NBER WORKING PAPER SERIES

MEDICAL MARIJUANA LAWS AND TEEN MARIJUANA USE

D. Mark Anderson
Benjamin Hansen
Daniel I. Rees

Working Paper 20332
http://www.nber.org/papers/w20332

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2014

Medical Marijuana Laws and Teen Marijuana Use
D. Mark Anderson, Benjamin Hansen, and Daniel I. Rees
NBER Working Paper No. 20332
July 2014
JEL No. D78,I1,K4

ABSTRACT

While at least a dozen state legislatures in the United States have recently considered bills to allow the consumption of marijuana for medicinal purposes, the federal government is intensifying its efforts to close medical marijuana dispensaries. Federal officials contend that the legalization of medical marijuana encourages teenagers to use marijuana and have targeted dispensaries operating within 1,000 feet of schools, parks and playgrounds. Using data from the national and state Youth Risk Behavior Surveys, the National Longitudinal Survey of Youth 1997 and the Treatment Episode Data Set, we estimate the relationship between medical marijuana laws and marijuana use. Our results are not consistent with the hypothesis that legalization leads to increased use of marijuana by teenagers.

D. Mark Anderson
Department of Agricultural Economics and Economics
Montana State University
P.O. Box Box 173700
Bozeman, MT 59717-3700
dwight.anderson@montana.edu

Benjamin Hansen
Department of Economics
1285 University of Oregon
Eugene, OR 97403
and NBER
bchansen@uoregon.edu

Daniel I. Rees
University of Colorado Denver
Department of Economics
Campus Box 181
P.O. Box 173364
Denver, CO 80217-3364
Daniel.Rees@ucdenver.edu

These last couple years, the amount of attention that's been given to medical marijuana has been huge. And when I've done focus groups with high school students in states where medical marijuana is legal, they say "Well, if it's called medicine and it's given to patients by caregivers, then that's really the wrong message for us as high school students."

--R. Gil Kerlikowske, Director of the Office of National Drug Control Policy

1. INTRODUCTION

Tobacco and alcohol use by American high school students has been declining since the mid-1990s. Marijuana use followed a similar trend until the mid-2000s, when, according to data from Monitoring the Future, there was a 3 to 4 percentage-point increase in the percentage of high school students who reported having smoked marijuana in the past 30 days accompanied by a similarly-sized decrease in the percentage of 10^{th} and 12^{th} graders who view regular marijuana use as risky (Johnston et al. 2011). Federal officials, including the Director of the Office of National Drug Control Policy (also known as the "Drug Czar"), have attributed these developments to the legalization of medical marijuana, noting that the medical marijuana industry has grown dramatically since the mid-2000s.

In an effort to combat youth marijuana use, John Walsh, the U.S. Attorney for Colorado, recently sent letters to medical marijuana dispensaries located within 1,000 feet of schools asking them to relocate or close. Walsh cited figures from the Colorado Department of Education showing that drug-related school suspensions, expulsions and law enforcement referrals increased dramatically from 2008 through 2011 (Ingold 2012), and he was quoted as saying that many school districts in Colorado "have seen a dramatic increase in student abuse of marijuana, with resulting student suspensions and discipline" (McCrimmon and Jones 2012). Melinda Haag, the U.S. Attorney for the Northern California district, has targeted dispensaries located within 1,000 feet of schools, parks, and playgrounds, arguing that marijuana serves as a gateway

drug and that, because "brains are not fully developed until your mid 20s", youth are particularly susceptible to its effects (Brooks 2012). Local law enforcement authorities have also argued that there is a connection between the legalization of medical marijuana and the use of marijuana by teenagers. For instance, Tim O'Connell, the Deputy Police Chief in Billings, Montana, was quoted by Uken (2012) as saying, "We are definitely seeing an increase in the schools, and it's definitely related to bad legislation…We can thank the passage of legalizing marijuana."

There is, in fact, evidence that adolescents and young adults who use marijuana are more likely to use other substances such as alcohol and cocaine (Saffer and Chaloupka 1999; DeSimone and Farrelly 2003; Williams et al. 2004; Yörük and Yörük 2011), as well as evidence that they are more likely to suffer from mental health problems (Fergusson et al. 2003; van Ours and Williams 2011), partake in risky sexual behaviors (Rashad and Kaestner 2004), and do poorly in school (Yamada et al. 1996; Roebuck et al. 2003; van Ours and Williams 2009). However, only two previous studies have examined the relationship between medical marijuana laws (hereafter MMLs) and marijuana use among minors.[1] Drawing on data from the National Survey on Drug Use and Health (NSDUH) for the years 2002 through 2007, Wall et al. (2011) found that rates of marijuana use among 12- through 17-year-olds were higher in states that had

[1] Several studies have examined the relationship between MMLs and marijuana consumption without focusing on minors. Khatapoush and Hallfors (2004) used data on 16- though 25-year-olds living in California and 10 other states. They found no evidence that marijuana consumption went up after California legalized medical marijuana in 1996. 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 the legalization of medical marijuana. Chu (2013) found that legalization was associated with an increase in arrests of young adult males for marijuana possession. Cerdá et al. (2012) examined the cross-sectional relationship between MMLs and marijuana use among adults 18 years of age and above. Other studies have examined the relationship between the decriminalization of marijuana and marijuana use (Thies and Register 1993; Saffer and Chaloupka 1999; Damrongplasit et al. 2010; Williams 2004). See also Van het Loo et al. (2002) who discussed the decriminalization of drug use in Portugal, and Adda et al. (2011) who analyzed the relationship between the depenalization of cannabis possession and crime in London.

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 (p. 714). Drawing on 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.

The current study examines the relationship between MMLs and marijuana consumption among high school students using data from the national and state Youth Risky Behavior Surveys (YRBS) for the years 1993 through 2011. These data cover a period when 16 states, including Alaska, California, Maine, Oregon and Washington, legalized medical marijuana.[2] The NSDUH did not provide information on substance use at the state level prior to 1999. As a consequence, neither Wall et al. (2011) nor Harper et al. (2012) had information on substance use among 12- through 17-year-olds in these states before legalization occurred.

Another advantage to using the YRBS data is that they contain information on the behavior and characteristics of individuals, allowing us to examine the relationship between MMLs and marijuana use by age and gender. With two exceptions (Khatapoush and Hallfors 2004; Cerdá et al. 2012), previous studies in this area have relied on aggregate data, despite the fact that the choice to smoke marijuana is made at the individual level. Finally, the YRBS data contain information on marijuana use and availability at school. These outcomes are of special interest given the current efforts in California and Colorado to close dispensaries operating near schools.

[2] Appendix Table 1 provides a list of states that have legalized medical marijuana during the period 1993 through 2011. A number of states legalized medical marijuana prior to 1999, including California, Oregon and Washington. The District of Columbia legalized medical marijuana on July 27, 2010. Although the New Jersey medical marijuana law came into effect on October 1, 2010, implementation was delayed (Brittain 2012). Coding New Jersey as a non-medical marijuana state in 2011 has no appreciable impact on the results presented below.

Our results suggest that the legalization of medical marijuana is not accompanied by increases in the use of marijuana among high school students. Specifically, estimates from our preferred specification are small, negative and statistically indistinguishable from zero. Using the 95 percent confidence interval around these estimates suggests that the impact of legalizing medical marijuana on the probability of marijuana use in the past 30 days is no larger than 0.8 percentage points.

In addition to analyzing data from the YRBS, we conduct two complementary analyses. The first uses data from the National Longitudinal Survey of Youth 1997 (NLSY97). The behavior of NLSY97 respondents can be observed over time, allowing for the estimation of models that control for unobserved heterogeneity at the individual level. The second uses data from the Treatment Episode Data Set (TEDS), which contains information from drug treatment providers on patients who reported using marijuana before being admitted. These analyses provide further evidence that youth marijuana consumption does not increase with the legalization of medical marijuana.

2. BACKGROUND

In 1996, California became the first state to legalize medical marijuana. Since then, 20 additional states and the District of Columbia have legalized medical marijuana, and more than a dozen state legislatures have recently considered medical marijuana bills (Klofas and Letteney 2012). In addition to removing criminal penalties for using, possessing and cultivating medical marijuana, medical marijuana laws provide immunity from prosecution to physicians who recommend medical marijuana to their patients.

While the therapeutic properties of marijuana are the subject of debate (Gilman 2005; Cohen 2009), the client base of doctors who recommend medical marijuana has expanded to include adolescents with conditions such as autism, insomnia, obsessive compulsive disorder, and attention deficit hyperactivity disorder (Browstein 2009; Ellison 2009; Joseph et al. 2010).[3] Advocates of recommending medical marijuana for these conditions maintain that it is safer than alternative medicines such as methylphenidate (also known as "Ritalin"), the stimulant most often prescribed to treat attention deficit hyperactivity disorder (Lucido 2004; Ellison 2009), and zolpidem tartrate (also known as "Ambien"), a medication prescribed to treat insomnia (Chaboya-Hembree 2012).

Patients under the age of 18 must have the permission of a parent or legal caregiver in order to use medical marijuana, and must be accompanied by a parent or legal caregiver when visiting a dispensary (Ellison 2009). Moreover, there is evidence from registry data that only a small percentage of medical marijuana patients are minors. For instance, only 0.08 percent of medical marijuana patients are under the age of 18 in Arizona; in Montana, 0.13 percent of patients are under the age of 18.[4] However, 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, diversion to the recreational market almost certainly occurs, and ambiguity surrounding the source of supply creates legitimacy for illegal suppliers and decreases

[3] Medical marijuana has also been used to treat adolescents suffering from chronic pain. Belkin (2009) described the case of a 9-year-old autistic boy who used medical marijuana to treat constant pain.

