evidence in Figures 1-3, their estimated coefficients are small and jointly insignificant.

In Table 6, we replace *Fatalities Total*$_{st}$ with *Fatalities (No Alcohol)*$_{st}$, *Fatalities (BAC > 0)*$_{st}$, and *Fatalities (BAC* $\geq$ *0.10)*$_{st}$. The results suggest that MMLs are related to traffic fatalities through the consumption of alcohol. 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 a 13.2 percent decrease in fatalities involving alcohol, and a 15.5 percent decrease in fatalities resulting from accidents in which at least one driver had a BAC over 0.10. Lagging the MML indicator produces a similar

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[21] In comparison, Dee (1999) found that increasing the minimum legal drinking age (MLDA) to 21 reduced traffic fatalities by at least 9 percent among 18- through 20-year-olds. Kaestner and Yarnoff (2011) analyzed the long-term effects of MLDA laws. They found that raising the MLDA to 21 was associated with a 10 percent reduction in traffic fatalities among adult males. Carpenter and Stehr (2008) found that mandatory seatbelt laws decreased traffic fatalities among 14- through 18-year-olds by approximately 8 percent; Dee et al. (2005) found that graduated driver licensing laws decreased traffic fatalities among 15- through 17-year-olds by nearly 6 percent. Because all states raised their MLDA to 21 prior to 1990, we do not include it as a control. However, our estimates suggest that mandatory seatbelt laws decrease traffic fatalities among 15- through 19-year-olds by approximately 11 percent, and graduated driver licensing laws decrease traffic fatalities among 15- through 19-year-olds by approximately 6 percent. While the estimated relationship between 0.08 BAC laws and traffic fatalities is generally negative and often large, it is never statistically significant at conventional levels. This is consistent with the results of Young and Bielinska-Kwapisz (2006) and Freeman (2007) who found little evidence that 0.08 BAC laws reduced traffic fatalities. Finally, consistent with the results of Grant (2010), we find little evidence that Zero Tolerance laws reduce traffic fatalities.

pattern of results: the MML lags jointly predict crashes involving alcohol, but are insignificant in the *Fatalities (No Alcohol)*$_{st}$ equation.[22]

Table 7 provides additional evidence with regard to the role of alcohol consumption. The first two columns of Table 7 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 an 8.0 percent decrease in the weekday traffic fatality rate; in comparison, it is associated with a 10.9 percent decrease in the weekend traffic fatality rate. The former estimate is not significant at conventional levels, while the latter is significant at the 10 percent level.[23]

The remaining columns of Table 7 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 7.3 percent decrease in the daytime traffic fatality rate; in comparison, it is associated with an 11.0 percent decrease in the nighttime traffic fatality rate. The former estimate is not significant at conventional levels, while the latter is significant at the 10 percent level.[24]

Table 8 presents estimates of the relationship between MMLs and traffic fatalities by age. Among 15- through 19-year-olds, the estimate of β_1 is negative, but is small in magnitude and statistically insignificant. However, legalization is associated with a 16.7 percent decrease in the

[22] Restricting our attention to crashes in which at least one driver had a BAC greater than 0, legalization is associated with a (statistically insignificant) 11.6 percent decrease in fatalities among drunk drivers (BAC > 0) and their passengers. This estimate is similar in magnitude to the estimate in column (3) of Table 6. Nonetheless, we find evidence of third-party effects: legalization is associated with a 23.4 percent reduction in fatalities among sober drivers and their passengers, and a 19.9 percent reduction in fatalities among pedestrians, cyclists and individuals in other types of non-motorized vehicles.

[23] The hypothesis that these estimates are equal can be rejected at the 10 percent level.

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

fatality rate of 20- through 29 year-olds, and a 16.1 percent decrease in the fatality rate of 30- through 39-year-olds. Although registry data indicate that many medical marijuana patients are over the age of 40, estimates of β_1 are smaller and statistically insignificant among 40- through 49-year-olds, 50- through 59-year-olds, and individuals over the age of 60.

Table 9 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 10.8 percent decrease in the male traffic fatality rate as compared to a 6.9 percent decrease in the female fatality rate. The former estimate is significant at the 10 percent level, while the latter is not significant at conventional levels.[25] This pattern of results is consistent with registry data showing that the majority of medical marijuana patients are male.[26]

4.4. Tests of Endogeneity

Until this point in the analysis, we have addressed the possibility that legalization went hand in hand with other behaviors or policies related to traffic fatalities by employing a rich set of controls. Table 10 presents our attempts to tackle the endogeneity issue head on.

[25] The hypothesis that these estimates are equal can be rejected at the 5 percent level. Appendix Tables 4A and 4B 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 59.

[26] Roughly half of the states that have legalized medical marijuana permit collective cultivation, also known as "group growing." However, states such as Alaska, Hawaii, Maine, New Jersey, New Mexico and Vermont limit caregivers to one patient, prohibit collective cultivation by caregivers, or prohibit home cultivation altogether (Appendix Table 2). In these states, possession limits are easier to enforce, and illegal suppliers are easier to identify (Selecky 2008). Estimates available upon request suggest that the relationship between legalization and traffic fatalities is strongest when collective cultivation is permitted. Although negative, the estimated effect of legalization on traffic fatalities is smaller and statistically insignificant among states that prohibit collective cultivation.

