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THE EFFECT OF MEDICAL MARIJUANA LAWS ON MARIJUANA, ALCOHOL, AND HARD DRUG USE

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ABSTRACT

21 states and the District of Columbia currently have laws that permit marijuana use for medical purposes, often termed medical marijuana laws (MMLs). We tested the effects of MMLs adopted in seven states between 2004 and 2011 on adolescent and adult marijuana, alcohol, and hard drug use. We employed a restricted-access version of the National Survey on Drug Use and Health (NSDUH) micro-level data with geographic identifiers. For those 21 and older, we found that MMLs led to a relative increase in the probability of marijuana use of 16 percent, an increase in marijuana use frequency of 12-17 percent, and an increase in the probability of marijuana abuse/dependence of 15-27 percent. For those 12-20 years old, we found a relative increase in marijuana use initiation of 5-6 percent. Among those aged 21 or above, MMLs increased the frequency of binge drinking by 6-9 percent, but MMLs did not affect drinking behavior among those 12-20 years old. MMLs had no discernible impact on hard drug use in either age group. Taken together, MML implementation increases marijuana use mainly among those over 21, where there is also a spillover effect of increased binge drinking, but there is no evidence of spillovers to other substance use.

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1. INTRODUCTION

As of April, 2014, 21 states and the District of Columbia have implemented medical marijuana laws (MMLs) which permit marijuana use for medical purposes. An additional twelve states[1] are considering similar legislation. Medical marijuana bills are also likely to land on the legislative agenda in many of the remaining states. Understanding the behavioral and public health implications of this evolving regulatory environment is critical for the ongoing implementation of the MMLs and future iterations of marijuana policy reform. Despite the growing consensus about the relief medical marijuana can bring for a range of serious illnesses, concerns have been voiced that MMLs may give rise to increased marijuana use in the general population and increased use of other substances. Legislative and public attention have focused on these issues, but the empirical evidence is limited.

We contribute to the literature on the effects of marijuana liberalization policies by examining effect of the implementation of MMLs in seven states between 2004 and 2011 on marijuana, excessive alcohol use, and hard drug use. To examine the effects of MML implementation, we exploited the geographic identifiers in a restricted-access version of the National Survey on Drug Use and Health (NSDUH) micro-level data and estimated two-way fixed effects models with state-specific linear time trends.

With respect to marijuana use itself, we found that MML implementation led to a 1.4 percentage point or a 16 percent relative increase in the probability of past-month marijuana use for adults aged 21 or above, and a 12-17 percent increase in the frequency of past-month marijuana use for this age group. In this age group, MML implementation also resulted in a 15-27 percent increase in the probability of marijuana abuse/dependence. Among adolescents and young adults aged 12-20, we found a 0.3-0.5 percentage point or a 5-6 percent relative increase in the probability of marijuana use initiation attributable to MML implementation.

[1] 12 states with pending medical marijuana bills include Florida, Kansas, Kentucky, Minnesota, Missouri, New York, Ohio, Pennsylvania, South Carolina, Tennessee, West Virginia, and Wisconsin.

In addition to the increases in marijuana use, MML implementation also increased the frequency of binge drinking among those aged 21 or above, partially through the increase in simultaneous use of the two substances. In contrast, MML implementation did not affect underage drinking among those aged 12-20. Hard drug use among both age groups was unaffected.

Overall, our findings indicate that MML implementation increased marijuana use, but had limited impacts on other types of substance use (i.e., underage drinking, cocaine use, and heroin use), except for binge drinking among adults of legal drinking age.

The article proceeds as follows. Section 2 provides background information on medical marijuana and state MMLs, and outlines the theoretical framework. Section 3 summarizes the existing literature. Section 4 describes the data sources, variable measurement, and identification strategy. Section 5 presents the estimated policy effects, and the robustness checks. Concluding remarks are given in the last section of the article.

2. BACKGROUND

2.1. Prevalence & Risks of Marijuana Use, & Federal Prohibition

Marijuana is the most widely used illicit drug in the United States. In 2011, 18 million Americans were current (i.e., past-month) marijuana users. The prevalence of current marijuana use has increased over time from 5.8% in 2004 to 7.0% in 2011 (SAMHSA 2012). Marijuana use has been associated with an increased risk of cognitive impairment, respiratory and cardiovascular problems, immune deficiency, psychotic symptoms, and the development of marijuana abuse/dependence (See Hall and Degenhardt (2009) for a comprehensive review). Marijuana use is also shown to have temporary negative effects on driving ability (Asbridge, Hayden, and Cartwright, 2012), memory and learning (Riedel and Davies, 2005), as well as school and work performance (Lynskey and Hall, 2000; Wadsworth, et al., 2006). Furthermore, studies also suggest a positive correlation between marijuana use and other substance use such as binge drinking and cocaine use (Wagner and Anthony, 2002a). Considering the high prevalence and potential risks of marijuana use, the federal government continues to classify marijuana as a schedule I controlled substance and prohibits marijuana use for any purpose.

2.2. Medical Value of Marijuana, & State MMLs

By classifying marijuana as a schedule I controlled substance, the federal government has concluded that marijuana has "no currently accepted medical value". However, a growing body of evidence supports to the efficacy and safety of marijuana as medical therapy to alleviate symptoms and treat diseases. Marijuana can effectively and safely serve as an antiemetic and appetite stimulant to relieve nausea and vomiting induced by chemotherapy and anorexia associated with HIV/AIDS, as an analgesic to ease chronic pain caused by neuropathy and fibromyalgia, and as an antispasmodic to help combat multiple sclerosis (See Ben Amar (2006) for a comprehensive review). Other medical applications of marijuana such as treating epilepsy (Pertwee, 2012), dementia (Campbell and Gowran, 2007), and Tourette's (Singer, 2005) have also been studied and shown promise (See, for instance, Krishnan, Cairns, and Howard, 2009; Gloss and Vickrey, 2012).

In the last two decades, this growing scientific evidence on marijuana's medicinal value propelled many states toward a more tolerant legal approach to medical marijuana. Since 1996, when California signed the Compassionate Use Act into law (Proposition 215) and became the first state in the U.S. to permit the medical use of marijuana, a total of 21 states and the District of Columbia passed MMLs (Table 1). These laws protect patients from state prosecution for their use of marijuana in treatment recommended by a qualified doctor for an eligible condition (Hoffmann and Weber, 2010).

In contrast to the state MMLs, federal law prohibits marijuana use for any purpose under the Controlled Substances Act (CSA) of 1970. A 2005 Supreme Court decision (*Gonzales v. Raich*) reaffirmed that federal law enforcement has the authority to prosecute patients for medical marijuana use in accordance with state laws (Gostin, 2005). It is only recently that the Obama administration and the Department of Justice clarified the position that federal law enforcement resources should not be dedicated to prosecuting persons whose actions comply with their states' permission of medical marijuana (Hoffmann and Weber, 2010). This change in the prosecutorial stance strengthened the legitimacy of existing MMLs and paved the way for the passage of new MMLs.

2.3. Potential Spillover Effect of MML

In principle, an MML should only provide protection for medical marijuana patients. In practice however, the legal protection intended for the patients may have a spillover effect on marijuana use in the non-patient population. The spillover effect may arise from three key dimensions of the existing MMLs that create a de facto legalized environment for marijuana use in the general population. First, although the MMLs typically specify a list of conditions that are eligible for medical marijuana[2], most MMLs include in their list a generic term "chronic pain", rather than specific diseases causing the pain (e.g., neuropathy, fibromyalgia, rheumatoid arthritis, etc.) (Pacula, et al., 2013). The interpretation of "chronic pain" can extend the medical marijuana patients beyond the original legislative intent to those to whom research evidence has demonstrated a therapeutic benefit, analogous to the practice of off-label prescribing of other medications. The concern with this spillover effect is similar to that of prescription opioid medications. Namely pain can often be non-descript and difficult to verify medically, and lack of vigilance on the part of prescribers can effectively lead to recreational use of drugs intended to be used as medicine.

[2] California is the only exception that allows medical marijuana for any condition "for which marijuana provides relief" and leaves the interpretation almost entirely to the discretion of doctors.

Second, some MMLs do not mandate a patient registry and renewal system. This, coupled with the loosely-defined eligibility criteria, further blurs the boundary between the targeted patients and the non-patient population (Cohen, 2010).

Third, MMLs provide medical marijuana patients with access to the drug by allowing regulated dispensaries and/or home cultivation. These supply channels exist in a legal grey area and may proliferate as a result of the reduced threat of prosecution under the protection of the MMLs (Pacula, et al., 2014).[3] In particular, Andersen, Hansen, and Rees (2013) provided empirical evidence that MMLs have led to a substantial increase in the supply of high-grade marijuana. As the medical marijuana supply rises, the non-patient population may also gain access to the drug, akin to how prescription opioids eventually find their way into the street drug market. This is most likely to occur in places where marijuana possession is decriminalized, prosecution of a marijuana offense is local law enforcement's "lowest priority", and federal interference in marijuana regulation is limited (Sekhon, 2009). In addition to those specific provisions of the laws, MMLs symbolize liberalization of marijuana policy, which in turn, may give rise to normalization of marijuana use behavior in society (Hathaway, Comeau, and Erickson, 2011).