[4] Arizona and Montana are the only MML states that publicly record the age distribution of registered patients.

the risk of selling marijuana to recreational users (Pacula et al. 2010).[5] These supply-side factors could, in theory, lead to lower prices in the illegal market and increase youth consumption.

On the demand side, researchers, policymakers and law enforcement officials contend that legalization reduces the stigma associated with the use of marijuana (Roan 2011; Suthers 2012; Uken 2012) and encourages young people to underestimate the health risks associated with marijuana use (O'Connor 2011; Roan 2011). In addition, legalization could increase demand by providing more opportunities for young people to interact with legitimate users (Pacula et al. 2010). Not surprisingly, past research has shown that attitudes and perceptions with regard to the harmfulness of marijuana are strongly correlated with use (Bachman et al. 1998; Pacula et al. 2001).

Our empirical analysis is reduced-form, based on the approach taken by previous researchers interested in the determinants of marijuana use. For instance, Farrelly et al. (1999) examined the reduced-form relationship between more stringent anti-marijuana policies and marijuana use, while Thies and Register (1993), Saffer and Chaloupka (1999) and Williams (2004) examined the impact of decriminalization. In a similar vein, Pacula (1998), Farrelly et al. (2001), and Williams et al. (2004) examined the impact of alcohol and cigarette policies on marijuana use.

[5] It has been estimated that thousands of pounds of surplus medical marijuana are diverted to the illegal market in Colorado (Wirfs-Brock et al. 2010), and there is anecdotal evidence that MMLs have led to a substantial increase in the supply of high-grade marijuana in California (Montgomery 2010). Consistent with this anecdotal evidence, Anderson et al. (2013) found that the legalization of medical marijuana was associated with a substantial reduction in the price of high-quality marijuana. Thurstone et al. (2011) 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 four eighth-graders in Montana who received marijuana-laced cookies from a medical marijuana cardholder.

These studies provide some evidence that marijuana use is sensitive to changes in policy. For example, Farrelly et al. (1999) found that stricter enforcement of marijuana laws by police and higher fines for marijuana possession decreased use among adults. However, Farrelly et al. (1999) found that these policies had little impact on marijuana use among those under the age of 21. Using data from the United States, Thies and Register (1993) found that decriminalization did not lead to increased use of marijuana, while Saffer and Chaloupka (1999) found that decriminalization increased the probability of having smoked marijuana in the past 30 days. Using Australian data, Williams (2004) found that decriminalization increased marijuana use among males over the age of 25, but had no effect on marijuana use by females or by younger males. Finally, Farrelly et al. (2001) found that cigarette taxes were negatively related to marijuana use, while Williams et al. (2004) found that cigarette prices were essentially unrelated to marijuana use.

3. THE DATA

The primary data for this study come from the national and state YRBS. They are at the individual (micro) level and cover the period 1993 through 2011.[6] The national YRBS is conducted biennially by the Centers for Disease Control and Prevention (CDC) and is a nationally representative sample of U.S. high school students. Federal agencies rely upon the national YRBS to track trends in adolescent behavior including eating and exercise habits, violence, sexuality, and substance use. Previous studies such as Merrill et al. (1999) and Abdel-Ghany and Wang (2003) have used these data to examine determinants of youth marijuana use.

[6] The national YRBS was first conducted in 1991. However, because the 1991 wave is based on only a handful of schools, we chose to omit it from the analysis.

The state surveys are coordinated by the CDC and are administered by state education and health agencies. Like the national YRBS, the state YRBS is school-based and contains multiple items designed to elicit information on risky behaviors. To our knowledge, no previous study has used state YRBS data to examine the determinants of youth marijuana use.

Our analysis draws on both of these data sources in order to ensure that identification is based on as many MML changes as possible. Although intended to be nationally representative, not all 50 states are represented in any given wave of the national YRBS. In fact, between 1993 and 2011, only 6 states contributed data to the national YRBS every year (California, Florida, Georgia, Michigan, New York, and Texas), and 11 states contributed data to the national YRBS before and after the legalization of medical marijuana (Arizona, California, Colorado, Delaware, Hawaii, Maine, Michigan, New Jersey, New Mexico, Oregon, and Washington). Appendix Table 2 shows the number of observations by year and state in the national YRBS. States that legalized medical marijuana are denoted with a star superscript and post-legalization observations are italicized.[7]

With a few exceptions, most states conducted their own version of the YRBS sometime between 1993 and 2011, and at least 15 administered the YRBS in any given year during this period.[8] However, only 24 states have given the CDC permission to release their data, while 20 states require that requests to use their data be made directly. We obtained data from 11 of these 20 states, bringing our total to 35, 11 of which conducted surveys before and after the

[7] In the regression analyses, the fraction of the year that the law was in effect was used when a state legalized medical marijuana during a survey year. We experimented with assigning 0 to these years; we also experimented with assigning 1 to these years. The results, which are available upon request, were similar to those reported below.

[8] The following CDC webpage provides a detailed history of the state YRBS: http://www.cdc.gov/healthyyouth/yrbs/history-states.htm.

legalization of medical marijuana (Alaska, Arizona, Delaware, Maine, Michigan, Montana, Nevada, New Jersey, New Mexico, Rhode Island, and Vermont). Appendix Table 3 shows the number of observations each state contributed to the state YRBS analysis. Again, states that legalized medical marijuana are denoted with a star superscript and post-legalization observations are italicized.

When combined, the national and state YRBS data cover the District of Columbia and 49 states; sixteen of these states contributed data before and after the legalization of medical marijuana.[9] Table 1 provides descriptive statistics for the national and state YRBS samples by whether medical marijuana was legal at the time of the interview. According to the national YRBS data, 22 percent of high school students used marijuana at least once in the past 30 days, and 9 percent used marijuana at least 10 times during the past 30 days (our definition of frequent use). In the state YRBS data, 21 percent of respondents used marijuana in the past 30 days and 8 percent were frequent users.

Figure 1 presents trends in marijuana use based on weighted national YRBS data. It shows a steady decline in marijuana use among high school students from the late 1990s through

[9] For instance, California contributed two years of pre-legalization data and 8 years of post-legalization data to the combined analysis; Colorado contributed 3 years of pre-legalization data and 4 years of post-legalization data to the combined analysis; Maine contributed 3 years of pre-legalization data and 7 years of post-legalization data to the combined analysis; Michigan contributed 8 years of pre-legalization data and two years of post-legalization data to the combined analysis; Montana contributed 6 years of pre-legalization data and 4 years of post-legalization data to the combined analysis; New Mexico contributed 5 years of pre-legalization data and 3 years of post-legalization data to the combined analysis; Rhode Island contributed 5 years of pre-legalization data and 3 years of post-legalization data to the combined analysis; Vermont contributed 4 years of pre-legalization data and 3 years of post-legalization data to the combined analysis; and Washington contributed 3 years of pre-legalization data and 4 years of post-legalization data to the combined analysis. Wyoming is the only state for which we do not have national YRBS or state YRBS data. Medical marijuana was illegal in Wyoming during the period under study. Although the District of Columbia legalized medical marijuana in 2010, it has never conducted a state YRBS and contributed observations to the national YRBS in only two years, 1995 and 2011.

2007. From 2007 to 2011, the percentage of high school students who used marijuana in the past 30 days increased from 19.7 percent to 23.1 percent. Figure 2 presents trends in marijuana use based on unweighted state YRBS data. Despite the fact that they are designed to be representative at the state level, these data show the same steady decline in marijuana use from the late-1990s through the mid-2000s and a comparable increase after 2007, suggesting that the national and the state YRBS are capturing the same broad changes in tastes and policies.

Figures 3 and 4 present pre- and post-legalization trends in marijuana use based on national and state YRBS data, respectively. We report marijuana use for the three years prior to legalization, the year in which the law changed (year 0), and the three years following legalization. These figures provide simple and direct tests for whether youth marijuana consumption changed with the legalization of medical marijuana. In Figure 3, there appears to be a small decrease in marijuana use immediately after legalization, followed by an increase of comparable magnitude. A similar pattern is evident in Figure 4: marijuana use decreases immediately after legalization, increases after one year, and then decreases again by a comparable amount after two years. Although neither figure provides strong evidence of an increase in marijuana use after legalization, other factors related to, for instance, economic conditions could be masking the impact of legalization.