First, we ran a series of regressions in which placebo MMLs were randomly assigned to control states.[27] Because 14 states and the District of Columbia legalized medical marijuana during the period 1990 through 2010, we assigned 15 placebos per trial. The estimated coefficient of the placebo MML was negative and statistically significant at the 10 percent level only 10 times out of 300 trials.

Next, we estimated the relationship between MMLs and traffic fatalities in which either tire or wheel failure was cited as a potential cause of the crash. Although road improvements, increased spending on road maintenance, and increased commercial vehicle inspections could reduce tire/wheel failure, we found little evidence of a relationship between legalization and this outcome. In fact, the estimated coefficient of the *MML* indicator was positive.

We also examined the relationship between MMLs and three variables that could have potentially influenced traffic fatalities: per capita police expenditures, per capita highway law enforcement expenditures, and per capita highway service and maintenance expenditures.[28] Again, the results provided little evidence of policy endogeneity: the estimated coefficient of the *MML* indicator was small and insignificant in all three of these regressions.

Finally, we examined whether the policy variables included in the vector $\boldsymbol{X}_{st}$ predict the passage of MMLs. The results are reported in Table 11. In column (2) of Table 11, we focus on alcohol-related policies, such as the beer tax and whether a 0.08 BAC limit was in effect. In column (3) we include marijuana decriminalization and drug per se laws, which prohibit the

[27] This approach is similar that of Luallen (2006), who examined the relationship between teacher strike days and juvenile crime. Assignment of the placebo MML was based on random numbers drawn from the uniform distribution.

[28] The data on per capita police expenditures are from the Bureau of Justice Statistics. The data on per capita highway law enforcement expenditures and per capita highway service and maintenance expenditures are from *Highway Statistics*, an annual publication produced by the U.S. Department of Transportation. Data on police expenditures are not available for the years 2001, 2003, and 2010; data on highway expenditures are not available for the District of Columbia.

operation of a motor vehicle with drugs (or drug metabolites) in the system. Neither the alcohol- nor drug-related policies predict the legalization of medical marijuana. However, when the full set of policy variables is included, we find evidence of a negative relationship between banning the use of handheld cell phones while driving and the probability of legalizing medical marijuana (column 4). This result raises the possibility that other, more difficult-to-measure, polices affecting traffic fatalities may be related to legalization.

5. MEDICAL MARIJUNA LAWS AND ALCOHOL CONSUMPTION

5.1. Evidence from the BRFSS

In this section, we use individual-level data from the Behavioral Risk Factor Surveillance System (BRFSS) to examine the effects of MMLs on direct measures of alcohol consumption. Begun in 1984 and 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). In 1993, the BRFSS was expanded to include all 50 states. As part of the core questionnaire, BRFSS respondents are asked:

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?

Using the answers to these questions, we constructed a variety of outcome variables, including: *Drank > 0*, an indicator for whether the respondent consumed alcohol in the past month; *30 + Drinks*, an indicator for whether the respondent had 30 or more drinks in the past month; *60 + Drinks*, an indicator for whether the respondent had 60 or more drinks in the past month; and

Number of Drinks, equal to the number of drinks consumed in the past month conditional on drinking.

Table 12 presents estimates of the following equation by age group for the period 1993-2010:

$$(3) \qquad Y_{ist} = \beta_0 + \beta_1 MML_{ist} + \boldsymbol{X_{st}\beta_2} + \boldsymbol{Z_{ist}\beta_3} + v_s + w_t + \Theta_s \cdot t + \varepsilon_{ist},$$

where Y_{ist} measures alcohol consumption, $\boldsymbol{X_{st}}$ is a vector of state-level controls, $\boldsymbol{Z_{ist}}$ is a vector of individual-level controls, and state-specific linear trends are represented by $\Theta_s \cdot t$.[29]

The estimates in Table 12 offer additional support for the hypothesis that legalization reduces traffic fatalities through its impact on alcohol consumption. They are uniformly negative and often statistically significant at conventional levels. Moreover, the relationship between legalization and alcohol consumption appears to be strongest among young adults, the group for whom the relationship between legalization and traffic fatalities was strongest.

For instance, 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).[30] During the period 1990-2010, almost one fourth of individuals killed in traffic

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[29] The vector $\boldsymbol{X_{st}}$ includes per capita income, the state unemployment rate, the beer tax, an indicator for whether a Zero Tolerance drunk driving law was in effect, and an indicator for whether a 0.08 BAC law was in effect. The vector $\boldsymbol{Z_{ist}}$ includes indicators for race, ethnicity, educational attainment, marital status, employment status, and the season in which the BRFSS interview took place.

[30] Descriptive statistics for the drinking outcomes are presented in Appendix Table 5.

accidents, and more than one third of individuals killed in traffic accidents involving alcohol, were between the ages of 20 and 29.[31]

BRFSS respondents are also asked how many times in the past month they binge drank, defined as having 5 or more alcoholic beverages on an occasion.[32] The estimates in Table 12 suggest that the legalization of medical marijuana leads to sharp reductions in binge drinking, a form of alcohol abuse considered to have "particularly high social and economic costs" (Naimi et al. 2003, p. 70). 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 40- through 49-year-olds, legalization is associated with an 8.8 percent (.013/.147) reduction in this probability. 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.

5.2. Evidence from alcohol sales

Information on alcohol sales is collected by the Beer Institute and published annually in the *Brewers Almanac*. Data on per-capita beer sales (in gallons) are available for the period 1990-2010. Data on per-capita wine and spirits sales (in gallons) are available for the period 1994-2010. We use these data to estimate the relationship between legalization and alcohol consumption at the state level.