On top of the spillover of marijuana use from medical marijuana patients to the non-patient population, the potential interdependence of substance use may lead to a further spillover from marijuana use to the use of other psychoactive substances.[4] A "joint intoxication model" derived from Marshallian demand functions assumes that an individual with the goal of intoxication chooses from a range of intoxicants (i.e., both licit and illicit substances including

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[3] Anderson and Rees (2014), however, found discrepancies between the time when states passed their MMLs and the time when states explicitly allowed dispensaries, which Pacula and colleagues (2014) did not make a clear distinction. They also found potential measurement errors in counting the number of the dispensaries that actually operated. Data on the medical marijuana retail sales and marijuana-related emergency department (ED) visits in the Denver area did not provide evidence that dispensaries were an important contributor to the increase in marijuana use among Coloradans (Anderson and Rees, 2014).

[4] However, if the increased marijuana use arising from an MML is not for recreational purpose (i.e., "intoxication") but for medical purpose only, the use of other substance is unlikely to be affected.

alcohol, "soft drugs" like marijuana, and "hard drugs" such as cocaine and heroin), each differing in their anticipated effects on the individual's intoxication experience and in their expected costs comprised of both market prices and non-market consequences (e.g., health risks, legal penalties, social sanctions, etc.). An exogenous shock to the cost of one intoxicant, therefore, may shift the individual demand for other intoxicants, through the interaction between the intoxicants in the individual's utility function under one's budget constraint (Chaloupka and Laixuthai, 1997; Pacula, 1998).

Assuming marijuana has a downward sloping demand, the effect of an MML on marijuana use should be unequivocally positive. The effect on other substance use, however, can be positive or negative, depending on the relative magnitude of the income and substitution effects (Chaloupka and Laixuthai, 1997; Pacula, 1998). Specifically, contemporaneous substitution of marijuana for another substance in response to the implementation of an MML is most likely to occur for substances whose pharmacological effect is the most similar to that of marijuana; whereas a complementary relationship is most likely to occur between marijuana and another substance if their combined use produces a synergistic interaction (Moore, 2010). In addition to the contemporaneous relationship between marijuana use and other substance use, there may also be a progression from the demand for marijuana to the craving and thus future demand for a more powerful substance with more intense and longer-lasting effects (Kandel, 1975; Kandel, 2002).

2.4. Pharmacologic Evidence on the Relationship between Marijuana & Other Substances

Marijuana and alcohol target many common neural pathways in human brains (Maldonado, Valverde, and Berrendero, 2006). On the one hand, marijuana use produces rewarding and sedative effects that are comparable to the effect of alcohol use (Boys, Marsden, and Strang, 2001; Heishman, Arasteh, and Stitzer, 1997), especially low-dose alcohol consumption[5] (King, et al., 2011). In this case, when MML lowers the cost of marijuana use, an individual may substitute marijuana for alcohol to achieve a similar experience of euphoria and relaxation, perhaps with fewer immediate negative physical symptoms (e.g. hangovers).

Conversely, the overall intoxication experience may be enhanced by the simultaneous use of marijuana and alcohol together (Boys, Marsden, and Strang, 2001). Evidence from one randomized control trial (RCT) suggests that ethanol facilitates the absorption of delta 9-tetrahydrocannabinol (THC), which in turn, leads to more episodes and a longer duration of euphoria reported by human subjects. Higher doses of ethanol can expedite euphoria and lengthen its duration (Lukas and Orozco, 2001). This scenario points towards a competing hypothesis that marijuana and alcohol are complements rather than substitutes, and MMLs should increase the use of both substances.

Marijuana is also widely portrayed as a "gateway" drug, essentially inducing the use of drugs with more serious health, legal and social consequences (Kandel, 1975; Kandel, 2002). One hypothesized pathway is through pharmacological mechanisms: once users tolerate the psychoactive effects of marijuana use, they may crave and seek out more powerful drugs with more intense and longer-lasting effects. This pharmacological mechanism would thus predict a positive effect of MML implementation on the subsequent use of hard drugs.

Nonetheless, the pharmacological account of the gateway hypothesis is difficult to identify empirically in the absence of controlled experiments on humans[6] (Caulkins, et al., 2012; Anthony, 2012). An alternative to this pharmacological mechanism is that the observed hierarchical sequence from marijuana use to hard drug use may simply reflect common

[5] High-dose alcohol consumption, in contrast, tends to lower sedation and heighten stimulation (King, et al., 2011).

[6] Although converging lines of evidence from experimental animal models suggest interactions between the cannabinoid and opioid system, they are insufficient and inconclusive to date (see, for instance, Ledent, et al., 1999; Cadoni, et al, 2001; Klein, 2001; Navarro, et al., 2001; Solinas, Panlilio, and Goldberg, 2004; Ellgren, Spano, and Hurd, 2007; Cadoni, Valentini, and Di Chiara, 2008; DiNieri and Hurd, 2012; Cadoni, et al., 2014).

predisposing factors rooted in genetic or environmental factors coupled with an exposure opportunity mechanism through which marijuana users may be introduced to a shared market or subculture of hard drugs (Morral, et al., 2002; Wagner and Anthony, 2002a). If predisposing factors and exposure opportunities are the primary mechanisms that lead to transition from marijuana use to hard drug use, then an MML should not result in an increase in hard drug use because the predisposing factors and exposure opportunities[7] for hard drug use remain unaffected.

3. PREVIOUS LITERATURE

3.1. Literature on MMLs & Marijuana Use

Empirical evidence is inconclusive with respect to the effect of MMLs on marijuana use in the general population. The cross-sectional correlation found in earlier studies (e.g., Cerdá, et al., 2011) largely comes from the underlying high prevalence of marijuana use in MML states prior to the laws (Wall, et al., 2011). Later studies that addressed state heterogeneity generally found no within-state variation in marijuana use attributable to an MML (Harper, et al., 2012; Lynne-Landsman, et al., 2013; Anderson, Hansen, and Rees, 2012). Nonetheless, these previous studies focused on youth marijuana use and on measures of current marijuana use. The adult population, with different underlying risk attitudes, budget constraints, and exposures to drug markets and subculture, is likely to respond differently to an MML. Furthermore, an MML may have consequences for other previously overlooked dimensions of marijuana use. And such dimensions as initiation and abuse/dependence may have differential elasticities[8] and expected harms.

[7] The existing MMLs help marijuana users gain access to the drug through medical marijuana dispensaries and home cultivation, which are unlikely to expose the marijuana users to the market or subculture of hard drugs.

[8] Although the literature on differential elasticities of marijuana demand is thin, Manning, Blumberg, and Moulton (1995) provided evidence for differential responses to alcohol prices between light, moderate, and heavy drinkers.

3.2. Literature on Marijuana & Other Substances

Through the increased marijuana use, a further consequence of an MML could also be the spillover to the use of other psychoactive substances (e.g., excessive alcohol use and hard drug use). Identification of the spillover effect in an observational study hinges on the isolation of the exogenous variation in substance use arising from policy/price shocks from the endogenous variation due to “common factors” or “exposure opportunities.”

Epidemiological studies have attempted to rule out the common genetic and environmental factors through a discordant twin design or panel data analysis (Lynskey, et al., 2003; Fergusson, Boden, and Horwood, 2006). Lynskey and colleagues (2003) compared substance use between monozygotic twins in the Austrian Twin Register to remove their shared genetic and environmental influence. Fergusson, Boden, and Horwood (2005) analyzed 25-year longitudinal substance use data of a birth cohort in the New Zealand Christchurch Health and Development Study, and included individual fixed effects to control, statistically, for the heterogeneity in genetic and environmental factors that do not change over time. According to these studies, the estimated effect of marijuana use on excessive alcohol use and hard drug use shrinks, but remains significant even when through the study design. However, a major limitation of the monozygotic twin comparison is that it cannot remove the unshared environmental influence that contributes to different decisions about substance use in identical twins. A limitation of the fixed effects method is that it cannot control for the time-variant environmental factors evolving with age or specific to a life stage that contribute to the substance use progression in individuals.

Another limitation of the literature is that the prior studies have not examined the effect of marijuana use on the use of other substances within the context of an MML. Even if marijuana use, in general, does lead to excessive alcohol use and hard drug use, those who use marijuana in response to the implementation of an MML may differ from a typical marijuana user in drinking behavior and other substance use. Thus, we cannot draw any inference about the effect of an MML from what is observed among those who use marijuana regardless of the law.

Economic studies rely on the exogenous shocks in policy/price related to one substance to estimate a joint demand function for the target substance itself (e.g., alcohol and cocaine) and its potential complements/substitutes (e.g., marijuana). Previous studies have exploited changes in state excise taxes on beer (Pacula, 1998), the minimum legal drinking age (MLDA) (DiNardo and Lemieux, 2001; Yörük and Yörük, 2011, 2012; Crost and Guerrero, 2012) composite market prices of alcohol (Saffer and Chaloupka, 1999) and market prices of cocaine (Saffer and Chaloupka, 1999; DeSimone and Farrelly, 2003). Although they generally found a direct policy/price effect on the use of the target substance itself that follows a downward sloping demand curve, the downstream effect on marijuana use is mixed. Chaloupka and Laixuthai (1997), DiNardo and Lemieux (2001), Crost and Guerrero (2012), and Crost and Rees (2013) found evidence for a substitution between marijuana and alcohol, whereas Pacula (1998), Saffer and Chaloupka (1999), and Yörük and Yörük (2011, 2013) found evidence supporting the complementarity hypothesis. Moreover, evidence from Saffer and Chaloupka (1999) and DeSimone and Farrelly (2003) suggests a complementary relationship between marijuana and cocaine.