4. STATISTICAL METHODS

In an effort to control for economic conditions and other policies (as well as any changes in the composition of the YRBS), we turn to a standard regression framework that exploits both temporal and spatial variation in MMLs. Specifically, we estimate the following equation:

(1) $$Marijuana\ Use_{ist} = \beta_0 + \beta_1 MML_{st} + \boldsymbol{X1_{ist}\beta_2} + \boldsymbol{X2_{st}\beta_3} + \nu_s + w_t + \Theta_s \cdot t + \varepsilon_{ist},$$

where *i* indexes individuals, *s* indexes states, and *t* indexes years. The vectors ν_s and w_t represent state and year fixed effects, respectively, and state-specific linear time trends are represented by $\Theta_s \cdot t$. The state-specific linear time trends are included to control for unobserved factors at the state level that evolve smoothly over time such as preferences and tastes. The variable MML_{st} is an indicator for whether medical marijuana was legal in state *s* and year *t.* The coefficient of interest, β_1, represents the effect of medical marijuana legislation.[10]

The dependent variable, $Marijuana\ Use_{ist}$, is equal to 1 if respondent *i* reported using marijuana in the past 30 days, and equal to 0 otherwise. The vector $\boldsymbol{X1_{ist}}$ includes individual-level controls for age, sex, race and grade, while the vector $\boldsymbol{X2_{st}}$ includes state-level controls for whether marijuana use and possession was decriminalized, the presence of a BAC 0.08 law, the state beer tax, income per capita, and the unemployment rate. Previous research has shown that marijuana use is sensitive to decriminalization (Saffer and Chaloupka 1999), alcohol policies (Pacula 1998; DiNardo and Lemieux 2001) and economic conditions (Hammer 1992). All regressions are estimated as linear probability models and standard errors are corrected for clustering at the state level (Bertrand et al. 2004). In addition to examining marijuana use in the past 30 days, we examine frequent marijuana use, marijuana use at school, and whether the respondent was offered or bought marijuana on school property. Descriptive statistics for these outcomes are presented in Table 1.

[10] Anderson et al. (2013) used a similar empirical strategy to examine the effects of MMLs on the price of marijuana, traffic fatalities, and alcohol consumption. As a test of exogeneity, these authors regressed changes in MMLs on state-level policies. Neither alcohol- nor drug-related policies predicted the legalization of medical marijuana.

5. RESULTS

Tables 2 through 5 present unweighted OLS estimates of the relationship between MMLs and the outcomes discussed above. Separate estimates for the national and state YRBS are presented along with estimates based on the combined data.

Using the national YRBS and a "bare bones" specification without covariates or state-specific linear time trends, legalization of medical marijuana is associated with a 5.6 percentage point decrease in the probability of marijuana use within the past 30 days, and a 3.5 percentage point decrease in the probability of frequent use (Table 2). We can reject the hypothesis that the relationship between MMLs and these outcomes is positive at conventional levels. The same specification yields smaller, but still negative, estimates of β_1 using the state YRBS data. When the national and state YRBS data are combined, we find that the legalization of medical marijuana is associated with a 2.1 percentage point decrease in the probability of marijuana use within the past 30 days, and a 1.1 percentage point decrease in the probability of frequent use. We can reject the hypothesis that the relationship between legalization and these outcomes is positive at conventional levels.

A similar pattern of results emerges when the covariates and state-specific linear time trends are included on the right-hand side of the estimating equation. In these specifications, the estimates of β_1 are uniformly negative, although they are not statistically distinguishable from zero.[11] Ninety-five percent confidence intervals around the point estimates produced when using the combined YRBS data and controlling for state-specific linear time trends suggest that the impact of legalization on the probability of marijuana use in the past 30 days is no larger than 0.8

[11] Appendix Table 4 presents estimates that incorporate the sample weights provided by the national YRBS. Again, there is little evidence that legalization of medical marijuana led to increased marijuana use among high school students.

percentage points and the impact of legalization on the probability of frequent marijuana use in the past 30 days is no larger than 0.7 percentage points. In comparison, based on nationally representative data from Monitoring the Future, marijuana use among 12th graders increased by 4.3 percentage points from 2006 to 2011; marijuana use among 10th graders increased by 3.4 percentage points over this same period.[12] Based on national YRBS data, marijuana use among high school students increased by 3.4 percentage points from 2007 to 2011.

In Table 3, we explore whether the relationship between MMLs and marijuana use depends on gender. These estimates are from our preferred specification that includes the full set of covariates and state-specific linear time trends. With one exception, they are negative and statistically indistinguishable from zero. The hypothesis that β_1 for male respondents is equal to β_1 for female respondents is never rejected.

Table 4 compares estimates of β_1 for YRBS respondents who were under the age of 17 when they were interviewed with estimates for respondents who were 17 years of age or older.[13] In the national YRBS data, the relationship between legalization and marijuana use is negative and significant among respondents under the age of 17, but insignificant among respondents 17 years of age and older. The relationship between legalization and frequent use is negative (but

[12] Estimates of marijuana use in the past 30 days for 8th, 10th, and 12th graders are available from Johnston et al. (2011) and are based on data from Monitoring the Future. Monitoring the Future has interviewed nationally representative samples of 8th, 10th, and 12th graders since 1991. However, state identifiers are generally not made available to researchers. Our efforts to obtain these data were politely rebuffed.

[13] The YRBS data include information on all high school students, some of whom are as old as 19.

statistically insignificant) among both younger and older respondents. The remaining estimates of β_1 in Table 4 are small and statistically insignificant.[14]

Table 5 reports estimates of the effect of legalization on the use of marijuana on school property in the past 30 days and estimates of the effect of legalization on the probability a student reported having been offered, sold, or given an illegal drug at school in the past year. These estimates are of particular interest given the recent attempts to close dispensaries operating near schools (Brooks 2012; McCrimmon and Jones 2012). The estimated relationship between MMLs and the use of marijuana on school property is consistently negative, but never statistically significant. In the combined sample, legalization is associated with a 2.7 percentage point decrease in the probability of having been offered, sold, or given an illegal drug at school in the past year

5.1 Analysis of the National Longitudinal Survey of Youth 1997

In this section, we examine the relationship between MMLs and the use of marijuana by youth in the National Longitudinal Survey of Youth 1997 (NLSY97). The NLSY97, which is conducted annually, is a nationally representative sample of individuals who were 12 through 16 years of age as of December 31st, 1996. It contains detailed information on educational attainment, family background and socio-economic status, and its respondents are asked a host questions with regard to marijuana use including, "On how many days have you used marijuana

[14] Although the results are not reported, we estimated equation (1) for respondents 18 years of age and older. There was no evidence that the legalization of medical marijuana was associated with an increase in marijuana use among this age group. Appendix Table 5 presents estimates that incorporate the sample weights provided by the national YRBS. They are similar to those reported in Table 3 and Table 4.

in the last 30 days?"[15] Because our focus is on teenagers, we limit the analysis to respondents ages 12 through 19 at the time of the survey.

There are two primary benefits to using the NLSY97 data. First, unlike the YRBS, the NLSY97 includes high school dropouts. This is important because high school dropouts are more likely to use marijuana than their counterparts who stay in school (Bray et al. 2000). Second, because the NLSY97 data follow adolescents over time, it is possible to control for unobserved heterogeneity at the individual level.

However, there are two significant drawbacks to using NLSY97 data. First, California legalized medical marijuana before data collection began and several other states legalized medical marijuana when most of the NLSY97 respondents were in their twenties and thirties.[16] Second, several of the states that legalized medical marijuana in the late 1990s and early 2000s contributed only a handful of observations to the NLSY97.

Table 6 presents descriptive statistics from the NLSY97 and Table 7 presents regression results. Specifically, we report estimates from the following equation:

$$(2) \qquad Marijuana\ Use_{ist} = \beta_0 + \beta_1 MML_{st} + \boldsymbol{X1_{ist}\beta_2} + \boldsymbol{X2_{st}\beta_3} + \lambda_i + w_t + \Theta_s \cdot t + \varepsilon_{ist},$$

where i indexes individuals, s indexes states, and t indexes years. Year fixed effects are represented by w_t, and state-specific linear time trends are represented by $\Theta_s \cdot t$. The variable

[15] Based on the answers to this question, we are able to construct measures of marijuana use that correspond to the marijuana use measures in the YRBS data. Economists who have used these data to study determinants of marijuana use include Aughinbaugh and Gittleman (2004), Cowen (2011), and Yörük and Yörük (2011).

[16] For instance, New Mexico legalized medical marijuana in 2007, when the average age of NLSY97 respondents was 25.

MML_{st} is defined as above and β_1 represents the effect of medical marijuana legislation on marijuana use in the past 30 days. In addition, we examine the relationship between MMLs and frequent marijuana use defined as having used marijuana on at least 10 of the past 30 days. The vectors $\boldsymbol{X1_{ist}}$ and $\boldsymbol{X2_{st}}$ are composed of the individual- and state-level controls, respectively.[17]

Because NLSY97 respondents are observed in multiple years, we are able to include individual fixed effects, λ_i, on the right-hand side of the estimating equation. In addition to absorbing time-invariant heterogeneity at the individual level, these effects account for factors at the state level that may be correlated with marijuana use and the legalization of medical marijuana, although it is important to note that identification comes from changes in the law and from movement between states with different MMLs. All regressions are estimated as linear probability models and standard errors are corrected for clustering at the state level (Bertrand et al. 2004).

Each cell in Table 7 represents the results from a separate regression. Estimates in column (1) are based on a specification that includes only individual and year fixed effects; estimates in column (2) are based on a specification that also includes the covariates listed in Table 6; and estimates in column (3) are based on a specification that adds state-specific linear time trends. Consistent with the YRBS analyses above, there is little evidence to support the hypothesis that MMLs encourage marijuana use by teenagers. Although 5 of the 6 coefficient estimates are positive, none are statistically significant at conventional levels. If the largest estimates are taken at face value, the legalization of medical marijuana is associated with a 0.7 percentage point increase in the probability of marijuana use in the past 30 days, and a 1.3 percentage point increase in the probability of frequent use. Appendix Table 6 presents

[17] The state-level controls are identical to those used in the YRBS analysis. The individual-levels controls include indicators for education status, which are not available in the YRBS.

estimates that incorporate the sample weights provided by the NLSY97.[18] They are consistent with those reported in Table 7.