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[31] 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 drinks consumed (p-value = 0.17) and a 12.2 percent decrease in traffic fatalities (p-value = 0.16), for an implied elasticity of 0.81 (i.e., 0.122/0.150).

[32] In 2006, the BRFSS began asking female respondents whether they had had 4 or more drinks on an occasion. Male respondents were asked whether they had had 5 or more drinks on an occasion throughout the period under study (1993-2010).

The results, presented in the top panel of Table 13, are consistent with the hypothesis that marijuana and beer are substitutes. Specifically, legalization is associated with an almost 5 percent increase in the consumption of beer, the most popular beverage among 18- through 29-year-olds (Jones 2008).[33] Legalization is negatively related to wine sales, and positively related to spirits sales, but these estimates are not statistically significant.

Estimates of the relationship between beer consumption and traffic fatalities using *MML* as an instrument are presented in the bottom panel of Table 13.[34] 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 in 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), while there is evidence that light and moderate drinkers are more responsive to increases in the price of alcohol than heavy drinkers (Manning et al. 1995). A 10 percent increase in per-capita beer sales is associated with a 24 percent increase in fatalities involving alcohol and a 32 percent increase in fatalities resulting from accidents in which at least one driver had a BAC greater than or equal to 0.10.

[33] 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).

[34] This empirical strategy is based on the assumption that legalization is related to traffic fatalities exclusively through beer consumption. Because the first-stage F-statistic for the null hypothesis that legalization is unrelated to beer consumption is less than 10, the standard proposed by Staiger and Stock (1997), the second-stage estimates should be interpreted cautiously.

6. CONCLUSION

To date, 17 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 information collected from back issues of *High Times*, a monthly magazine that advocates for the legalization of marijuana, we find that MMLs lead to a substantial decrease in the price of high-quality marijuana. Using data from the Fatality Analysis Reporting System (FARS) for the period 1990-2010, we find that traffic fatalities fall by 8 to 11 percent the first full year after legalization. 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 7.2 percent decrease in traffic fatalities in which there was no reported alcohol involvement, but this estimate is not statistically significant at conventional levels. In comparison, the legalization of medical marijuana is associated with a 13.2 percent decrease in fatalities in which at least one driver involved had a positive BAC level.

The negative relationship between the legalization of medical marijuana and traffic fatalities involving alcohol lends support to 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. We find that the legalization of medical marijuana is associated with reduced alcohol consumption, especially among young adults. Evidence from simulator and driving course studies provides a potential explanation for why substituting marijuana for alcohol could lead to fewer traffic fatalities. These studies show 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 through 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.[35] Even where it is not explicitly

[35] 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

prohibited, anecdotal evidence suggests that public use of medical marijuana can be controversial.[36] 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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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.

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

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Table 1. Medical Marijuana Laws, 1990-2010

	Effective date
Alaska	March 4, 1999
California	November 6, 1996
Colorado	June 1, 2001
District of Columbia	July 27, 2010
Hawaii	December 28, 2000
Maine	December 22, 1999
Michigan	December 4, 2008
Montana	November 2, 2004
Nevada	October 1, 2001
New Jersey	October 1, 2010
New Mexico	July 1, 2007
Oregon	December 3, 1998
Rhode Island	January 3, 2006
Vermont	July 1, 2004
Washington	November 3, 1998

Note: Medical marijuana laws came into effect in Arizona, Connecticut and Delaware after 2010.

Table 2A. Medical Marijuana Laws and the Price of High-Quality Marijuana, 1990-2011

	(1)	(2)	(3)	(4)	(5)
MML	-0.304***	-0.103*	…	…	…
	(0.037)	(0.058)			
3 years before MML	…	…	…	…	0.022
					(0.074)
2 years before MML	…	…	…	…	0.003
					(0.075)
1 year before MML	…	…	…	…	-0.037
					(0.076)
Year of law change	…	…	-0.117*	-0.059	-0.060
			(0.061)	(0.069)	(0.096)
1 year after MML	…	…	-0.156***	-0.082	-0.084
			(0.044)	(0.070)	(0.097)
2 years after MML	…	…	-0.203***	-0.110	-0.113
			(0.074)	(0.082)	(0.120)
3 years after MML	…	…	-0.211***	-0.128	-0.130
			(0.062)	(0.084)	(0.118)
4 years after MML	…	…	-0.387***	-0.283**	-0.286**
			(0.123)	(0.115)	(0.125)
5+ years after MML	…	…	-0.439***	-0.257**	-0.262*
			(0.048)	(0.116)	(0.145)
N	920	920	920	920	920
R^2	0.224	0.310	0.241	0.315	0.315
Year FEs	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes
State-specific trends	No	Yes	No	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 the median price of marijuana in state *s* and year *t*. The covariates are listed in Appendix Table 3. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 2B. Medical Marijuana Laws and the Price of Low-Quality Marijuana, 1990-2011