Not only is there a lack of consistent evidence, it is also difficult to extrapolate the effect of an MML on alcohol use/cocaine use from the estimated reduced-form effect of alcohol- or cocaine-related policy/price on marijuana use or the implied structural relationship between marijuana use and alcohol use. This difficulty arises out of the nature of the underlying Marshallian demand function, which does not require symmetric relationships between substances (i.e., from substance A to B vs. from substance B to A), nor does it require symmetric responses to policy/price changes (i.e., permissive policy/lower price vs. restrictive policy/higher price). Thus it is possible for marijuana to be a substitute for alcohol when alcohol regulations become more restrictive (e.g., blue laws that ban Sunday sales of alcohol for off-premises consumption) but for alcohol be a complement to marijuana following a shift towards more permissive marijuana policies (e.g., MMLs).[9]

3.3. Significance of Our Study

To inform the current debate on MMLs, we examine the effect of state implementation of MMLs between 2004 and 2011 on marijuana, alcohol, and hard drug use for both adolescent and adult populations. Our study advances the existing literature by: (i) providing the first estimates of the effect of MML implementation on adult marijuana use using micro-level data; (ii) estimating directly a reduced-form effect of MML implementation on alcohol use and hard drug use, rather than an implied contemporaneous relationship induced by alcohol- or hard drug-related policies/price; and (iii) estimating the effect of MML implementation on a full range of substance use outcomes with differential elasticities and expected harms, including current use and frequency, initiation, and abuse/dependence.

4. METHODS

4.1. Data Sources

Eight years of cross-sectional data were pooled from a restricted version of the National Survey on Drug Use and Health (NSDUH) 2004-2011 (CBHSQ, 2013). NSDUH is a nationally and state-representative[10] survey sponsored by the Substance Abuse and Mental Health Services Administration (SAMHSA), and the primary source of information on substance use behavior by

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[9] Anderson, Hansen, and Rees (2013) provided one of the most direct evidence within the context of MMLs that states with MMLs saw a reduction in alcohol-related traffic fatalities. However, due to the ambiguity in the policy effect on marijuana use in the first place, this finding does not necessarily imply that alcohol is a substitute for (or a complement to) marijuana. In fact, when taking into account the key components of MMLs, Pacula and colleagues (2013) concluded that the finding from traffic fatalities are more consistent with a complementarity hypothesis.

[10] The NSDUH sampling is designed as state-based with an independent, multistage area probability sample within each state and the District of Columbia. The eight states with the largest population (i.e., California, Florida, Illinois, Michigan, New York, Ohio, Pennsylvania, and Texas)[10] have an annual sample size of about 3,600 each. For the remaining 42 states and the District of Columbia, each has a sample size of about 900 annually.

the U.S. civilian, noninstitutionalized[11] population aged 12 or above. Adolescents and young adults aged 12 to 25 are oversampled in the survey.

The majority of the NSDUH interview is conducted by self-administrated audio computer-assisted self-interviewing (ACASI), a highly private and confidential mode that encourages honest reporting of substance use and other sensitive behaviors (Johnson, Fendrich, and Mackesy-Amiti, 2010). The response rates range from 73% to 76% between 2004 and 2011.

4.2. Variable Measurement

4.2.1. Dependent Variables

Marijuana Use Outcomes:

NSDUH provides information on the recency and frequency of the use of each substance, the timing of the first use of each substance, and the assessment of substance abuse/dependence based on DSM-IV diagnostic criteria (APA, 2000). This information allows us to examine the effect of MML implementation on a full range of marijuana use outcomes with differential elasticities and expected harms, including current marijuana use and frequency, marijuana use initiation, and marijuana abuse/dependence. Four measures of marijuana use outcomes were created accordingly: (i) a dichotomous indicator assessing whether a respondent used marijuana during the past month prior to the interview; (ii) the number of days during the past month that a respondent used marijuana, which is an unconditional frequency ranging from 0 to 30; (iii) a dichotomous indicator for using marijuana for the first time during the past year; (vi) a dichotomous indicator for being classified as abuse of or dependence on marijuana during the past year according to DSM-IV criteria.

Alcohol Use Outcomes:

[11] Institutionalized individuals (e.g. in jails/prisons or hospitals), homeless or transient persons not in shelters, and military personnel on active duty were excluded from the NSDUH sample.

As noted above, empirical support exists both for a substitution and for a complementary relationship between marijuana use and alcohol use. An explanation for this contradiction, as we mentioned in Section 2.4., is related to the dose of alcohol consumption: lower-dose alcohol consumption is hypothesized to be replaced by marijuana use (King, et al., 2011), whereas higher-dose alcohol consumption is hypothesized to be accompanied by marijuana use (Lukas and Orozco, 2001).

Therefore, for alcohol use outcomes, we examined any alcohol use as well as binge drinking. By doing so, we accounted for the differences in the elasticity of demand for alcohol and consequent effect of MML implementation across different levels of drinking intensity. Binge drinking, in the NSDUH, is defined as having five or more drinks on the same occasion on at least one day during the past month[12]. We created the following measures for alcohol use: (i) the total amount of drinks consumed during the past month, (ii) the unconditional frequency of alcohol use counting the number of days alcohol was consumed during the past month, (iii) the unconditional frequency of binge drinking days,[13] and (iv) the probability of being classified as having alcohol abuse/dependence during the past year.

We also created a dichotomous indicator to assess whether a respondent used marijuana while drinking alcohol during the past month.[14] This measure of simultaneous use of marijuana and alcohol can provide further insight into the contemporaneous complementarity between the two substances.

<u>Hard Drug Use Outcomes:</u>

[12] A commonly used alternative defines "binge drinking" as five or more drinks for men and four or more drinks for women consumed on one occasion (Wechsler, et al., 1995). Our estimates are robust to this gender-specific definition (not shown).

[13] Carpenter and Dobkin (2009), for instance, find evidence for the differential elasticity of alcohol demand along the distribution of drinking intensity and frequency.

[14] The question about simultaneous use of marijuana and alcohol is not included in NSDUH 2004 and 2005 surveys, while the MMLs in Vermont and Montana both came into effective in 2004. Thus we cannot estimate the effect of these two states' implementation of the MMLs on this outcome.

We focus our analysis of hard drugs on cocaine and heroin, not only because they are widely prevalent[15] and highly dangerous[16], but also because these are the two substances most often linked to the potential gateway effect of marijuana use (Kandel, 2002). We created dichotomous indicators for: (i) past-month cocaine use and heroin use, and (ii) past-year initiation of the two drugs.

4.2.2. Independence Variables

MML-Implementation Indicator:

The recent launch of the Data Portal system by the CBHSQ provides us with access to state identifiers in micro-level NSDUH data, allowing us to create a dichotomous indicator for the implementation of a MML in a given state during a given year. As summarized in Table 1, during 2004-2010, MMLs came into effect in seven states in various years. The MML-implementation indicator was assigned a value of 1 for each full year subsequent to the effective date of the laws[17], and a value of 0 for the remaining years and for the control states. Control states include those that did not have any MML by the end of 2010 (i.e., "no MML states"). Note that we excluded eight states that had an MML in place prior to 2004 (i.e., "always MML

[15] The prevalence rates of past-month use of cocaine and heroin are 0.6% and 0.1%, respectively. The combined total of past-month cocaine users and heroin users accounts for 19% of the illicit drug users who use substances other than marijuana during the past month. When we further exclude the non-medical use of psychotherapeutic drugs, 55% of the remaining past-month illicit drug users (i.e., who use substances other than marijuana and psychotherapeutic drugs) used cocaine or heroin or both during the past month.

[16] For instance, the Independent Scientific Committee on Drugs (ISCD) in the U.K., led by the former chief government drugs adviser, assessed the individual and societal harmfulness of 20 substances including tobacco, alcohol and 18 commonly used illicit drugs, and concluded that heroin, cocaine, and methamphetamine were the most harmful drugs to individuals, whereas alcohol, heroin, and cocaine were the most harmful to others (Nutt, King, and Phillips, 2010).

[17] The effective date of the MMLs cannot be matched precisely with the survey date of the NSDUH, which raises concerns about measurement error: the years during which MMLs came into effective and the first full years after the effective date of MMLs may capture a mixture of pre-MML and post-MML behaviors. Nonetheless, this potential misclassification is unlikely to bias our findings because the estimates are consistent when we excluded these years and when we reclassified the pre-/post-MML periods.

states”), because all but Hawaii amended their laws during the study period.[18] We also excluded Maryland, Arizona, and Delaware, which fall short of being classified as “MML states” during the study period: Maryland passed two laws in 2003 and in 2011 favorable to medical marijuana, albeit not legalizing it; Arizona and Delaware did not begin to implement MMLs until 2011. Our main analyses, therefore, excluded these states from the control group.

Covariates:

We controlled for individual-level and state-level factors that are correlated with both the individual choice to use substances and with state decisions about MMLs. Individual-level covariates for adolescents and adults include: (i) age (linear and squared terms), (ii) gender, (iii) race/ethnicity (non-Hispanic White, Hispanic, non-Hispanic African/Black, non-Hispanic Asian, or other racial/ethnic origins), (iv) self-reported health (excellent, very good, good, or fair/poor health), (v) past-month cigarette smoking (daily smoker, non-daily smoker, or non-smoker), (vi) urban residence (living in a metropolitan, micropolitan, or non-core-based statistical area), (vii) family income relative to federal poverty level (living below 100% FPL, 100%-200% FPL, or above 200% FPL). For adults, we also included measures of: (i) marital status (never married, married, divorced/separated, or widowed), (ii) educational attainment (less than high school, high school graduate, some college, or college graduate), (iii) college enrollment (full-time enrolled, part-time enrolled, or non-student), and (iv) employment status (full-time employed, part-time employed, unemployed, or not in labor force).