5.2 Analysis of the Treatment Episode Data Set

Finally, we examine the relationship between MMLs and marijuana use based on state-level data from the Treatment Episode Data Set (TEDS) for the period 1992 through 2009. Federally funded drug treatment facilities are required to provide information to TEDS including whether a patient reported using marijuana prior to admission. Using these data, we constructed rates of marijuana use at the state level by year.[19]

There are at least two advantages to using the TEDS data. First, like the NLSY97, the TEDS data include high school dropouts. Second, the TEDS data are compiled annually and very few states fail to provide admissions data. In contrast, the YRBS data are collected biennially and only a subset of states contribute data in any given year. Descriptive statistics for the TEDS data are presented in Table 8.

To estimate the relationship between MMLs and marijuana-positive admission rates, we estimate the following equation:

$$(2) \qquad \ln(\textit{Marijuana admission rate}_{ast}) = \beta_0 + \beta_1 MML_{st} + \boldsymbol{X_{st}\beta_2} + \nu_s + w_t + \Theta_s \cdot t + \varepsilon_{ast},$$

[18] Following Mellor (2011), we used the average of the sample weights for each individual for the years in which he or she participated in the NLSY97.

[19] Other economists who have used these data include Anderson (2010), Corman et al. (2010), Cunningham and Finlay (2011), and Nonnemaker et al. (2011).

where *a* indexes whether the observed admission rate is for males or females, *s* indexes states, and *t* indexes years. The dependent variable is the natural logarithm of the sex-specific marijuana admissions rate per 100,000 of the relevant population. Because TEDS does not provide the exact age or date of birth, we consider marijuana admission rates for two age groups: 15- through 17-year-olds and 18- through 20-year-olds. Again, the variable MML_{st} indicates whether a MML was in effect in state *s* and year *t*, the vector $\boldsymbol{X_{st}}$ is composed of the controls described in Table 8, and v_s and w_t are state and year fixed effects, respectively, and state-specific linear time trends are represented by $\Theta_s \cdot t$.

Table 9 presents the estimates from (3).[20] Each cell represents the results of a separate regression. Estimates in column (1) are based on specifications that only include state and year fixed effects. The estimates in column (2) are based on specifications that add the covariates, and the estimates in column (3) are based on specifications that include state-specific linear time trends. Consistent with the YRBS and NLSY97 analyses above, there is no evidence to support the hypothesis that MMLs increase marijuana use among 15- through 17-year-olds. In fact, the estimates of β_1, although statistically insignificant, are uniformly negative. Likewise, there is no evidence that medical marijuana laws are associated with increased use among 18- through 20-year-olds.

6. CONCLUSION

Medical marijuana is popular with the general public. A recent Gallup poll found that 70 percent of Americans say they favor making marijuana legally available for doctors to prescribe in order to reduce pain and suffering (Mendes 2010).

[20] The slight difference in sample size between estimates for 15- through 17-year-olds and 18- through 20-year-olds is due to missing values.

Given this level of support, it could be viewed as surprising that only 21 states have legalized medical marijuana. However, opponents of medical marijuana have employed a number of effective arguments, several of which focus on the use of marijuana by teenagers. For instance, Montana State Senator Jeff Essmann was quoted in 2011 as saying, "The number one goal is to reduce access and availability to the young people of this state that are being sent an incorrect message that this is an acceptable product for them to be using" (Florio 2011).

In order to examine the relationship between medical marijuana laws and youth consumption, we draw on data from the national and state Youth Risk Behavior Surveys (YRBS) for the years 1993 through 2011. These data cover a period when 16 states, including California, Colorado, Montana, Oregon and Washington, legalized medical marijuana, and allow us to estimate the effect of legalization on outcomes such as marijuana use in the past month, frequent marijuana use, and the use of marijuana on school property.

Our results are not consistent with the hypothesis that the legalization of medical marijuana caused an increase in the use of marijuana among high school students. In fact, estimates from our preferred specification are small, consistently negative, and are never statistically distinguishable from zero. Using the 95 percent confidence interval around these estimates suggests that the impact of legalizing medical marijuana on the probability of marijuana use in the past 30 days is no larger than 0.8 percentage points, and the impact of legalization on the probability of frequent marijuana use in the past 30 days is no larger than 0.7 percentage points. In comparison, based on nationally representative data from Monitoring the Future, marijuana use in the past 30 days among 12th graders increased by 4.3 percentage points from 2006 to 2011 (Johnston et al. 2011); based on national YRBS data, marijuana use among high school students increased by 3.4 percentage points from 2007 to 2011. One potential

explanation for this pattern of results is provided by Anderson and Rees (forthcoming). These authors noted that legalization allows suppliers to sell to adults with some assurance of not being prosecuted, while selling marijuana to a minor is still a risky proposition even with the legalization of medical marijuana.

In addition to the YRBS analysis, we examine data from the National Longitudinal Survey of Youth 1997 (NLSY97) and the Treatment Episode Data Set (TEDS). The NLSY97 allows us to follow survey respondents over time, while the TEDS data allow us to examine a high-risk population. There is little evidence that marijuana use is related to the legalization of medical marijuana in either of these data sources, a result that is consistent with research showing that marijuana use among adults is more sensitive to changes in policy than marijuana use among youths (Farrelly et al. 1999; Williams 2004).

Although our estimates do not lend support to the often-voiced argument that legalization leads to increased consumption of marijuana among teenagers, it is important to note that our study has at least one limitation: the YRBS data are only available through 2011 and the TEDS data are only available through 2009. In the past few years several states have seen dramatic changes to the market for medical marijuana. For instance, as a result of Drug Enforcement Agency raids, the number of providers in Montana has plummeted. As future waves of the YRBS are released, researchers will be in a position to update our estimates and explore whether these changes have affected the behavior of teenagers.

REFERENCES

Abdel-Ghany, Mohamed and Min Qi Wang. "Contemporaneous and Intertemporal Relationship Between the Consumption of Licit and Illicit Substances by Youth." *Journal of Family and Economic Issues* 24: 281-289.

Adda, Jérôme, Brendon McConnell and Imran Rasul. 2011. "Crime and the Depenalization of Cannabis Possession: Evidence from a Policing Experiment." Working Paper, University College of London.

Anderson, D. Mark. 2010. "Does Information Matter? The Effect of the Meth Project on Meth Use among Youths." *Journal of Health Economics* 29: 732-742.

D. Mark Anderson and Daniel I. Rees. Forthcoming. "The Legalization of Recreational Marijuana: How Likely Is the Worst-Case Scenario?" *Journal of Policy Analysis and Management*.

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

Aughinbaugh, Alison and Maury Gittleman. 2004. "Maternal Employment and Adolescent Risky Behavior." *Journal of Health Economics* 23: 815-838.

Bachman, Jerald, Lloyd Johnston 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.

Bray, Jeremy, Gary Zarkin, Chris Ringwalt and Junfeng Qi. 2000. "The Relationship between Marijuana Initiation and Dropping Out of High School." *Health Economics* 9: 9-18.

Belkin, Lisa. 2009. "Medical Marijuana for Children." *New York Times*. Available at: http://parenting.blogs.nytimes.com/2009/10/20/medical-marijuana-for-children/.

Bertrand, Marianne, Esther Duflo and Sendhil Mullainathan. 2004. "How Much Should We Trust Differences-in-Differences Estimates?" *Quarterly Journal of Economics* 119: 249-276.

Brittain, Amy. 2012. "Medical Marijuana Boss: Gov. Christie's Pot Program Delay is Sabotage." *The Star Ledger*, March 23. Available at: http://www.nj.com/news/index.ssf/2012/03/medicial_marijuana_boss_gov_ch.html.

Brooks, Jon. 2012. "Interview with U.S. Attorney Haag on Pot Operations: 'If it's close to children, that's a line we're going to draw.'" *KQED News*. Available at: http://blogs.kqed.org/newsfix/2012/03/15/interview-w-us-attorney-haag-on-pot-operations-if-its-close-to-children-thats-a-line-were-going-to-draw/.

Brownstein, Joseph. 2009. "Mother Gives Son Marijuana to Treat His Autism." *ABC News*. Available at: http://abcnews.go.com/GMA/AutismNews/mother-son-marijuana-treat-autism/story?id=9153881#.T3pC69WrH0U.

Centers for Disease Control and Prevention. 2004. "Methodology of the Youth Risk Behavior Surveillance System." *Morbidity and Mortality Weekly Report* 53: 1-14.

Cerdá, Magdalenda, Melanie Wall, Katherine Keyes, Sandro Galea and Deborah Hasin. 2012. "Medical Marijuana Laws in 50 States: Investigating the Relationship between State Legalization of Medical Marijuana and Marijuana Use, Abuse and Dependence." *Drug and Alcohol Dependence* 120: 22-27.

Chaboya-Hembree, Jan. 2012. "Medical Marijuana and Insomnia." Available at: http://medicalmarijuana.com/medical-uses/condition.cfm?conID=44.

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

Chu, Yu-Wei. 2013. "*Medical Marijuana Laws and Illegal Marijuana Use."* Working Paper, Michigan State University. Available at: https://www.msu.edu/~chuyuwei/

Cohen, Peter. 2009. "Medical Marijuana: The Conflict Between Scientific Evidence and Political Ideology." *Utah Law Review* 1: 35-104.