	(1)	(2)	(3)	(4)	(5)
MML	-0.096	-0.075	…	…	…
	(0.105)	(0.150)			
3 years before MML	…	…	…	…	0.135
					(0.197)
2 years before MML	…	…	…	…	0.103
					(0.108)
1 year before MML	…	…	…	…	-0.088
					(0.200)
Year of law change	…	…	-0.035	-0.056	-0.013
			(0.154)	(0.193)	(0.196)
1 year after MML	…	…	-0.250*	-0.182	-0.106
			(0.146)	(0.176)	(0.136)
2 years after MML	…	…	-0.058	-0.016	0.053
			(0.176)	(0.190)	(0.166)
3 years after MML	…	…	-0.244**	-0.114	-0.028
			(0.098)	(0.141)	(0.138)
4 years after MML	…	…	0.032	0.046	0.131
			(0.403)	(0.373)	(0.429)
5+ years after MML	…	…	-0.038	0.271	0.370
			(0.073)	(0.335)	(0.267)
N	483	483	483	483	483
R^2	0.720	0.748	0.723	0.751	0.753
Year FEs	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes
State-specific trends	No	Yes	No	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 the median price of marijuana in state *s* and year *t*. The covariates are listed in Appendix Table 3. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 3. Descriptive Statistics for FARS Analysis (Dependent Variables)

Variable	Mean (SD)	Description
Fatalities Total	14.58 (5.05)	Number of fatalities per 100,000 population
Fatalities (No Alcohol)	9.67 (3.45)	Number of fatalities per 100,000 population with no indication of alcohol involvement
Fatalities (BAC > 0)	3.97 (1.74)	Number of fatalities per 100,000 population where at least one driver involved had a BAC > 0.00
Fatalities (BAC ≥ 0.10)	3.13 (1.43)	Number of fatalities per 100,000 population where at least one driver involved had a BAC ≥ 0.10

Variable	Mean (SD)	Denominator
Fatalities, 15-19 year-olds	24.55 (9.75)	per 100,000 15- through 19-year-olds
Fatalities, 20-29 year-olds	23.59 (8.41)	per 100,000 20- through 29-year-olds
Fatalities, 30-39 year-olds	15.45 (6.49)	per 100,000 30- through 39-year-olds
Fatalities, 40-49 year-olds	14.00 (5.63)	per 100,000 40- through 49-year-olds
Fatalities, 50-59 year-olds	13.22 (4.93)	per 100,000 50- through 59-year-olds
Fatalities, 60 plus	17.39 (5.28)	per 100,000 60-year-olds and above
Fatalities males	20.48 (7.15)	per 100,000 males
Fatalities females	9.03 (3.29)	per 100,000 females
Fatalities weekdays	8.32 (2.88)	per 100,000 population
Fatalities weekends	6.22 (2.25)	per 100,000 population
Fatalities daytime	7.04 (2.59)	per 100,000 population
Fatalities nighttime	7.42 (2.60)	per 100,000 population

Note: Weighted means based on the FARS state-level panel for 1990-2010.

Table 4. Descriptive Statistics for FARS Analysis (Independent Variables)

Variable	Mean (SD)	Description
MML[a]	0.130 (0.334)	= 1 if a state had a medical marijuana law in a given year, = 0 otherwise
Mean age	35.90 (1.66)	Mean age of the state population
Unemployment	5.87 (1.87)	State unemployment rate
Income	10.27 (0.156)	Natural logarithm of state real income per capita (2000 dollars)
Miles driven	14.13 (2.05)	Vehicle miles driven per licensed driver (thousands of miles)
Decriminalized[a]	0.330 (0.470)	= 1 if a state had a marijuana decriminalization law in a given year, = 0 otherwise
Drug per se	0.142 (0.345)	= 1 if a state had a drug per se law in a given year, = 0 otherwise
GDL[a]	0.522 (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]	0.461 (0.494)	= 1 if a state had a primary seatbelt law in a given year, = 0 otherwise
Secondary seatbelt[a]	0.518 (0.494)	= 1 if a state had a secondary seatbelt law in a given year, = 0 otherwise
BAC 0.08[a]	0.584 (0.485)	= 1 if a state had a .08 BAC law in a given year, = 0 otherwise
ALR[a]	0.721 (0.445)	= 1 if a state had an administrative license revocation law in a given year, = 0 otherwise
Zero Tolerance[a]	0.763 (0.417)	= 1 if a state had a "Zero Tolerance" drunk driving law in a given year, = 0 otherwise
Beer tax	0.245 (0.207)	Real beer tax (2000 dollars)
Speed 70	0.462 (0.499)	= 1 if a state had a speed limit of 70 mph or greater in a given year, = 0 otherwise
Texting ban	0.041 (0.185)	= 1 if a state had a cell phone texting ban in a given year, = 0 otherwise
Hands Free	0.025 (0.150)	= 1 if a state had a "Hands Free" cell phone law in a given year, = 0 otherwise

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

Note: Weighted using state populations.

Table 5. Medical Marijuana Laws and Traffic Fatalities, 1990-2010

	(1) *Fatalities Total*	(2) *Fatalities Total*	(3) *Fatalities Total*	(4) *Fatalities Total*	(5) *Fatalities Total*
MML	-0.110***	-0.098	…	…	…
	(0.030)	(0.065)			
3 years before MML	…	…	…	…	-0.004
					(0.018)
2 years before MML	…	…	…	…	-0.001
					(0.030)
1 year before MML	…	…	…	…	-0.008
					(0.024)
Year of law change	…	…	-0.049**	-0.026	-0.029
			(0.023)	(0.029)	(0.028)
1 year after MML	…	…	-0.115***	-0.087*	-0.090*
			(0.036)	(0.051)	(0.048)
2 years after MML	…	…	-0.125**	-0.095	-0.099
			(0.059)	(0.080)	(0.074)
3 years after MML	…	…	-0.137***	-0.107	-0.111*
			(0.051)	(0.071)	(0.065)
4 years after MML	…	…	-0.138***	-0.108*	-0.112*
			(0.038)	(0.063)	(0.058)
5+ years after MML	…	…	-0.102***	-0.042	-0.047
			(0.026)	(0.062)	(0.059)
p-value: joint significance of lags			0.000***	0.089*	0.060*
N	1071	1071	1071	1071	1071
R^2	0.969	0.979	0.969	0.979	0.979
Year FEs	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes
State-specific trends	No	Yes	No	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 total fatalities per 100,000 population and the covariates are listed in Table 4. Regressions are weighted using state populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 6. Medical Marijuana Laws and Traffic Fatalities: The Role of Alcohol