In addition to the individual-level demographic and socioeconomic characteristics, we also controlled for the time-variant state-level economic and policy environment. State-level economic measurements include: (i) unemployment rate, (ii) average personal income, and (iii)

[18] We concerned that when including the “always MMLs states” in our control states, the estimated effect of MML implementation may be clouded by the effect of the policy tweaking and amendment of the existing MMLs. Therefore, we decided to exclude those “always MML states” from main analyses. We included those states in a set of sensitivity analyses and added an indicator for the amendment of the existing MMLs in a given “always MML states” during a given year. Our main findings were robust to the inclusion of “always MML states” in the model specification (Table 7 & 8).

median household income of the state. Three additional continuous measures were created to capture relevant changes in the state policy environment concerning beer taxes between 2004 and 2011: (i) specific excise taxes levied per gallon at the wholesale or retail; (ii) ad valorem excise taxes levied as a percentage of the retail price for on-premises sales (e.g., bars, restaurants); and (iii) ad valorem excise taxes for off-premises sales.[19] Another major policy change that occurred during the study period was related to marijuana decriminalization: Massachusetts, California, and several cities and counties in other states relaxed penalties for recreational marijuana use or placed it "the lowest law enforcement priority." We excluded these decriminalization areas from the analytic sample.[20]

Table 2 presents descriptive statistics for the marijuana, alcohol, and hard drug use outcomes in 2004 and 2011, separately for "no MML states" vs. "MML states". For most of the outcomes, the 2004 and 2011 statistics in the "MML states" mirrored those in the "no MML states". For the outcomes including the probability of past-month marijuana use, the number of marijuana use days, the number of binge drinking days, and the probability of simultaneous use of marijuana and alcohol among adults aged 21 or above, as well as the probability of marijuana initiation among adolescents and young adults aged 12-20, we observed slightly higher probabilities/counts in the "MML states" than those in the "no MML states" in 2004. By 2011, however, these probabilities and counts diverged markedly.[21]

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[19] We did not control for the market price of cocaine or heroin. The most commonly used source is the U.S. Drug Enforcement Administration's System to Retrieve Information from Drug Evidence (STRIDE) dataset. Empirical studies often find that STRIDE prices are not predictive or only weakly predictive of drug use (Horowitz, 2001). As French and Popovici (2009) pointed out, "part of difficulty here is that conventional prices for illicit drug are not readily available and alternative measures are not yet found." Nonetheless, fluctuations in cocaine prices and heroin prices are unlikely to be correlated with the MML implementation, thus omitting these variables is unlikely to bias our results.

[20] The estimated effects of MML implementation are robust to the alternative specifications in which we included the decriminalization areas in our sample and included as a covariate an indicator for the implementation of marijuana decriminalization in these areas (not shown).

[21] A more rigorous regression approach that we discuss in the next section can help identify to what extent this observed divergence can be attributed to the MML implementation during 2004-2011.

Table 3 reports the descriptive statistics for the individual-level and state-level covariates we included in the regressions for the entire analytic sample.

4.3. Identification Strategy

To identify the effect of MML implementation on individual marijuana, alcohol, and hard drug use, we estimated the following two-way fixed effects models:

$$\boldsymbol{Y_{i,s,t}} = f(\beta_0 + \beta_1 \boldsymbol{MML_{s,t}} + \beta_2 X_{1\ i,s,t} + \beta_3 X_{2\ s,t} + \rho_s + \tau_t + \rho_s t + \varepsilon_{i,s,t})$$

where i denotes an/the individual, s denotes the state, and t denotes the year. $Y_{i,s,t}$ represents the four marijuana use outcomes, the six alcohol use outcomes, and the four hard drug use outcomes discussed above. $MML_{s,t}$ is the policy indicator for the implementation of an MML in a state s during a year t. $X_{1\ i,s,t}$ is the full vector of individual-level covariates. $X_{2\ s,t}$ includes the state-level economic indicators and beer tax rates. The two-way fixed effects are captured in our models by ρ_s and τ_t to account for the time-invariant state heterogeneity as well as the national secular trend and common shocks related to substance use. We also added state-specific linear time trends $\rho_s t$ to account for the unobserved state-level factors that evolve over time at a constant rate (e.g., social norms and sentiments towards substance use).

This two-way fixed effects method can be viewed as an extension of the difference-in-differences (DD) framework to fit multi-unit and multi-time models that go beyond the traditional two groups (i.e., treatment vs. control) and two periods (i.e., pre vs. post) (Wooldridge, 2001). It can produce consistent estimates unless there were concurrent shocks to substance use that affected the outcomes only in the "MML states". To our knowledge, no such concurrent shocks existed.

Standard errors were clustered at the state level to correct for the serial correlation. The clustered standard errors allow for arbitrary within-state correlation in error terms but assume independence across the states (Bertrand, et al., 2004).

We stratified the sample into two age groups, adolescents and young adults aged 12-20 (N ≈ 183,600) and adults aged 21 or above (N ≈ 219,400). We chose age-21 as the cutoff point in light of the previous evidence of an age-21 discontinuity in both alcohol use and marijuana use (Crost and Guerrero, 2012; Yörük and Yörük, 2011, 2012).[22] We tested four cut-off points in our analyses, age-18, age-21, age-25 and age-30. Only the age-21 stratification, which also coincides with the legal drinking age, produced significant and meaningful differences in the estimated policy effect between age groups.

We estimated Probit regressions for the dichotomous dependent variables in our study. The other four discrete dependent variables we studied (i.e., the unconditional number and frequency measures) possess "excess zeroes" and positive skewness compared to a standard normal distribution, which requires a more flexible estimation approach than an ordinary least squares (OLS) estimation. A generalized linear model (GLM) with gamma distribution and log link[23] was estimated for the total amount of drinks during the past month among those aged 21 or above. For the total amount of drinks among those aged 12-20, on the other hand, we estimated a two-part model with Probit in the first part and GLM (gamma distribution and log link) in the second part. Because there is an explicit decision process regarding legality of alcohol consumption among those under 21, we use the TPM to model the decision to engage in underage drinking and the quantity consumed conditional upon deciding to engage in underage drinking as separate processes. We followed the same logic when estimating the frequency variables. Considering the underlying decision processes and the proportions of zero values, we estimated a negative binomial regression[24] for the number of alcohol use days among those aged

[22] The age-21 discontinuity may be created by minimum legal drinking age (MLDA) as the studies suggest. It may also be related to other shocks to cognitive development, risk preference, legal responsibility and social environment.

[23] The selection of distribution family under the GLM was made based on the modified Park test results.

[24] The likelihood ratio test for overdispersion rejects the Poisson distribution in favor of the binomial distribution.

21 or above and a zero-inflated negative binomial regression[25] for the number of alcohol use days among those aged 12-20.[26] Zero-inflated negative binomial regressions were also estimated for the number of marijuana use days and the number of binge drinking days in both age groups.

For ease of interpretation, we converted the coefficient of $MML_{s,t}$ in each of the estimations to the average marginal effect calculated at $MML_{s,t} = 0$ and the observed values of other covariates.

5. RESULTS

5.1. Estimated Effect of MML Implementation on Marijuana Use

In Table 4 we first present the marginal effect of MML implementation on the four marijuana use outcomes (Panel A). Among adults aged 21 or above, the implementation of an MML increased the probability of using marijuana during the past month by 1.37-1.40 percentage points (Row 1 Column 3 & 4), which is robust to the inclusion of the state-specific linear time trends. This percentage point change can be translated into a 16 percent relative increase from a baseline predicted marijuana use probability of 8.60 percentage points.

The NSDUH data do not allow us to distinguish between medical marijuana patients and the non-patient population. Nonetheless, according to the registry data (Anderson, Hansen and Rees. 2013), the number of registered medical marijuana patients accounts for an average of 0.8 percent of the population across the five "MML states" on which the registry information is

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[25] The likelihood ratio tests for overdispersion reject the zero-inflated Poisson regression in favor of a zero-inflated negative binomial regression. Furthermore, the Vuong tests for zero-inflation confirm our choice of zero-inflated regressions instead of ordinary negative binomial regressions.

[26] An alternative to a zero-inflated regression is a hurdle model (i.e., "TPM" for counts). A practical challenge, however, is that cluster-adjusted standard errors from the combined marginal effects (i.e., combining the first- and second-part estimates) from the hurdle model (Belotti, et al., 2014). Nonetheless, the point estimates for the combined effects we obtained from the hurdle models with first-part Probit and second-part zero-truncated negative binomial (not shown) were very similar to the zero-inflated negative binomial estimates from our main analyses. In another set of sensitivity analyses, we also treated the count variables as continuous and estimated the combined marginal effects and their cluster-adjusted standard errors using the STATA command "TPM" (Belotti, et al., 2014). The TPM estimates (not shown) were slightly larger and more significant than the zero-inflated negative binomial estimates.

available[27]. Therefore, the 1.4 percentage point increase in the probability of marijuana use we found among adults aged 21 or above is not likely to come exclusively from an increase in use among registered patients. Though we cannot test this directly, it suggests that there may also be a considerable increase in recreational marijuana use or self-medication by the non-patient population associated with MML implementation.