Corman, Hope, Dhaval Dave, Nancy Reichman and Dhiman Das. 2010. "Effects of Welfare Reform on Illicit Drug Use of Adult Women." NBER Working Paper No. 16072.

Cowen, Benjamin. 2011. "Forward-thinking Teens: The Effects of College Costs on Adolescent Risky Behavior." *Economics of Education Review* 30: 813-825.

Crost, Benjamin and Santiago Guerrero. 2012. "The Effect of Alcohol Availability on Marijuana Use: Evidence from the Minimum Legal Drinking Age." *Journal of Health Economics* 31: 112-121.

Cunningham, Scott and Keith Finlay. 2011. "Parental Substance Abuse and Foster Care: Evidence from Two Methamphetamine Supply Shocks?" Working Paper, Baylor University.

Damrongplasit, Kannika, Cheng Hsiao and Xueyan Zhao. 2010. "Decriminalization of Marijuana Smoking Prevalence: Evidence from Australia." *Journal of Business & Economic Statistics* 28: 344-356.

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

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

Ellison, Katherine. 2009. "Medical Marijuana: No Longer Just for Adults." *New York Times*. Available at: http://www.nytimes.com/2009/11/22/health/22sfmedical.html.

Farrelly, Matthew, Jeremy Bray, Gary Zarkin, Brett Wendling 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.

Farrelly, Matthew, Jeremy Bray, Gary Zarkin and Brett Wendling. 2001. "The Joint Demand for Cigarettes and Marijuana: Evidence from the National Household Surveys on Drug Abuse." *Journal of Health Economics* 20: 51-68.

Fergusson, D.M., L.J. Horwood and N.R. Swain-Campbell. 2003. "Cannabis Dependence and Psychotic Symptoms in Young People." *Psychological Medicine* 33: 15-21.

Florio, Gwen. 2011. "Kids' Use of Medical Marijuana Stirs Debate Over Future in Montana." *Missoulian.* Available at: http://missoulian.com/news/local/article_fe14a69c-5833-11e0-9593-001cc4c002e0.html.

Gilman, Victoria. 2005. "The Marijuana Debate: Healing Herb or Dangerous Drug?" *National Geographic News*. Available at: http://news.nationalgeographic.com/news/2005/06/0621_050621_marijuana.html.

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

Hammer, Torlid. 1992. "Unemployment and Use of Drug and Alcohol among Young People: A Longitudinal Study in the General Population." *British Journal of Addiction* 87: 1571-1581.

Harper, Sam, Erin Strumpf and Jay Kaufman. 2012. "Do Medical Marijuana Laws Increase Marijuana Use? Replication Study and Extension." *Annals of Epidemiology* 22: 207-212.

Ingold, John. 2012. "U.S. Attorney John Walsh Justifies Federal Crackdown on Medical-Marijuana Shops." *Denver Post*. Available at: http://www.denverpost.com/news/marijuana/ci_19780414.

Joseph, Jennifer and Astrid Rodrigues. 2010. "Marijuana From Mom: Mother Says Drug Helps Son Cope with Severe OCD." *ABC News*. Available at: http://abcnews.go.com/2020/MindMoodNews/marijuana-alternative-treatment-children-ocd-autism/story?id=11227283#.T3pCiNWrH0V.

Johnston, Lloyd, Patrick O'Malley, Jerald Bachman and John Schulenberg. 2011. "Monitoring the Future: National Results on Adolescent Drug Use. Overview of Key Findings, 2011." Institute for Social Research, University of Michigan. Available at: http://www.monitoringthefuture.org/pubs/monographs/mtf-overview2011.pdf.

Khatapoush, Shereen and Denise Hallfors. 2004. "'Sending the Wrong Message': Did Medical Marijuana Legalization in California Change Attitudes about and Use of Marijuana?" *Journal of Drug Issues* 34: 751-770.

Klofas, John and Kyle Letteney. 2012. "The Social and Legal Effects of Medical Marijuana: State Legislation and Rules." Working Paper, Center for Public Safety Initiatives, Rochester Institute of Technology.

Lucido, Frank. 2004. "Implementation of the Compassionate use Act in a Family Medicine Practice: Seven Years Clinical Experience." Available at: http://www.medboardwatch.com.

McCrimmon, Katie and Rebecca Jones. 2012. "Feds Warn Marijuana Shops Close to Schools." *Education News Colorado*. Available at: http://www.ednewscolorado.org/2012/01/13/31121-feds-warn-medical-marijuana-facilities-near-schools.

Merrill, Jeffrey, Herbert Kleber, Michael Shwartz, Hong Liu and Susan Lewis. 1999. "Cigarettes, Alcohol, Marijuana, Other Risk Behaviors, and American Youth." *Drug and Alcohol Dependence* 56: 205-212.

Montgomery, Michael. 2010. "Plummeting Marijuana Prices Create a Panic in California" *All Things Considered*. May 15. Available at: http://www.npr.org/templates/story/story.php?storyId=126806429&ps=rs.

Nonnemaker, James, Mark Engelen and Daniel Shive. 2011. "Are Methamphetamine Precursor Control Laws Effective Tools to Fight the Methamphetamine Epidemic?" *Health Economics* 20: 519-531.

O'Connor, Anahad. 2011. "Marijuana Use Growing Among Teenagers." *New York Times*. Available at: http://well.blogs.nytimes.com/2011/12/14/marijuana-growing-in-popularity-among-teenagers/.

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

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

Rashad, Inas and Robert Kaestner. 2004. "Teenage Sex, Drugs and Alcohol: Problems Identifying the Cause of Risky Behaviors." *Journal of Health Economics* 23: 493-503.

Roan, Shari. 2011. "Medical Marijuana Laws Linked to Higher Overall Usage." *Los Angeles Times*. Available at: http://articles.latimes.com/2011/sep/01/news/la-heb-medical-marijuana-20110901.

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

Suthers, John. 2012. "Medical Marijuana a Threat to Colorado's Children." *Solutions*. Available at: http://www.healthpolicysolutions.org/2012/02/04/opinion-medical-marijuana-a-threat-to-colorados-children/.

Thies, Clifford and Charles Register. 1993. "Decriminalization of Marijuana and the Demand for Alcohol, Marijuana and Cocaine." *Social Science Journal* 30: 385-399.

Thurstone, Christian, Shane Lieberman and Sarah Schmiege. 2011. "Medical Marijuana Diversion and Associated Problems in Adolescent Substance Treatment." *Drug and Alcohol Dependence* 118: 489– 492.

Uken, Cindy. 2012. "Too Much Pot." *Billings Gazette* 6 April 2002: A1.

van het Loo, Mirjam, Ineke van Beusekom, and James Kahan. 2002. "Decriminalization of Drug Use in Portugal: The Development of a Policy." *Annals of the American Academy of Political and Social Science* 582: 49-63.

van Ours, Jan and Jenny Williams. 2009. "Why Parents Worry: Initiation into Cannabis Use by Youth and their Educational Attainment." *Journal of Health Economics* 28: 132-142.

van Ours, Jan and Jenny Williams. 2011. "Cannabis Use and Mental Health Problems." *Journal of Applied Econometrics* 26: 1137-1156.

Wall, Melanie M., Ernest Poh, Magdalenda Cerdá, Katherine M. Keyes, Sandro Galea 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* 21: 714-716.

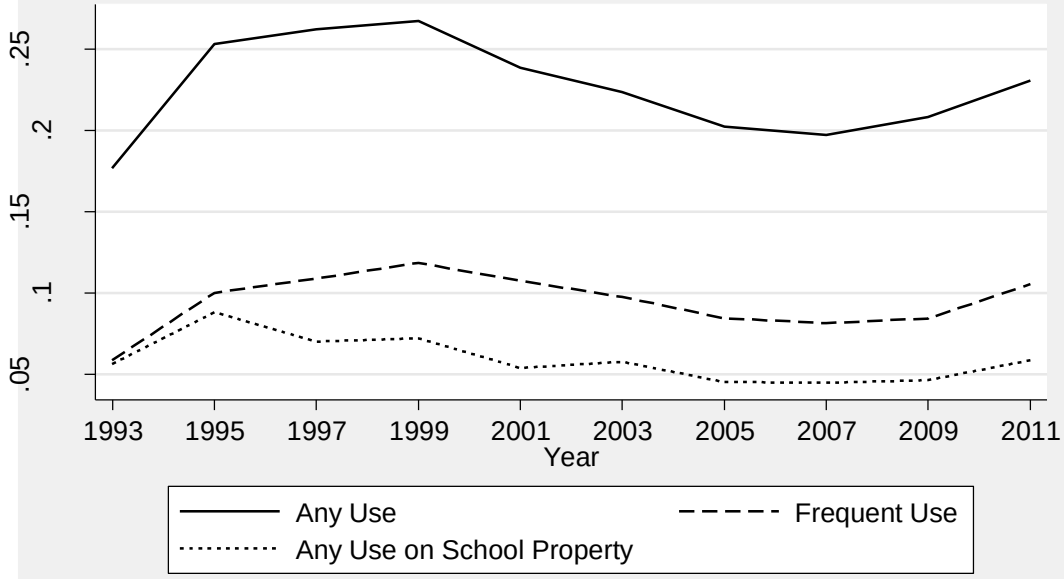
Williams, Jenny. 2004. "The Effects of Price and Policy on Marijuana Use: What Can Be Learned from the Australian Experience?" *Health Economics* 13: 123-137.