	(1) *Fatalities No Alcohol*	(2) *Fatalities No Alcohol*	(3) *Fatalities BAC > 0*	(4) *Fatalities BAC > 0*	(5) *Fatalities BAC ≥ 0.10*	(6) *Fatalities BAC ≥ 0.10*
MML	-0.075	…	-0.141*	…	-0.168**	…
	(0.062)		(0.077)		(0.082)	
Year of law change	…	-0.026	…	-0.011	…	-0.041
		(0.031)		(0.040)		(0.051)
1 year after MML	…	-0.071	…	-0.103	…	-0.124
		(0.047)		(0.068)		(0.086)
2 years after MML	…	-0.085	…	-0.091	…	-0.117
		(0.079)		(0.083)		(0.081)
3 years after MML	…	-0.065	…	-0.237***	…	-0.292***
		(0.077)		(0.083)		(0.100)
4 years after MML	…	-0.076	…	-0.223**	…	-0.256**
		(0.063)		(0.092)		(0.105)
5+ years after MML	…	-0.024	…	-0.138*	…	-0.197**
		(0.062)		(0.081)		(0.090)
p-value: joint significance of lags		0.244		0.002***		0.082*
N	1071	1071	1071	1071	1071	1071
R^2	0.964	0.964	0.905	0.906	0.906	0.906
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 and the covariates are listed in Table 4. Regressions are weighted using state populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 7. Medical Marijuana Laws and Traffic Fatalities by Day and Time

	Fatalities weekdays	*Fatalities weekend*	*Fatalities daytime*	*Fatalities nighttime*
MML	-0.083	-0.115*	-0.076	-0.117*
	(0.069)	(0.061)	(0.066)	(0.069)
N	1071	1071	1071	1071
R^2	0.970	0.961	0.968	0.966
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 population and the covariates are listed in Table 4. Regressions are weighted using state populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 8. Medical Marijuana Laws and Traffic Fatalities by Age

	Fatalities 15-19	*Fatalities 20-29*	*Fatalities 30-39*	*Fatalities 40-49*	*Fatalities 50-59*	*Fatalities 60+*
MML	-0.022	-0.183**	-0.175*	-0.094	-0.038	-0.048
	(0.083)	(0.073)	(0.096)	(0.070)	(0.056)	(0.048)
N	1071	1071	1071	1071	1071	1071
R^2	0.915	0.940	0.943	0.939	0.874	0.921
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 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.

Table 9. Medical Marijuana Laws and Traffic Fatalities by Sex

	Fatalities males	*Fatalities females*
MML	-0.114*	-0.072
	(0.065)	(0.073)
N	1071	1071
R^2	0.974	0.960
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 and the covariates are listed in Table 4. Regressions are weighted using the relevant state-by-sex populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 10. Tests of Endogeneity

	Placebo MML			Falsification Test	Spending on Enforcement and Highway Services		
	Fatalities Total	*Fatalities BAC > 0*	*Fatalities BAC ≥ 0.10*	*Fatalities Tire or Wheel Failure a Factor*	*Police Expenditures*	*Highway Law Enforcement Expenditures*	*Highway Maintenance Expenditures*
Average *Placebo MML* estimate	0.003	0.011	0.012	…	…	…	…
MML	…	...	…	0.018 (0.147)	-0.009 (0.020)	-0.004 (0.051)	-0.092 (0.068)
N	1071	1071	1071	1020	919	1050	1050
Number of trials	100	100	100	…	…	…	…
Placebo Coefficient < 0	42	44	42	…	…	…	…
Placebo Coefficient < 0 and sig. at 5% level	2	3	3	…	…	…	…
Placebo Coefficient < 0 and sig. at 10% level	2	4	4				
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

Notes: The first three columns represent the results from a series of regressions in which 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 state populations and standard errors are corrected for clustering at the state level. In the fourth column, the dependent variable is equal to the natural log of fatalities per 100,000 population from crashes in which tire or wheel failure was cited as a potential contributing factor to the accident. Covariates are listed in Table 4, the regression is weighted using state populations, and the standard error, corrected for clustering at the state-level, is in parentheses. The remaining columns represent the results from separate regressions in which the dependent variable is equal to the natural log of the indicated spending measure. The covariates are the state unemployment rate and income per capita. Regressions are weighted using state populations, and standard errors, corrected for clustering at the state level, are in parentheses.