Among adults aged 21 or above, we also found a 0.14-0.21 day or a 12-17 percent increase in the number of marijuana use days (Row 2 Column 3 & 4) arising from MML implementation. Among adolescents and young adults aged 12-20, in contrast, no change in the probability or frequency of past-month marijuana use can be attributed to MML implementation (Row 1 & 2 Column 1 & 2).

With regard to marijuana use initiation in the preceding year, MML implementation led to 0.32-0.46 percentage point or a 5-6 percent increase in the probability of first-time marijuana use among adolescents and young adults aged 12-20 (Row 3 Column 1 & 2). Yet, the lack of a positive policy effect on the probability and frequency of past-month marijuana use among this age group suggests that many of these individuals are engaging in experimental use with relatively low health, behavioral, and social consequences. In other words, these findings are consistent with a scenario in which adolescents and young adults who experiment with marijuana use because of the potentially increased availability and social acceptance and reduced penalties brought about by an MML are not transitioning to regular use, at least in the short term.

Among those aged 21 or above, we also found a 0.22 percentage point increase in marijuana use initiation (Row 3 Column 3). However, this was largely offset by the inclusion of the state-specific linear time trends (Row 3 Column 4). This insignificant increase in initiation suggests that the significant increases in the probability and frequency of past-month use we found earlier come largely from the adults who first tried marijuana long before its medical use

[27] The registry information is not available for the two most recent "MML states", namely New Jersey and the District of Columbia, despite that both states mandate patient registry in their laws.

was permitted by law. After the introduction of an MML that helped reduce costs of marijuana use (i.e., market prices as well as non-market health, legal and social consequences), those with prior marijuana use experience would likely reinitiate or increase their marijuana use.

The effect arguably most salient to the public health implications of MMLs is the effect on marijuana abuse/dependence among adults aged 21 or above, as this occurs even for other legal pharmaceuticals such as prescription opioid medications. We found a 15-27 percent increase in the probability of marijuana abuse/dependence (Row 4 Column 3 & 4), which is higher than the relative increase in the probability and frequency of marijuana use in this age group. This finding suggests that those who used marijuana in response to MML implementation had a higher risk of progressing to abuse/dependence than those who used marijuana regardless of the law.

5.2. Estimated Effect of MML Implementation on Alcohol Use

To the extent that alcohol is a complement or substitute to marijuana, the significant effect of MML implementation on marijuana use may spread to alcohol use (Table 4 Panel B). Our estimates indicate that, among adults aged 21 or above, MML implementation was not associated with either the total number of drinks or the number of drinking days (Row 1 & 2 Column 3 & 4). The implementation of an MML was, however, positively associated with the frequency of binge drinking, with an effect size of 0.10-0.14 binge drinking days or a relative increase of 6-9 percent (Row 3 Column 3 & 4). The spillover increase in binge drinking implies a complementarity between marijuana use and high-dose alcohol consumption among adults aged 21 or above. Not only was this contemporaneous complementarity reflected in the independent measures of marijuana use and binge drinking, it was further confirmed by the measure of simultaneous use of the two substances: among adults aged 21 or above we found a 0.62-0.89 percentage point or a 15-22 percent increase in the probability of marijuana use while drinking as a result of MML implementation (Row 4 Column 3 & 4).

However, we found no significant change in any measure of alcohol use among adolescents and young adults aged 12-20, which suggests that the increased marijuana use initiation we reported previously is unlikely to spread to underage drinking.

5.3. Immediate & Delayed Effect of MML Implementation on Alcohol Abuse/Dependence & on Hard Drug Use

In addition to increased marijuana use and binge drinking, MML implementation may have a spillover effect on alcohol abuse/dependence and the use of hard drugs such as cocaine and heroin. Given that the progression from marijuana use and binge drinking to these downstream outcomes may be a gradual transition (Wagner & Anthony, 2002b), we estimated not only the contemporaneous policy effect but also the one-year and two-year lagged policy effect. For both age groups, we found neither an immediate effect nor a delayed effect of MML implementation on alcohol abuse/dependence, past-month cocaine use, cocaine use initiation, past-month heroin use, and heroin use initiation (Table 5).

5.4. Policy Endogeneity of MML Adoption

There is a geographic concentration of MMLs: states that have adopted MMLs are all in the West and Northeast. This geographic similarity raises concern that there may be some past shocks to marijuana use in these regions leading to their adoption of MMLs and not accounted for by the state fixed effects and the state-specific linear trends. In other words, MML adoption could be endogenous to marijuana use. To check for this potential policy endogeneity, specifications with a series of lagged and leading indicators for adopting an MML were estimated for key marijuana use outcomes (Table 6). We found that only the contemporaneous and lagged policy indicators had significant effects, while all the leads had small and statistically insignificant effects. These estimates suggest that it is in fact the policy shocks from adopting an

MML that drive the changes in marijuana use, rather than some past disturbances in marijuana use that drive the adoption of an MML.[28]

5.5. State-Aggregate Effect of MML Implementation

To further check the robustness of our individual-level estimates with regard to serial correlation, we aggregated the data to the state level and estimated the effect of MML implementation on state-level prevalence rates of our key individual-level findings.[29] The previously highlighted policy effects on past-month marijuana use, marijuana use initiation, marijuana abuse/dependence, past-month binge drinking, and simultaneous use of marijuana and alcohol remain significant in these state-level specifications (Table 9 Panel A & B). The policy effects on the other downstream outcomes remain insignificant (Table 9 Panel C), with the only exception being a one-year lagged policy effect on the state-level prevalence of alcohol abuse/dependence among adults aged 21 or above (Panel C Row 1 Column 3 & 4).

5.6. State Heterogeneity of the Effect of MML Implementation

By examining the implementation of MMLs between 2004 and 2011 in seven states collectively, our estimates capture the average policy effect across all seven "MML states". However, the policy effects for each of these states may not necessarily have the same magnitude or even the same direction (Pacula, et al., 2013). From a statistical standpoint, a substantial policy effect from one or two states could potentially account for the overall finding. To test for heterogeneity of the estimated policy effect, we replaced the single indicator for MML

[28] As another set of sensitivity analyses, we also included the "always MML states" in our control states, which enables us to account for the past disturbances that "MML states" shared with "always MML states". Our main findings were robust to the inclusion of "always MML states" in the model specification (Table 7 & 8).

[29] In Column 1 and 3 (Table 9) we clustered the standard errors at the state level; while in Column 2 and 4, we removed the time-series information from the standard errors by averaging the pre-MML data and the post-MML data (Donald and Lang, 2007). We followed a two-step procedure described in Bertrand, Duflo, and Mullainathan (2001, pp. 267) to accommodate staggered adoption of the MMLs across states. As a result, the data were collapsed into pre- and post-MML two periods across 7 "MML states". The standard errors were adjusted to take into account the smaller number of "MML states" (Donald and Lang, 2007).

implementation with seven separate indicators for MML implementation in each of the seven "MML states". We found, in most cases, across-the-board significant policy effects in the same direction, although states vary in the magnitude of the effect (Table 10). Pacula and colleagues (2013) note that key components of MMLs, such as the ambiguity in "chronic pain", the allowance for dispensaries and/or home cultivation, and (the absence of) mandatory registry and renewal may help explain the heterogeneity of the policy effect across these seven states. However, we do not have sufficient policy variation during the study period to elucidate which of these components may have accounted for the heterogeneity in the effect size of MML implementation.

6. DISCUSSION

Three main pieces of evidence from our study inform the policy discussions of MMLs. First, we found a significant effect of MML implementation on increasing marijuana use. Estimates suggest that the populations responsive to MMLs were adolescents and young adults aged 12-20 who experimented with marijuana for the first time and adults aged 21 or above who had tried marijuana prior to the implementation of the law. This latter group had an increased risk of progression to marijuana abuse/dependence.[30] The effect of MML implementation on marijuana abuse/dependence constitutes a potential public health concern similar to that of prescription drug abuse/dependence (CDC, 2012): even if we assume that the increases in marijuana use we observed come from those who use the drug for validated medical purposes, there may still be possibility that marijuana abuse/dependence would increase as a result of MML implementation.

[30] A diagnosis of substance abuse/dependence, by definition, indicates that an individual is experiencing a cluster of psychological, physical, cognitive, and behavioral symptoms associated with substance use. The DSM-IV considers marijuana abuse and marijuana dependence to be valid psychiatric disorders, and marijuana abuse/dependence as experienced in clinical population and general population appears very similar to other substance abuse/dependence disorders (Budney, et al., 2007).

Second, among those aged 21 or above, we found a spillover effect of MML implementation on the increasing frequency of binge drinking, possibly through increased use of the two substances simultaneously. The complementarity between marijuana use and binge drinking among adults of legal drinking age could magnify the expected harms of an MML. As Pacula and Sevigny (2014) commented, "even if consumption (of marijuana) were assumed to rise by 100 percent, the savings of liberalization policies would dwarf the known health costs associated with using marijuana. However, all potential savings … could be entirely erased, and tremendous losses incurred, if alcohol and marijuana turn out to be economic complements." The 6-9 percent increase in the frequency of binge drinking and the 15-22 percent increase in the probability of simultaneous marijuana and alcohol use[31] that we estimated may result in considerable economic and social costs from downstream health care expenditures and productivity loss (Naimi, et al., 2003).