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

Yamada, Tetsuji, Michael Kendix and Tadashi Yamada. 1996. "The Impact of Alcohol Consumption and Marijuana Use on High School Graduation." *Health Economics*. 5: 77-92.

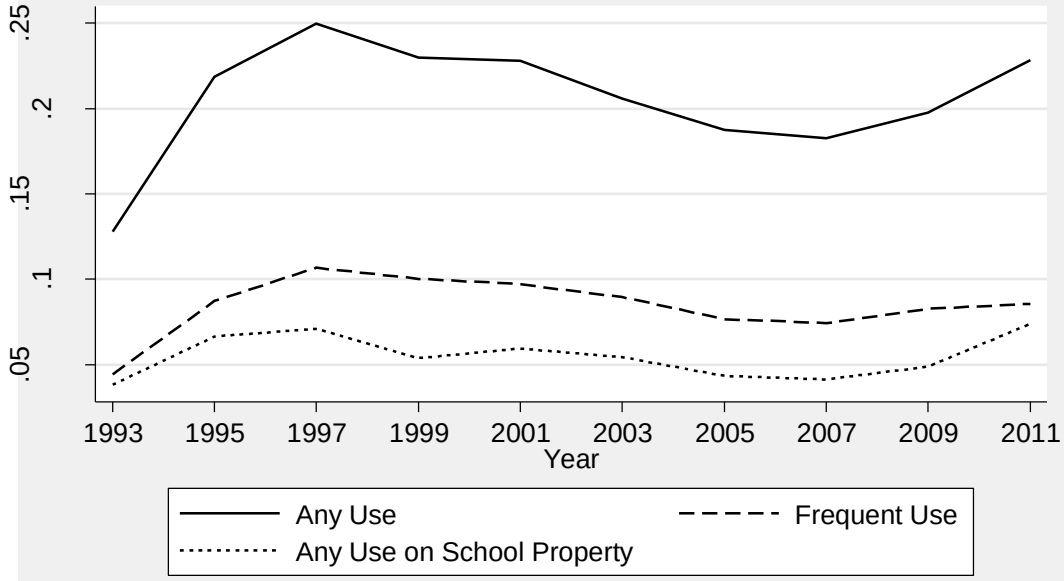
Yörük, Bariş and Ceren Yörük. 2011. "The Impact of Minimum Legal Drinking Age Laws on Alcohol Consumption and Marijuana Use: Evidence from a Regression Discontinuity Design Using Exact Date of Birth." *Journal of Health Economics* 30: 740-753.

Figure 1. Past 30 Day Marijuana Use
National YRBS 1993-2011



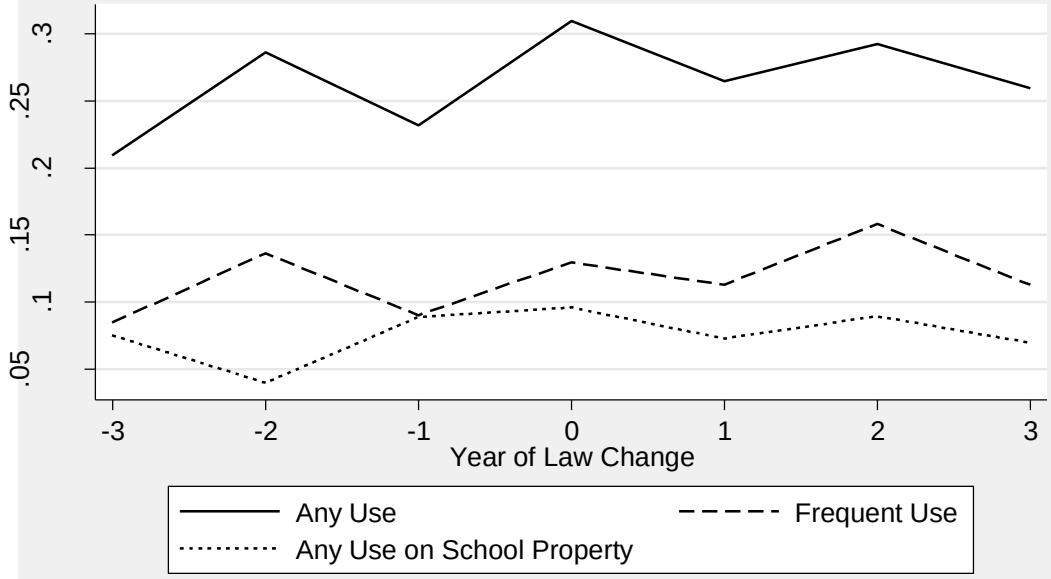
Based on weighted data from the national YRBS. Appendix Table 1 presents information on which states passed a MML between 1993 and 2011.

Figure 2. Past 30 Day Marijuana Use
State YRBS 1993-2011



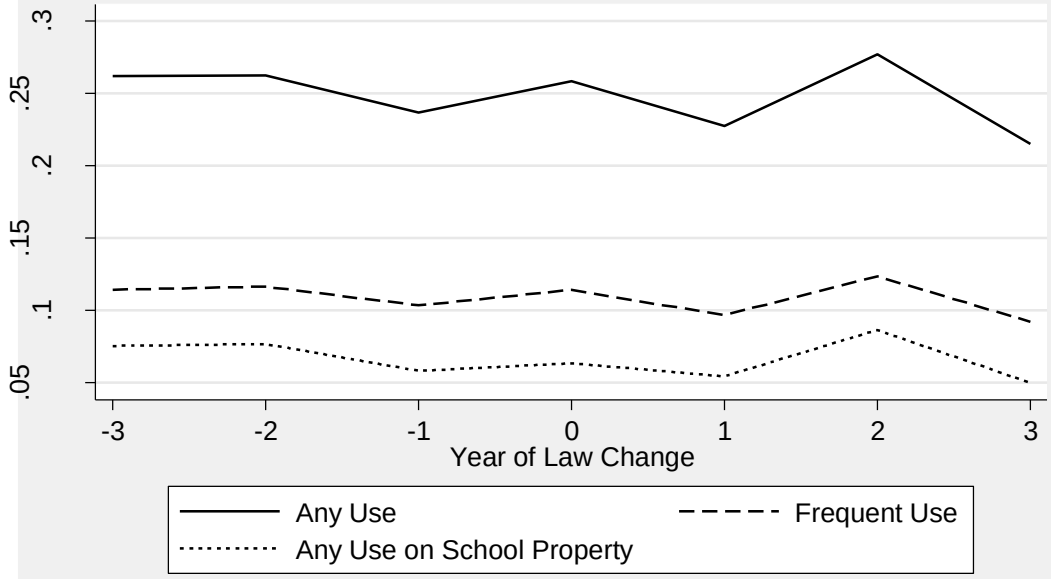
Based on unweighted data from the state YRBS. Appendix Table 1 presents information on which states passed a MML between 1993 and 2011.

Figure 3. Past 30 Day Marijuana Use
National YRBS 1993-2011



Based on weighted data from the national YRBS. Appendix Table 1 presents information on which states passed a MML between 1993 and 2011.

Figure 4. Past 30 Day Marijuana Use
State YRBS 1993-2011



Based on unweighted data from the state YRBS. Appendix Table 1 presents information on which states passed a MML between 1993 and 2011.

Table 1. Descriptive Statistics: YRBS 1993-2011

	National YRBS		State YRBS		
	MML = 1	MML = 0	MML = 1	MML = 0	Description
Dependent Variables					
Marijuana Use in Past 30 Days	.234	.220	.221	.195	= 1 if respondent has used marijuana in past 30 days, = 0 otherwise
Frequent Marijuana Use in Past 30 Days	.094	.091	.095	.082	= 1 if respondent has used marijuana at least 10 out of the past 30 days, = 0 otherwise
Marijuana Use at School in Past 30 Days	.070	.060	.058	.048	= 1 if respondent has used marijuana at school in past 30 days, = 0 otherwise
Offered, Sold, or Given Drug on School Property	.314	.259	.254	.252	= 1 if respondent has been offered, sold, or given illegal drug at school, = 0 otherwise
Independent Variables					
Age	16.0	16.2	15.8	16.0	Age of respondent
Male	.485	.490	.487	.483	= 1 if respondent is male, = 0 if respondent is female
Grade 9	.248	.239	.259	.284	= 1 if respondent is in grade 9, = 0 otherwise
Grade 10	.239	.247	.275	.275	= 1 if respondent is in grade 10, = 0 otherwise
Grade 11	.253	.256	.252	.244	= 1 if respondent is in grade 11, = 0 otherwise
Grade 12	.259	.256	.213	.196	= 1 if respondent is in grade 12, = 0 otherwise
Black	.079	.260	.042	.161	= 1 if respondent is black, = 0 otherwise
White	.324	.435	.682	.633	= 1 if respondent is white, = 0 otherwise
Other Race	.597	.305	.276	.206	= 1 if respondent is of an other race, = 0 otherwise
Decriminalization Law	.812	.193	.366	.240	= 1 if state has decriminalized marijuana, = 0 otherwise
BAC 0.08 Law	.963	.587	.974	.666	= 1 if state has a BAC 0.08 law, = 0 otherwise
Beer tax	.182	.283	.231	.269	State real beer tax (2000 dollars)
Real State Income	10.4	10.2	10.3	10.2	Natural logarithm of state real income per capita
Unemployment Rate	7.61	5.94	6.94	5.78	State unemployment rate
Observations	23,504	116,889	105,602	540,573	

Notes: Means are based on unweighted data from the national and state YRBS (1993-2011).