Table 11. Medical Marijuana Laws and State-Level Covariates

	(1) *MML*	(2) *MML*	(3) *MML*	(4) *MML*
Mean age	0.035	0.035	0.041	0.037
	(0.131)	(0.148)	(0.152)	(0.139)
Unemployment	-0.011	-0.015	-0.014	0.007
	(0.037)	(0.039)	(0.039)	(0.027)
Income	0.231	0.187	0.241	0.255
	(0.362)	(0.359)	(0.348)	(0.363)
Miles driven	0.004	0.006	0.005	0.015
	(0.008)	(0.009)	(0.009)	(0.013)
BAC 0.08	…	0.062	0.052	0.061
		(0.047)	(0.045)	(0.048)
ALR	…	-0.034	-0.027	-0.027
		(0.063)	(0.061)	(0.069)
Zero Tolerance	…	-0.091	-0.090	-0.075
		(0.066)	(0.065)	(0.053)
Beer tax	…	0.375	0.364	0.119
		(0.643)	(0.636)	(0.286)
Decriminalized	…	…	0.212	0.180
			(0.245)	(0.282)
Drug per se	…	…	0.035	0.015
			(0.049)	(0.039)
GDL	…	…	…	0.035
				(0.031)
Primary seatbelt	…	…	…	0.010
				(0.057)
Secondary seatbelt	…	…	…	0.020
				(0.040)
Speed 70	…	…	…	0.060
				(0.066)
Texting ban	…	…	…	0.013
				(0.049)
Hands Free	…	…	…	-0.348**
				(0.164)
N	1071	1071	1071	1071
R^2	0.869	0.873	0.874	0.884
State-level characteristics	Yes	Yes	Yes	Yes
Alcohol policies	No	Yes	Yes	Yes
Drug policies	No	No	Yes	Yes
Other traffic policies	No	No	No	Yes
Year FE	Yes	Yes	Yes	Yes
State FE	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. Regressions are weighted using state populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 12. Medical Marijuana Laws and Alcohol Consumption in the Past 30 Days: Evidence from the BRFSS

	All respondents	18-19 years of age	20-29 years of age	30-39 years of age	40-49 years of age	50-59 years of age	60 + years of age
Drank > 0	-0.019*	-0.051**	-0.031*	-0.022	-0.017	-0.016*	-0.012
	(0.010)	(0.020)	(0.017)	(0.014)	(0.012)	(0.009)	(0.008)
	[3884082]	[54296]	[378058]	[614541]	[739094]	[760147]	[1337946]
15 + Drinks	-0.010*	-0.022*	-0.015	-0.015**	-0.009	-0.014**	-0.004
	(0.006)	(0.011)	(0.011)	(0.008)	(0.006)	(0.005)	(0.005)
	[3884082]	[54296]	[378058]	[614541]	[739094]	[760147]	[1337946]
30 + Drinks	-0.009*	-0.017**	-0.018*	-0.008	-0.010*	-0.009**	-0.003
	(0.005)	(0.008)	(0.009)	(0.007)	(0.006)	(0.004)	(0.004)
	[3884082]	[54296]	[378058]	[614541]	[739094]	[760147]	[1337946]
60 + Drinks	-0.004	-0.008	-0.011**	-0.003	-0.005	-0.003	-0.002
	(0.003)	(0.007)	(0.005)	(0.005)	(0.003)	(0.003)	(0.002)
	[3884082]	[54296]	[378058]	[614541]	[739094]	[760147]	[1337946]
Binge Drank	-0.007*	-0.018*	-0.012	-0.007	-0.013**	-0.007*	-0.002
	(0.003)	(0.009)	(0.010)	(0.006)	(0.005)	(0.004)	(0.002)
	[3928524]	[55426]	[383970]	[621722]	[746974]	[767567]	[1352865]
2+ Binges	-0.004*	-0.010	-0.012*	-0.002	-0.006*	-0.005	-0.001
	(0.002)	(0.011)	(0.007)	(0.004)	(0.003)	(0.003)	(0.002)
	[3928524]	[55426]	[383970]	[621722]	[746974]	[767567]	[1352865]
Number of drinks	-0.84	-1.38	-2.40**	-0.70	-0.66	-0.93	-0.44
conditional on	(0.66)	(1.83)	(0.97)	(0.95)	(0.57)	(0.57)	(0.75)
drinking	[1900760]	[19944]	[222500]	[350855]	[414093]	[386371]	[506997]

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

Notes: Based on information collected from the Behavioral Risk Factor Surveillance System (BRFSS) for the period 1993-2010. Each cell represents the results from a separate regression. The covariates include indicators for race, ethnicity, sex, marital status, employment status and educational attainment, state fixed effects, year fixed effects, state-specific linear time trends, the unemployment rate, per capita income, the state beer tax, and indicators for marijuana decriminalization, BAC 0.08 and Zero Tolerance. Indicators for age group are included when using all BRFSS respondents. Standard errors, corrected for clustering at the state level, are in parentheses. Sample sizes are in brackets.