Third, neither underage drinking among those aged 12-20 nor hard drug use in both age groups was affected by MML implementation. In this regard, the often-voiced concerns about the potential gateway effect of marijuana is not supported by our findings. We caution that our study is not intended to refute the gateway hypothesis. Rather it suggests that the gateway effect is not likely to occur in the context of an MML: for those who respond to MML implementation and use marijuana, their marijuana use is not likely to act as a gateway to more dangerous substance use through the pharmacological properties of marijuana.[32]

Taken together, our study findings provide evidence for a significant effect of MML implementation on increasing marijuana use, and a spillover effect among adults of legal drinking age from increased marijuana use to increased binge drinking. The findings do not,

[31] The interaction between marijuana and alcohol may magnify the risks posed by the two substances individually (Liguori, Gatto, and Jarrett, 2002; Medina, et al., 2007).

[32] Nonetheless marijuana may still be a gateway drug for other marijuana users through other pathways For instance, those who use marijuana regardless of the laws or those who use marijuana in response to decriminalization may progress to hard drug use because marijuana introduces them to a shared market or subculture of hard drugs.

however, provide evidence to support other types of substance use spillovers (i.e., underage drinking, cocaine use, and heroin use).

Table 1. Effective Time of State Medical Marijuana Laws

MML States	(1) Approved	(2) Effective
2004-2010 (7 States)		
Vermont	2004/05	2004/07
Montana	2004/11	2004/11
Rhode Island	2005/06	2006/01
New Mexico	2007/03	2007/07
Michigan	2008/11	2008/12
New Jersey	2010/01	2010/10 (07)†
District of Columbia	2010/05	2010/07
1996-2003 (8 States)		
California	1996/11	1996/11
Washington	1998/11	1998/11
Oregon	1998/11	1998/12
Alaska	1998/11	1999/03
Maine	1999/11	1999/12
Hawaii	2000/06	2000/12
Colorado	2000/11	2001/06
Nevada	2000/11	2001/10
2010-2014 (7 States)		
Arizona	2010/11	2011/04
Delaware	2011/05	2011/07
Connecticut	2012/05	2012/05 (10)‡
Massachusetts	2012/11	2013/01
New Hampshire	2013/07	2013/07
Illinois	2013/08	2014/01
Maryland	2014/04§	2014/06

Note:

† The effective date of New Jersey MML is 2010/07 as specified in the statute, while the state governor Chris Christie delays its implementation;

‡ Some sections of Connecticut MML came into effect from its passage (2012/05), while other sections on 2012/10;

§ Maryland passed two laws in 2003 and in 2011 favorable to medical marijuana, albeit not legalizing it.

Table 2. Descriptive Statistics of Dependence Variables in 2004 & 2011

Age 12-20	Year 2004				Year 2011			
	No MML States		MML States		No MML States		MML States	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A. Marijuana Use Outcomes								
%Pr(Past-Month Marijuana Use)	10.0	(30.0)	12.5	(33.1)	10.0	(30.0)	12.5	(34.6)
#Marijuana Use Days	1.18	(4.88)	1.54	(5.58)	1.24	(5.05)	1.72	(5.92)
%Pr(Marijuana Initiation)	7.07	(25.6)	7.77	(26.8)	7.47	(26.3)	9.29	(29.0)
%Pr(Marijuana Abuse/Dep.)	4.87	(21.5)	5.83	(23.4)	3.87	(19.3)	4.96	(21.7)
B. Alcohol Use Outcomes								
#Total Drinks‡	9.32	(45.3)	9.66	(35.5)	6.41	(34.4)	6.43	(30.4)
#Alcohol Use Days	1.59	(4.06)	1.62	(4.08)	1.16	(3.34)	1.24	(3.33)
#Binge Drinking Days	0.86	(2.76)	0.85	(2.69)	0.60	(2.20)	0.61	(2.14)
%Pr(Marijuana while Drinking)	3.59	(18.6)	5.62	(23.0)	3.89	(19.3)	5.49	(22.8)
C. Other Downstream Outcomes								
%Pr(Alcohol Abuse/Dep.)	9.35	(29.1)	9.86	(29.8)	6.05	(23.9)	7.44	(26.3)
%Pr(Past-Month Cocaine Use)	0.96	(9.76)	1.14	(10.6)	0.51	(7.15)	0.60	(7.74)
%Pr(Cocaine Initiation)	2.12	(14.1)	2.32	(15.1)	1.14	(10.6)	1.78	(13.2)
%Pr(Past-Month Heroin Use)	0.08	(2.76)	0.12	(3.44)	0.06	(2.50)	0.05	(2.19)
%Pr(Heroin Initiation)	0.23	(4.83)	0.33	(5.75)	0.25	(4.99)	0.36	(6.00)

Age 21+	Year 2004				Year 2011			
	No MML States		MML States		No MML States		MML States	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A. Marijuana Use Outcomes								
%Pr(Past-Month Marijuana Use)	8.07	(27.2)	11.1	(31.4)	8.35	(27.7)	14.2	(34.9)
#Marijuana Use Days	1.08	(4.84)	1.46	(5.53)	1.29	(5.35)	2.10	(6.85)
%Pr(Marijuana Initiation)	0.68	(8.24)	0.54	(7.33)	0.82	(8.99)	0.91	(9.47)
%Pr(Marijuana Abuse/Dep.)	2.23	(14.8)	2.66	(16.1)	2.00	(14.0)	2.72	(16.3)
B. Alcohol Use Outcomes								
#Total Drinks‡	19.7	(58.9)	20.4	(53.5)	18.6	(56.6)	19.8	(53.8)
#Alcohol Use Days	4.73	(7.15)	5.50	(7.42)	4.70	(7.01)	5.56	(7.38)
#Binge Drinking Days	1.61	(4.08)	1.64	(3.85)	1.41	(3.65)	1.61	(3.71)
%Pr(Marijuana while Drinking)	3.70	(18.9)	4.67	(21.1)	3.74	(19.0)	6.42	(24.5)
C. Other Downstream Outcomes								
%Pr(Alcohol Abuse/Dep.)	11.1	(31.4)	12.3	(32.8)	9.22	(28.9)	11.5	(31.9)
%Pr(Past-Month Cocaine Use)	1.33	(11.4)	1.58	(12.5)	0.63	(7.91)	1.31	(11.4)
%Pr(Cocaine Initiation)	0.87	(9.27)	0.98	(9.84)	0.50	(7.06)	0.72	(8.48)
%Pr(Past-Month Heroin Use)	0.11	(3.29)	0.10	(3.22)	0.10	(3.15)	0.12	(3.49)
%Pr(Heroin Initiation)	0.11	(3.29)	0.08	(2.88)	0.13	(3.58)	0.10	(3.17)

Note: ‡ One drink refers to a can or a bottle of beer, a glass of wine or a wine cooler, a shot of liquor, or a mixed drink with liquor in it.

Table 3. Descriptive Statistics of Individual-Level & State-Level Covariates

Age 12+	Year 2004-2011 (N≈403,000)			
	No MML States		MML States	
	Mean	S.D.	Mean	S.D.
A. Individual-Level Covariates				
#Age	27.1	(15.6)	27.0	(15.5)
%Male	48.2	(50.0)	48.0	(50.0)
Race/Ethnicity: Non-Hispanic White (ref.)				
%Hispanic/Latino	12.6	(33.2)	12.8	(33.4)
%Non-Hispanic African Black	12.8	(33.4)	13.6	(34.3)
%Non-Hispanic Asian	2.11	(14.4)	2.53	(15.7)
%Other Origins	3.51	(18.4)	4.79	(21.4)
Self-Reported Health: Excellent (ref.)				
%Very Good	40.1	(49.0)	41.1	(49.2)
%Good	23.8	(42.6)	23.9	(42.6)
%Fair/Poor	7.30	(26.0)	7.10	(25.7)
Cigarette Smoking: Non-Smoker (ref.)				
%Non-Daily Smoker	11.5	(31.9)	12.4	(32.9)
%Daily Smoker	14.1	(34.8)	13.2	(33.9)
Urbanicity: Non-CBSA (ref.)				
%Living in a Micropolitan	15.0	(35.7)	15.0	(35.7)
%Living in a Metropolitan	75.3	(43.1)	75.3	(43.1)
Family Income: >200% FPL (ref.)				
%Living 100-200% FPL	22.3	(41.6)	20.8	(40.6)
%Living <100% FPL	18.1	(38.5)	18.3	(38.7)
Marital Status: Married (ref.)				
%Never Married	49.9	(50.0)	54.8	(49.8)
%Separated/Divorces	2.47	(15.5)	2.38	(15.2)
%Widowed	9.01	(28.6)	8.24	(27.5)
Education Attainment: College Graduate (ref.)				
%Some College	29.1	(45.4)	29.2	(45.5)
%High School Graduate	33.5	(47.2)	31.8	(46.6)
%Less than High School	16.8	(37.4)	14.9	(35.6)
College Enrollment: Not Enrolled (ref.)				
%Part-Time Enrolled	5.37	(22.5)	6.90	(25.4)
%Full-Time Enrolled	19.9	(39.9)	20.3	(40.2)
Employment: Full-Time Employed (ref.)				
%Part-Time Employed	18.5	(38.9)	19.8	(39.9)
%Unemployed	6.69	(25.0)	7.31	(26.0)
%Not in Labor Force	22.3	(41.6)	21.6	(41.1)
B. State-Level Covariates				
%Unemployment Rate	6.23	(2.19)	7.41	(2.80)
$Average Personal Income (10K)	3.71	(0.57)	3.90	(1.03)
$Median Household Income (10K)	5.05	(0.63)	5.27	(0.69)
Beer Tax Rates				
$Specific Excise Tax (per gallon)	0.26	(0.22)	0.19	(0.09)
%Ad Valorem Tax (on-premises)	1.01	(3.31)	1.98	(3.99)
%Ad Valorem Tax (off-premises)	1.01	(3.21)	0.89	(2.69)