Table 2. Medical Marijuana Laws and Youth Consumption, 1993-2011

	National YRBS			State YRBS			Combined National and State		
Panel A: Marijuana Use in Past 30 Days									
MML	-.056***	-.047***	-.029	-.014*	-.011	-.005	-.021**	-.019*	-.010
	(0.019)	(.014)	(.026)	(.008)	(.010)	(.006)	(.009)	(.010)	(.009)
Observations	140,393	140,393	140,393	646,175	646,175	646,175	786,568	786,568	786,568
Panel B: Frequent Marijuana Use in Past 30 Days									
MML	-.035**	-.030***	-.016	-.006	-.004	-.003	-.011*	-.009	-.007
	(.015)	(.011)	(.018)	(.005)	(.005)	(.004)	(.006)	(.006)	(.007)
Observations	140,393	140,393	140,393	646,175	646,175	646,175	786,568	786,568	786,568
State FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariates	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific trends	No	No	Yes	No	No	Yes	No	No	Yes

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

Notes: Each cell represents a separate OLS estimate based on data from the YRBS (1993-2011); the covariates are listed in Table 1. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 3. Medical Marijuana Laws and Youth Consumption by Gender

	National YRBS		State YRBS		Combined National and State	
Panel A: Marijuana Use in Past 30 Days						
	Male	Female	Male	Female	Male	Female
MML	-.029	-.028	.002	-.009	-.006	-.012
	(.026)	(.028)	(.009)	(.009)	(.013)	(.013)
Observations	68,675	71,718	312,728	333,447	381,403	406,205
Panel B: Frequent Marijuana Use in Past 30 Days						
	Male	Female	Male	Female	Male	Female
MML	-.014	-.017	-.002	-.004	-.005	-.007
	(.020)	(.016)	(.005)	(.004)	(.008)	(.006)
Observations	68,675	71,718	254,371	333,447	381,403	406,205
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	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 cell represents a separate OLS estimate based on data from the YRBS (1993-2011); the covariates are listed in Table 1. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 4. Medical Marijuana Laws and Youth Consumption by Age Group

	National YRBS		State YRBS		Combined National and State	
Panel A: Marijuana Use in Past 30 Days						
	Age<17	Age≥17	Age<17	Age≥17	Age<17	Age≥17
MML	-.046*	-.006	-.008	.002	-.012	-.006
	(.023)	(.035)	(.007)	(.010)	(.011)	(.018)
Observations	80,494	59,899	423,043	222,132	492,457	282,031
Panel B: Frequent Marijuana Use in Past 30 Days						
	Age<17	Age≥17	Age<17	Age≥17	Age<17	Age≥17
MML	-.018	-.014	-.002	-.005	-.005	-.008
	(.017)	(.021)	(.003)	(.006)	(.006)	(.009)
Observations	80,494	59,899	423,043	222,132	492,457	282,031
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	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 cell represents a separate OLS estimate based on data from the YRBS (1993-2011); the covariates are listed in Table 1. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 5. Medical Marijuana Laws and School Accessibility

	National YRBS	State YRBS	Combined National and State
Panel A: Marijuana Use at School in Past 30 Days			
MML	-.013	-.002	- .004
	(.018)	(.003)	(.007)
Observations	140,393	612,488	752,881
Panel B: Offered, Sold, or Given Drug in Past 12 Months on School Property			
MML	-.023	-.031**	-.027**
	(.018)	(.014)	(.013)
Observations	140,393	577,229	717,622
State FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Covariates	Yes	Yes	Yes
State Linear Trends	Yes	Yes	Yes

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

Notes: Each cell represents a separate OLS estimate based on data from the YRBS (1993-2011); the covariates are listed in Table 1. Standard errors, corrected for clustering at the state level, are in parentheses. The sample sizes in Panel B are smaller than those in Panel A because several states did not ask the *Offered, Sold, or Given Drug in Past 12 Months on School Property* question every year.

Table 6. Descriptive Statistics: NLSY97

	MML = 1	MML = 0	Description
Dependent Variables			
Marijuana Use in Past 30 Days	.161	.145	= 1 if respondent has used marijuana in past 30 days, = 0 otherwise
Frequent Marijuana Use in Past 30 Days	.061	.058	= 1 if respondent has used marijuana at least 10 out of the past 30 days, = 0 otherwise
Independent Variables			
Age	16.8	16.6	Age of respondent
No High School Degree	.728	.771	= 1 if respondent has no high school degree, = 0 otherwise
GED/High School Degree	.271	.228	= 1 if respondent has a GED or a high school degree, = 0 otherwise
Over High School Degree	.001	.000	= 1 if respondent has more than a high school degree, = 0 otherwise
Decriminalization Law	.909	.225	= 1 if state has decriminalized marijuana, = 0 otherwise
BAC 0.08 Law	.920	.326	= 1 if state has a 0.08 BAC law, = 0 otherwise
Beer tax	.208	.261	State real beer tax (2000 dollars)
Real State Income	10.4	10.3	Natural logarithm of state real income per capita
Unemployment Rate	5.74	4.45	State unemployment rate

Notes: Means are based on unweighted data from the National Longitudinal Survey of Youth 1997.

Table 7. Medical Marijuana Laws and Youth Consumption: Evidence from the NLSY97

Panel A: Marijuana Use in Past 30 Days

MML	.001	.007	-.004
	(.016)	(.018)	(.022)
Observations	40,986	40,986	40,986

Panel B: Frequent Marijuana Use in Past 30 Days

MML	.011	.013	.008
	(.010)	(.011)	(.014)
Observations	40,986	40,986	40,986
Individual FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Covariates	No	Yes	Yes
State linear trends	No	No	Yes

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

Notes: Each cell represents a separate OLS estimate based on data from the National Longitudinal Survey of Youth 1997; the covariates are listed in Table 7. Standard errors, corrected for clustering at the state level, are in parentheses.

Table 8. Descriptive Statistics: Treatment Episode Data Analysis

	MML = 1	MML = 0	Description
Dependent Variables			
Marijuana admission rate, ages 15-17	1,326	779	Marijuana admission rate for 15- through 17-year-olds per 100,000
Marijuana admission rate, ages 18-20	817	657	Marijuana admission rate for 18- through 20-year-olds per 100,000
Independent Variables			
Male rate	.500	.504	= 1 if admissions rate is for males, = 0 otherwise
Decriminalization Law	.587	.181	= 1 if state has decriminalized marijuana, = 0 otherwise
BAC 0.08 Law	.903	.513	= 1 if state has a 0.08 BAC law, = 0 otherwise
Beer tax	.258	.256	State real beer tax (2000 dollars)
Real State Income	10.3	10.2	Natural logarithm of state real income per capita
Unemployment Rate	5.72	5.12	State unemployment rate

Notes: Means are based on unweighted data from the Treatment Episode Data Set (1992-2009).

Table 9. Medical Marijuana Laws and Treatment Episodes

	(1) *Marijuana admission rate, ages 15-17*	(2) *Marijuana admission rate, ages 15-17*	(3) *Marijuana admission rate, ages 15-17*
MML	-.027	-.034	-.067
	(.120)	(.113)	(.115)
N	1737	1737	1737
R^2	.608	.852	.909

	(1) *Marijuana admission rate, ages 18-20*	(2) *Marijuana admission rate, ages 18-20*	(3) *Marijuana admission rate, ages 18-20*
MML	-.045	-.026	-.061
	(.068)	(.068)	(.051)
N	1756	1756	1756
R^2	.493	.873	.899
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Covariates	No	Yes	Yes
State linear trends	No	No	Yes

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

Notes: Each cell represents a separate OLS estimate based on data from the Treatment Episode Data Set (1992-2009). The dependent variable is equal to the natural log of the marijuana admissions rate per 100,000 population; the covariates are listed in Table 9. Regressions are weighted using the relevant state age- and gender-specific populations. Standard errors, corrected for clustering at the state level, are in parentheses.

Appendix Table 1. Medical Marijuana Laws, 1993-2011

	Effective date
Alaska	March 4, 1999
Arizona	April 14, 2011
California	November 6, 1996
Colorado	June 1, 2001
Delaware	May 13, 2011
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: Connecticut, Illinois, Maryland, Massachusetts and New Hampshire legalized medical marijuana after 2011.