Table 13. Per-Capita Alcohol Sales, Medical Marijuana Laws and Traffic Fatalities

First-stage regressions

	ln(beer sales)	*ln(wine sales)*	*ln(spirits sales)*
MML	-0.049**	-0.008	0.002
	(0.022)	(0.013)	(0.011)
N	1071	867	867
R^2	0.981	0.990	0.990
F-test on instrument	4.8	0.36	0.03

Second-stage regressions

	Fatalities Total	*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
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: The dependent variable in the first-stage regressions 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. The dependent variable in the second-stage regressions is equal to the natural log of traffic fatalities per 100,000 population. 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. Available 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	128,698	94	69	40	…
Hawaii	8,000[c]	…	…	…	…
Maine	796	…	…	…	…
Michigan	105,458	…	…	…	…
Montana	30,036	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 2. Summary of Medical Marijuana Laws by State

Caregivers can have multiple patients or collective growing by patients is allowed		**Caregivers limited to one patient or collective growing by caregivers is prohibited**	
California	Caregivers can have multiple patients. Home cultivation and collectives/cooperatives allowed.	Alaska	Caregivers limited to one patient (unless a relative of more than one patient). Home cultivation allowed but dispensaries prohibited.
Colorado	Caregivers can have multiple patients. Home cultivation and dispensaries allowed.	District of Columbia	Caregivers limited to one patient. Home cultivation prohibited. Five licensed dispensaries and 10 cultivation facilities.
Michigan and Montana	Caregivers can have multiple patients. Home cultivation allowed.	Hawaii	Caregivers limited to one patient. Home cultivation allowed but dispensaries prohibited.
Nevada	Caregivers can have multiple patients. Home cultivation allowed. Dispensaries are prohibited.	Maine	Caregivers can have multiple patients but are prohibited from cultivating collectively. Home cultivation and a limited number of licensed, non-profit dispensaries are allowed.
Oregon	Caregivers can have multiple patients. Home cultivation for multiple patients allowed. Dispensaries are prohibited but collectives/ cooperatives are allowed.	New Jersey	Caregivers limited to one patient. Home cultivation prohibited. Ten licensed nonprofit dispensaries/cultivation centers.
Rhode Island	Caregivers can have multiple patients. Home cultivation and up to 3 licensed, non-profit compassion centers allowed.	New Mexico	Caregivers can have multiple patients but are prohibited from cultivating. Home cultivation allowed with license. Limited number of licensed, non-profit producers.
Washington	Caregivers limited to one patient, but home cultivation and collective cultivation by patients allowed.	Vermont	Caregivers limited to one patient. Home cultivation allowed. Four licensed, nonprofit dispensaries.

Notes: Based on information from the Marijuana Policy Project (www.mpp.org) and Jacobson et al. (2011).

Appendix Table 3. Descriptive Statistics for *High Times* Analysis, 1990-2011

Dependent Variable	Mean (SD)	Description
Price High-Quality Marijuana	313.25 (88.13)	Median per-ounce price of high quality marijuana (2000 dollars)
Price Low-Quality Marijuana	128.70 (64.24)	Median per-ounce price of low quality marijuana (2000 dollars)

Independent Variable	Mean (SD)	Description
MML[a]	0.135 (0.338)	= 1 if a state had a medical marijuana law in a given year, = 0 otherwise
Mean age	36.08 (1.78)	Mean age of the state population
Unemployment	5.70 (1.92)	State unemployment rate
Income	10.25 (0.173)	Natural logarithm of state real income per capita (2000 dollars)
Decriminalized[a]	0.250 (0.433)	= 1 if a state had a marijuana decriminalization law in a given year, = 0 otherwise
Beer tax	0.259 (0.230)	Real beer tax (2000 dollars)

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

Note: Price data are based on information from 8,271 purchases recorded in the Trans High Market Quotations section of *High Times*. Of these, 7,029 were classified as high-quality and 1,242 were classified as low-quality.

Appendix Table 4A. Traffic Fatalities and Medical Marijuana Laws by Age and Gender (Males)

	Fatalities 15-19	*Fatalities 20-29*	*Fatalities 30-39*	*Fatalities 40-49*	*Fatalities 50-59*	*Fatalities 60+*
MML	-0.071	-0.189**	-0.158*	-0.095	-0.040	-0.087*
	(0.067)	(0.080)	(0.089)	(0.074)	(0.059)	(0.046)
N	1071	1071	1071	1071	1071	1071
R^2	0.884	0.924	0.920	0.909	0.842	0.892
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 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.

Appendix Table 4B. Medical Marijuana Laws and Traffic Fatalities by Age and Gender (Females)

	Fatalities 15-19	*Fatalities 20-29*	*Fatalities 30-39*	*Fatalities 40-49*	*Fatalities 50-59*	*Fatalities 60+*
MML	0.037	-0.159***	-0.221*	-0.076	-0.040	0.019
	(0.123)	(0.058)	(0.127)	(0.080)	(0.079)	(0.059)
N	1071	1071	1071	1071	1071	1071
R^2	0.789	0.861	0.833	0.824	0.703	0.838
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.

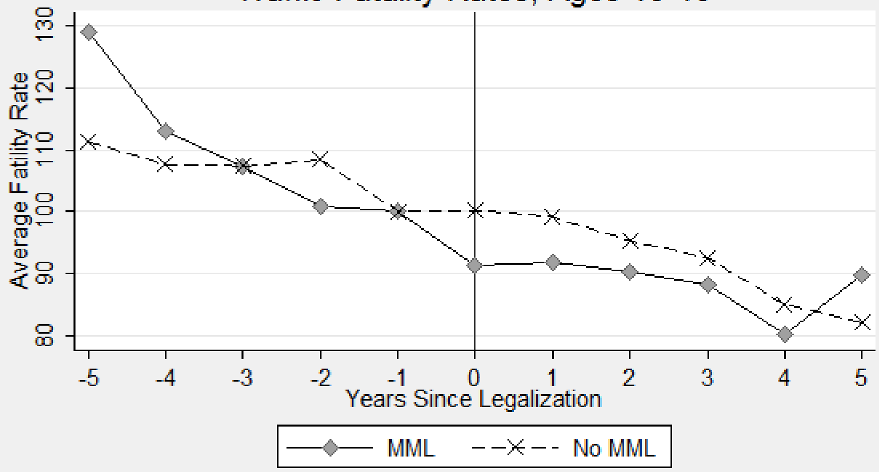
Notes: Each column represents the results from a separate regression. The dependent variable is equal to the natural log of fatalities per 100,000 population and the covariates are listed in Table 4. Regressions are weighted using the relevant state-by-age populations. Standard errors, corrected for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