Table 4. Estimated Marginal Effect of Medical Marijuana Laws on Individual Marijuana & Alcohol Use

	(1)	(2)	(3)	(4)
	Age 12-20	Age 12-20	Age 21+	Age 21+
A. Marijuana Use Outcomes				
%Pr(Past-Month Marijuana Use)	0.11 (0.31)	-0.62 (0.48)	**1.40*****(0.26)	**1.37*** (0.63)
	[10.1]	[10.2]	[8.60]	[8.60]
#Marijuana Use Days	-0.003 (0.01)	-0.04 (0.05)	**0.21*****(0.05)	**0.14**† (0.08)
	[1.22]	[1.23]	[1.19]	[1.20]
%Pr(Marijuana Initiation)	**0.46**† **(0.26)**	**0.32*** (0.17)	**0.22**** (0.07)	0.11 (0.11)
	[7.09]	[7.10]	[0.68]	[0.69]
%Pr(Marijuana Abuse/Dep.)	0.08 (0.27)	0.03 (0.44)	**0.32**† (0.18)	**0.58*** (0.25)
	[4.45]	[4.45]	[2.17]	[2.15]
B. Alcohol Use Outcomes				
#Total Drinks‡	-0.35 (1.03)	0.09 (2.78)	0.16 (0.46)	0.57 (1.33)
	[8.90]	[8.88]	[19.5]	[19.5]
#Alcohol Use Days	-0.02 (0.05)	0.04 (0.08)	0.03 (0.08)	0.08 (0.11)
	[1.35]	[1.35]	[4.88]	[4.88]
#Binge Drinking Days	0.01 (0.03)	0.08 (0.07)	**0.10**** (0.03)	**0.14**** (0.06)
	[0.68]	[0.68]	[1.55]	[1.54]
%Pr(Marijuana while Drinking)	-0.47 (0.29)	-0.15 (0.52)	**0.62**** (0.20)	**0.89**† (0.54)
	[3.96]	[3.93]	[4.04]	[4.01]
State-Specific Linear Trend ($\rho_s t$)	No	Yes	No	Yes
#Observations	≈ 183,600	≈ 183,600	≈ 219,400	≈ 219,400

Note: †p<0.10, ***p<0.05, ****p<0.01, *****p<0.001;
Standard errors in parentheses are clustered at the state level;
Baseline predicted means in square brackets are calculated as the average of predicted probabilities /counts when setting $MML_{s,t}$ to 0 and leaving the other covariates as the observed values;
‡ One drink refers to a can or a bottle of beer, a glass of wine or a wine cooler, a shot of liquor, or a mixed drink with liquor in it.

Table 5. Estimated Immediate & Delayed Effect of Medical Marijuana Laws on Individual Alcohol Abuse/Dependence, Cocaine Use & Heroin Use

	(1)	(2)	(3)	(4)	(5)	(6)
	Age 12-20	Age 12-20	Age 12-20	Age 21+	Age 21+	Age 21+
%Pr(Alcohol Abuse/Dep.)	0.08 (0.63) [7.91]	-0.34 (0.32) [7.93]	-0.31 (0.47) [7.93]	0.73 (0.63) [10.7]	-0.53 (0.33) [10.8]	-0.04 (0.26) [10.8]
%Pr(Past-Month Cocaine Use)	-0.05 (0.22) [0.75]	0.08 (0.14) [0.74]	0.07 (0.09) [0.74]	0.19 (0.15) [1.08]	0.006 (0.13) [1.10]	-0.09 (0.14) [1.10]
%Pr(Cocaine Initiation)	0.10 (0.22) [1.66]	0.32 (0.31) [1.65]	-0.01 (0.29) [1.67]	0.02 (0.12) [0.66]	-0.18 (0.15) [0.67]	0.07 (0.10) [0.66]
%Pr(Past-Month Heroin Use)	0.006 (0.03) [0.09]	-0.02 (0.03) [0.09]	-0.02 (0.04) [0.09]	0.03 (0.04) [0.14]	0.02 (0.04) [0.14]	0.02 (0.05) [0.14]
%Pr(Heroin Initiation)	-0.06 (0.08) [0.22]	-0.01 (0.09) [0.21]	-0.04 (0.09) [0.21]	-0.01 (0.05) [0.14]	0.01 (0.04) [0.14]	-0.03 (0.05) [0.14]
Immediate/Delayed Effect	Contemporaneous	1-Year Lagged	2-Year Lagged	Contemporaneous	1-Year Lagged	2-Year Lagged
State-Specific Linear Trend ($\rho_s t$)‡	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	≈ 183,600	≈ 183,600	≈ 183,600	≈ 219,400	≈ 219,400	≈ 219,400

Note: †*p*<0.10, *****p*<0.05, ******p*<0.01, *******p*<0.001;
Standard errors in parentheses are clustered at the state level;
Baseline predicted means in square brackets are calculated as the average of predicted probabilities/counts when setting $MML_{s,t}$ to 0 and leaving the other covariates as the observed values;
‡ State-specific linear trend is included in models assessing *%Pr(Alcohol Abuse/Dep)*, *%Pr(Past-Month Cocaine Use)*, *%Pr(Cocaine Initiation)* and *%Pr(Heroin Initiation)*, and the estimates are consistent with those excluding state-specific linear trend; Note that state-specific linear trend is not included in models assessing *%Pr(Past-Month Heroin Use)* because the convergence of maximum likelihood estimators fails in this case.

Table 6. Robustness Check for the Policy Endogeneity by Adding Leads & Lags

	(1)	(2)	(3)	(4)	(5)	
	T_{MML}-2‡	T_{MML}-1‡	T_{MML}‡	T_{MML}+1‡	T_{MML}+2‡	$\rho_s t$
Age 21+: *%Pr(Past-Month Marijuana Use)*	-0.04	0.16	**0.74****	**0.65**†	0.31	No
	(0.29)	(0.34)	(0.30)	(0.39)	(0.68)	
	-0.03	0.22	**0.89*****	**0.67**†	0.23	Yes
	(0.29)	(0.39)	(0.28)	(0.37)	(0.83)	
Age 12-20: *%Pr(Marijuana Initiation)*	-0.18	-0.14	0.26	0.18	0.42	No
	(0.29)	(0.30)	(0.25)	(0.51)	(0.60)	
	-0.01	0.34	**0.71***	**0.83**†	**0.11**†	Yes
	(0.39)	(0.46)	(0.37)	(0.44)	(0.06)	
Age 21+: *%Pr(Marijuana Abuse/Dep.)*	0.02	0.04	**0.21**†	0.26	0.22	No
	(0.21)	(0.20)	(0.13)	(0.29)	(0.35)	
	0.02	0.03	**0.35***	**0.42**†	0.31	Yes
	(0.22)	(0.22)	(0.18)	(0.26)	(0.42)	

Note: †p<0.10, *****p<0.05, ******p<0.01, *******p<0.001;
Standard errors in parentheses are clustered at the state level;
Baseline predicted means in square brackets are calculated as the average of predicted probabilities/counts when setting T_{MML}-2~T_{MML}+2 *to* 0 and leaving the other covariates as the observed values;
‡ T_{MML} indicates the first full year after the effective date of the MMLs; T_{MML}-2 and T_{MML}-1 (i.e., leads), and T_{MML}+1 and T_{MML}+2 (i.e., lags) indicate 2-year before, 1-year before, 1-year after and 2-year after T_{MML}; we also included 3-year leads and more, whose individual and joint effects are virtually zero.