Appendix Table 2. Number of Observations by State-Year: National YRBS

	1993	1995	1997	1999	2001	2003	2005	2007	2009	2011	Total
AL	782	97	781	55	306	630	…	475	1,027	308	4,461
AZ*	429	…	1,076	130	399	341	279	588	353	*1,087*	4,462
AR	393	282	358	…	…	261	…	411	297	…	2,002
CA*	2,082	1,161	*1,929*	*2,423*	*2,139*	*1,672*	*1,527*	*2,072*	*2,741*	*1,796*	19,542
CO*	256	99	267	…	*635*	…	…	…	*189*	*234*	1,680
CT	…	…	217	…	…	…	230	…	…	…	447
DE*	…	212	…	…	…	360	…	…	…	*221*	793
DC*	…	499	…	…	…	…	…	…	…	*295*	794
FL	513	532	664	845	1,042	1,393	532	732	222	1,361	7,836
GA	893	435	339	800	476	408	1,796	344	1,296	120	6,907
HI*	…	…	…	301	…	…	…	…	*229*	…	530
ID	…	…	…	…	155	…	238	…	…	258	651
IL	702	237	…	224	431	312	471	576	1,450	972	5,375
IN	…	…	…	…	176	407	169	395	…	266	1,413
IA	…	241	774	…	…	…	236	245	…	…	1,496
KS	170	…	201	…	…	307	275	…	197	295	1,445
KY	…	…	…	…	…	…	527	357	…	211	1,095
LA	…	278	568	606	…	677	155	…	411	…	2,695
ME*	247	150	236	*196*	*199*	*197*	…	…	…	…	1,225
MD	144	…	801	…	…	260	…	…	…	…	1,205
MA	357	269	1,606	…	249	211	255	708	…	282	3,937
MI*	144	1,076	490	509	329	392	283	295	*313*	*617*	4,448
MN	319	…	…	…	…	…	95	…	185	…	599
MS	352	478	326	624	335	…	…	348	…	93	2,556
MO	181	540	…	550	458	260	102	343	84	341	2,859
MT*	…	…	…	…	197	…	…	…	…	…	197
NE	396	…	…	…	…	…	…	…	…	…	396
NV*	…	…	…	…	*232*	...	...	...	*378*	*198*	808
NJ*	…	…	720	232	213	297	309	669	364	*111*	2,915
NM*	657	…	276	…	152	100	…	*218*	*596*	…	1,999
NY	1,217	510	355	700	298	893	450	894	1,159	622	7,098

Appendix Table 2. Number of Observations by State-Year: National YRBS (continued)

	1993	1995	1997	1999	2001	2003	2005	2007	2009	2011	Total
NC	296	114	327	506	659	…	628	558	…	686	3,774
OH	524	546	538	551	221	290	270	…	…	…	2,940
OK	…	…	223	…	392	…	232	277	…	…	1,124
OR*	188	…	…	…	*183*	...	*268*	...	*243*	…	882
PA	356	658	271	477	…	316	407	210	1,039	408	4,142
RI*	…	…	…	74	…	…	…	…	…	…	74
SC	390	…	330	776	…	874	283	…	…	…	2,653
SD	…	…	…	…	…	295	…	…	…	…	295
TN	507	346	564	263	588	…	391	162	…	286	3,107
TX	2,715	1,642	935	2,668	2,006	2,574	1,705	1,438	1,312	1,721	18,716
UT	…	…	…	…	…	178	268	193	…	…	639
VT*	…	…	…	…	…	57	…	…	…	…	57
VA	…	64	…	718	…	240	345	424	96	201	2,088
WA*	373	82	103	…	*52*	...	*100*	...	*245*	*165*	1,120
WV	301	…	…	…	260	…	228	243	457	251	1,740
WI	…	…	289	521	234	175	239	178	675	645	2,956

Notes: States that legalized medical marijuana are denoted with a star superscript and post-legalization observations are italicized.

Appendix Table 3. Number of Observations by State-Year: State YRBS

	1993	1995	1997	1999	2001	2003	2005	2007	2009	2011	Total
AL	4,269	3,773	3,544	2,007	1,508	1,038	975	…	1,418	1,328	19,860
AK*	…	1,595	…	…	…	*1,414*	…	*1,256*	*1,302*	*1,278*	6,845
AZ*	…	…	…	…	…	1,939	1,872	1,668	1,484	*1,948*	8,911
AR	…	2,223	1,950	1,426	1,661	…	1,438	1,535	1,580	1,302	13,115
CO*	…	…	…	…	…	…	*1,459*	…	*1,451*	*1,437*	4,347
CT	…	…	1,709	…	…	…	2,108	1,974	2,298	1,968	10,057
DE*	…	…	…	2,313	2,842	2,955	2,604	2,387	2,267	*2,165*	17,533
ID	3,907	…	…	…	1,680	1,694	1,414	1,378	2,114	1,663	13,850
IL	3,953	3,020	…	…	…	…	…	2,326	2,887	3,403	15,589
IA	…	…	1,498	…	…	…	1,339	1,425	…	1,519	5,781
KS	…	…	…	…	…	…	1,618	1,682	1,991	1,823	7,114
KY	…	…	1,561	…	…	1,528	3,178	3,391	1,692	1,650	13,000
ME*	…	1,375	1,795	*1,305*	…	*1,616*	*1,304*	*1,277*	*8,419*	*8,982*	26,073
MD	…	…	…	…	…	…	1,373	1,467	1,562	2,529	6,931
MI*	…	…	4,277	2,600	3,472	3,332	3,144	3,390	*3,271*	*4,052*	27,538
MS	1,431	1,251	1,462	1,579	1,777	1,458	…	1,537	1,749	1,729	13,973
MO	…	4,787	1,451	1,601	1,625	1,530	1,851	1,512	1,595	…	15,952
MT*	4,936	2,476	2,502	2,856	2,572	2,617	*2,947*	*3,849*	*1,766*	*4,002*	30,523
NE	3,154	…	…	…	…	2,862	3,651	…	…	2,644	12,311
NV*	2,001	1,507	1,441	1,659	*1,405*	*1,917*	*1,488*	*1,737*	*2,007*	…	15,162
NH	2,651	2,128	…	…	…	1,294	1,249	1,595	1,459	1,378	11,754
NJ*	…	…	…	…	2,026	…	1,470	…	1,716	*1,619*	6,831
NM*	…	…	…	…	…	…	5,020	*2,539*	*4,835*	*5,596*	18,290
NY	…	…	3,673	3,303	…	9,021	9,194	12,780	13,959	12,544	64,474
NC	2,686	1,921	…	…	2,477	2,479	3,762	3,363	5,485	2,174	24,347
ND	…	…	…	1,800	1,564	1,636	1,700	1,725	1,782	1,873	12,080
RI*	…	…	1,476	…	1,351	1,759	2,302	*2,102*	*3,093*	*3,813*	15,896
SC	4,636	5,302	5,347	4,449	…	1,238	1,202	1,202	1,055	1,382	24,612
SD	1,326	1,170	1,577	1,639	1,564	1,762	1,544	1,561	2,115	1,507	15,765
TN	3,226	…	…	…	…	1,899	1,519	2,020	2,176	2,584	13,464
TX	…	…	…	…	6,864	…	4,032	3,123	3,459	4,017	21,495

Appendix Table 3. Number of Observations by State-Year: State YRBS (continued)

	1993	1995	1997	1999	2001	2003	2005	2007	2009	2011	Total
UT	4,376	3,123	1,340	1,467	1,029	1,350	1,401	1,885	1,538	1,651	19,160
VT*	…	5,860	6,783	…	6,942	5,901	*6,941*	*5,825*	*8,347*	…	46,599
WV	2,778	2,045	1,796	1,365	…	1,701	1,298	1,358	1,578	2,121	16,040
WI	3,199	…	1,294	1,304	2,070	2,078	2,250	2,050	2,391	2,941	19,577

Notes: States that legalized medical marijuana are denoted with a star superscript and post-legalization observations are italicized.

Appendix Table 4. Weighted National YRBS Analysis

National YRBS

Panel A: Marijuana Use in Past 30 Days

MML	-.019	-.016	-.004
	(.015)	(.013)	(.018)
Observations	140,393	140,393	140,393

Panel B: Frequent Marijuana Use in Past 30 Days

MML	-.006	-.005	.013
	(.015)	(.013)	(.015)
Observations	140,393	140,393	140,393
State FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Covariates	No	Yes	Yes
State-specific trends	No	No	Yes

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

Notes: Each cell represents a separate OLS estimate based on data from the YRBS (1993-2011); the covariates are listed in Table 1. Standard errors, corrected for clustering at the state level, are in parentheses.

Appendix Table 5. Weighted National YRBS Analysis by Gender and Age

National YRBS

Panel A: Marijuana Use in Past 30 Days

	Male	Female	Age<17	Age≥17
MML	-.018	.010	-.030	.040
	(.020)	(.021)	(.018)	(.030)
Observations	68,675	71,718	80,494	59,899

Panel B: Frequent Marijuana Use in Past 30 Days

	Male	Female	Age<17	Age≥17
MML	.025	.000	.009	.023
	(.017)	(.017)	(.019)	(.014)
Observations	68,675	71,718	80,494	59,899
State FEs	Yes	Yes	Yes	Yes
Year FEs	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 cell represents a separate OLS estimate based on data from the YRBS (1993-2011); the covariates are listed in Table 1. Standard errors, corrected for clustering at the state level, are in parentheses.

Appendix Table 6. Weighted NLSY97 Analysis

Panel A: Marijuana Use in Past 30 Days

MML	-.003	.003	-.010
	(.013)	(.014)	(.022)
Observations	40,986	40,986	40,986

Panel B: Frequent Marijuana Use in Past 30 Days

MML	.011	.015	.009
	(.011)	(.011)	(.016)
Observations	40,986	40,986	40,986
Individual FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Covariates	No	Yes	Yes
State linear trends	No	No	Yes

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

Notes: Each cell represents a separate OLS estimate based on data from the National Longitudinal Survey of Youth 1997; the covariates are listed in Table 7. Standard errors, corrected for clustering at the state level, are in parentheses.