Appendix Table 5. Alcohol Consumption in the Past 30 Days: Variable Means

	All BRFSS respondents	18-19 years of age	20-29 years of age	30-39 years of age	40-49 years of age	50-59 years of age	60 + years of age
Drank > 0	0.489 [3884082]	0.367 [54296]	0.589 [378058]	0.571 [614541]	0.560 [739094]	0.508 [760147]	0.379 [1337946]
15 + Drinks	0.188 [3884082]	0.147 [54296]	0.237 [378058]	0.200 [614541]	0.210 [739094]	0.196 [760147]	0.154 [1337946]
30 + Drinks	0.106 [3884082]	0.091 [54296]	0.129 [378058]	0.100 [614541]	0.110 [739094]	0.111 [760147]	0.097 [1337946]
60 + Drinks	0.044 [3884082]	0.047 [54296]	0.056 [378058]	0.038 [614541]	0.045 [739094]	0.048 [760147]	0.041 [1337946]
Binge Drank	0.118 [3928524]	0.192 [55426]	0.258 [383970]	0.180 [621722]	0.147 [746974]	0.102 [767567]	0.040 [1352865]
2+ Binges	0.073 [3928524]	0.131 [55426]	0.163 [383970]	0.105 [621722]	0.090 [746974]	0.065 [767567]	0.026 [1352865]
Number of drinks conditional on drinking	20.26 (35.28) [1900760]	26.91 (51.03) [19944]	22.71 (40.56) [222500]	18.32 (33.05) [350855]	19.74 (35.16) [414093]	20.39 34.87 [386371]	20.61 (33.80) [506997]

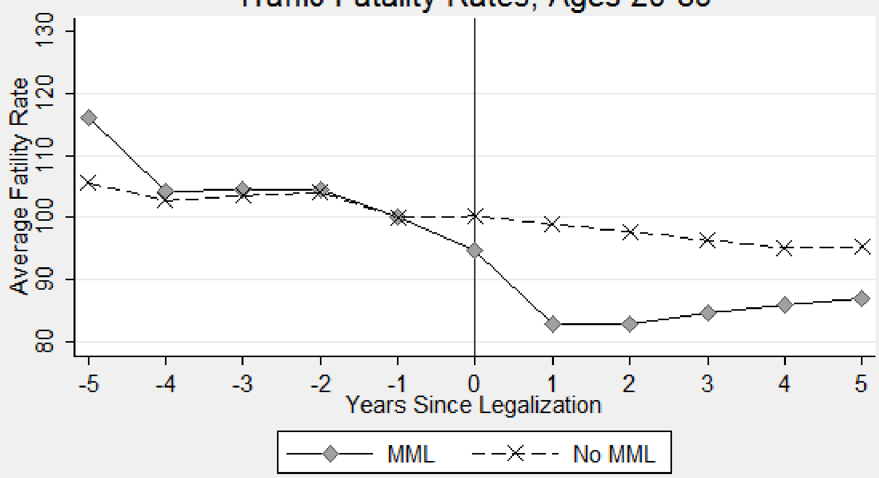
Notes: Based on information collected from the Behavioral Risk Factor Surveillance System (BRFSS) for the period 1993-2010. Standard deviations are in parentheses and sample sizes are in brackets.

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



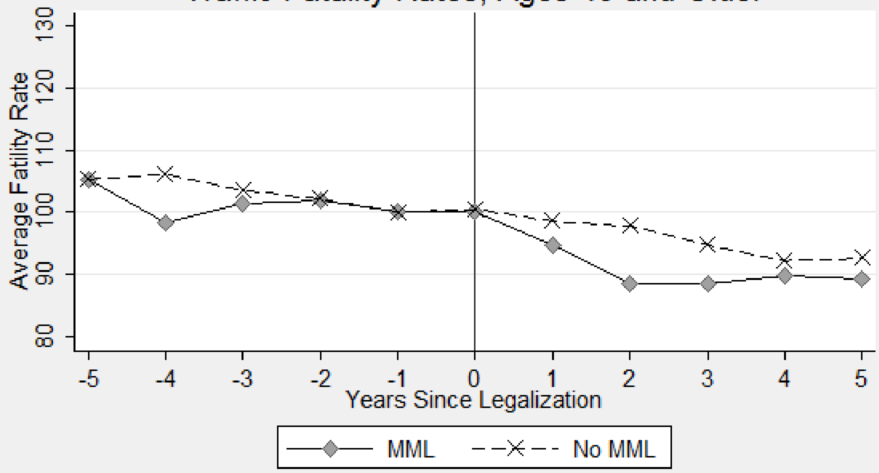
Based on FARS data for the period 1990-2010. On the horizontal axis, *0* represents the year in which medical marijuana was legalized. It was randomly assigned to states that did not legalize medical marijuana during the period under study. Fatality rates are expressed relative to year *-1*, and are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