Table 7. Robustness Check for the Policy Endogeneity by Adding "Always MML States" to the Controls

	(1) Age 12-20	(2) Age 12-20	(3) Age 21+	(4) Age 21+
A. Marijuana Use Outcomes				
%Pr(Past-Month Marijuana Use)	0.14 (0.29) [10.4]	-0.66 (0.49) [10.5]	**1.18***** (0.27) [9.00]	**1.28*** (0.61) [8.99]
#Marijuana Use Days	0.01 (0.01) [1.27]	-0.09 (0.12) [1.28]	**0.20***** (0.05) [1.26]	0.11 (0.08) [1.26]
%Pr(Marijuana Initiation)	**0.46**† (0.25) [7.21]	**0.33*** (0.18) [7.22]	**0.20**** (0.07) [0.69]	0.11 (0.11) [0.70]
%Pr(Marijuana Abuse/Dep.)	0.06 (0.28) [4.55]	-0.01 (0.45) [4.55]	**0.30**† (0.20) [2.22]	**0.54*** (0.27) [2.21]
B. Alcohol Use Outcomes				
#Total Drinks‡	-0.21 (1.07) [8.89]	0.12 (2.20) [8.89]	0.16 (0.50) [19.6]	0.70 (1.38) [19.5]
#Alcohol Use Days	-0.01 (0.04) [1.36]	0.01 (0.08) [1.36]	0.02 (0.08) [4.96]	0.06 (0.10) [4.96]
#Binge Drinking Days	0.02 (0.03) [0.69]	0.07 (0.06) [0.68]	**0.10**** (0.04) [1.55]	**0.13*** (0.06) [1.55]
%Pr(Marijuana while Drinking)	-0.42 (0.28) [4.06]	-0.15 (0.51) [4.03]	**0.54*** (0.23) [4.25]	**0.76**† (0.46) [4.22]
State-Specific Linear Trend ($\rho_s t$)	No	Yes	No	Yes
#Observations	≈ 208,800	≈ 208,800	≈ 249,700	≈ 249,700

Note: †p<0.10, *****p<0.05, ******p<0.01, *******p<0.001;
Standard errors in parentheses are clustered at the state level;
Baseline predicted means in square brackets are calculated as the average of predicted probabilities/ counts when setting $MML_{s,t}$ to 0 and leaving the other covariates as the observed values;
‡ One drink refers to a can or a bottle of beer, a glass of wine or a wine cooler, a shot of liquor, or a mixed drink with liquor in it.

Table 8. Robustness Check for the Policy Endogeneity by Adding "Always MML States" to the Controls

	(1)	(2)	(3)	(4)	(5)	(6)
	Age 12-20	Age 12-20	Age 12-20	Age 21+	Age 21+	Age 21+
%Pr(Alcohol Abuse/Dep.)	0.09 (0.63) [7.98]	-0.34 (0.33) [8.00]	-0.26 (0.46) [8.00]	0.66 (0.64) [10.9]	-0.44 (0.35) [11.0]	-0.07 (0.24) [10.9]
%Pr(Past-Month Cocaine Use)	-0.04 (0.23) [0.76]	0.08 (0.14) [0.75]	0.08 (0.08) [0.75]	0.20 (0.16) [1.10]	-0.005 (0.13) [1.13]	-0.09 (0.15) [1.13]
%Pr(Cocaine Initiation)	0.14 (0.24) [1.70]	0.32 (0.33) [1.70]	-0.03 (0.29) [1.72]	0.01 (0.13) [0.67]	-0.19 (0.17) [0.68]	0.07 (0.09) [0.67]
%Pr(Past-Month Heroin Use)	0.006 (0.03) [0.09]	-0.02 (0.03) [0.09]	-0.02 (0.04) [0.09]	0.02 (0.04) [0.14]	0.02 (0.04) [0.14]	0.02 (0.05) [0.14]
%Pr(Heroin Initiation)	-0.07 (0.08) [0.22]	-0.03 (0.08) [0.22]	-0.02 (0.09) [0.22]	0.001 (0.05) [0.14]	0.01 (0.05) [0.14]	-0.02 (0.05) [0.14]
Immediate/Delayed Effect	Contemporaneous	1-Year Lagged	2-Year Lagged	Contemporaneous	1-Year Lagged	2-Year Lagged
State-Specific Linear Trend ($\rho_s t$)‡	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	≈ 208,800	≈ 208,800	≈ 208,800	≈ 249,700	≈ 249,700	≈ 249,700

Note: †p<0.10, *****p<0.05, ******p<0.01, *******p<0.001;
Standard errors in parentheses are clustered at the state level;
Baseline predicted means in square brackets are calculated as the average of predicted probabilities/counts when setting $MML_{s,t}$ to 0 and leaving the other covariates as the observed values;
‡ State-specific linear trend is included in models assessing *%Pr(Alcohol Abuse/Dep), %Pr(Past-Month Cocaine Use), %Pr(Cocaine Initiation)* and *%Pr(Heroin Initiation)*, and the estimates are consistent with those excluding state-specific linear trend; Note that state-specific linear trend is not included in models assessing *%Pr(Past-Month Heroin Use)* because the convergence of maximum likelihood estimators fails in this case.

Table 9. Robustness Check for the State-Aggregated Policy Effect on State-Level Prevalence Rates

	(1)	(2)	(3)	(4)
	Age 12-20	Age 12-20	Age 21+	Age 21+
A. Marijuana Use Outcomes				
% Past-Month Marijuana Use	-0.06 (0.47)	0.26 (0.35)	**1.32**** (0.47)	**1.69**** (0.54)
	[10.3]	[10.3]	[8.72]	[8.72]
% Marijuana Initiation	**0.94*** (0.44)	**0.83**** (0.31)	0.12 (0.12)	**0.14*** (0.08)
	[7.23]	[7.23]	[0.70]	[0.70]
% Marijuana Abuse/Dep.	0.45 (0.52)	0.52 (0.36)	**0.47*** (0.25)	**0.43**** (0.15)
	[4.45]	[4.45]	[2.17]	[2.17]
B. Alcohol Use Outcomes				
% Past-Month Alcohol Use	0.19 (1.00)	0.84 (0.72)	-0.77 (0.75)	-0.14 (0.47)
	[25.3]	[25.3]	[60.5]	[60.5]
% Past-Month Binge Drinking	0.62 (0.75)	0.62 (0.65)	**1.30**** (0.51)	**1.01**** (0.34)
	[16.9]	[16.9]	[32.5]	[32.5]
% Marijuana while Drinking	-0.25 (0.43)	0.02 (0.24)	**0.83**** (0.37)	**1.16***** (0.21)
	[4.04]	[4.04]	[4.07]	[4.07]
C. Other Downstream Outcomes				
% Alcohol Abuse/Dep. (1-year lagged effect)	-0.36 (0.40)	0.10 (0.29)	**1.23*** (0.58)	**1.51*** (0.62)
	[8.41]	[8.41]	[10.9]	[10.9]
% Alcohol Abuse/Dep. (2-year lagged effect)	-0.61 (0.43)	-0.66 (0.59)	0.41 (0.54)	0.71 (0.77)
	[8.42]	[8.42]	[10.9]	[10.9]
% Cocaine Initiation (1-year lagged effect)	0.07 (0.13)	-0.06 (0.24)	0.09 (0.30)	0.20 (0.14)
	[1.69]	[1.69]	[0.62]	[0.62]
% Cocaine Initiation (2-year lagged effect)	-0.06 (0.29)	-0.06 (0.34)	0.26 (0.23)	0.29 (0.40)
	[1.70]	[1.70]	[0.61]	[0.61]
% Heroin Initiation (1-year lagged effect)	-0.14 (0.15)	**-0.18**† (0.10)	0.06 (0.06)	0.07 (0.07)
	[0.20]	[0.20]	[0.11]	[0.11]
% Heroin Initiation (2-year lagged effect)	-0.17 (0.12)	-0.28 (0.23)	0.03 (0.05)	0.09 (0.13)
	[0.20]	[0.20]	[0.11]	[0.11]
Serial-Correlation Adjustment	State-Cluster ‡	2-Period Panels §	State-Cluster ‡	2-Period Panels §

Note: †$p<0.10$, *****$p<0.05$, ******$p<0.01$, *******$p<0.001$;
Standard errors in parentheses are clustered at the state level;
Baseline predicted means in square brackets are calculated as the average of predicted probabilities/ counts when setting $MML_{s,t}$ to 0 and leaving the other covariates as the observed values;

‡ As what we did in the individual-level analyses, we excluded the 8 states which had MMLs in place prior to 2004 (i.e., "always MML states"), exclude Arizona and Delaware whose MMLs came into effect during 2011, exclude Maryland which passed two laws in 2003 and in 2011 favorable to medical

marijuana, and exclude California (already excluded as one of the “always MML states”) and Massachusetts which relaxed penalties for recreational marijuana use during the study period. The exclusion left us with 39 states across 8 years in the state-aggregate analyses;

§ We further averaged the pre-MML data and the post-MML data (Donald and Lang, 2007) following a two-step procedure described in Bertrand, Duflo, and Mullainathan (2001, pp. 267). The second-step equation is estimated based on pre- and post-MML two-period panels of 7 “MML states”. The standard errors were adjusted to take into account the smaller number of “MML states” (Donald and Lang, 2007).

Table 10. Robustness Check for the State Heterogeneity of the Policy Effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
	VT_{MML}	MT_{MML}	RI_{MML}	NM_{MML}	MI_{MML}	NJ_{MML}	DC_{MML}	$MML_{s,t}$	$\rho_s\, t$ §
Age 21+: *%Pr(Past-Month Marijuana Use)*	**1.54*****	**4.40*****	**0.91*****	**0.49****	**1.35*****	**1.27*****	**1.98*****	**1.40*****	No
	(0.21)	(0.27)	(0.26)	(0.17)	(0.17)	(0.24)	(0.49)	(0.26)	
	-0.57	**5.07*****	**0.31**†	**0.42**†	**2.40*****	**1.62*****	**0.48***	**1.37***	Yes
	(0.30)	(0.32)	(0.20)	(0.26)	(0.40)	(0.25)	(0.24)	(0.63)	
Age 21+: *#Marijuana Use Days*	**0.15*****	**0.18*****	-0.05	**0.08*****	0.02	**0.19*****	0.05	**0.21*****	No
	(0.02)	(0.03)	(0.04)	(0.02)	(0.02)	(0.03)	(0.05)	(0.05)	
	0.10**	**0.06**†	-0.03	**0.06***	-0.01	0.04	**0.12****	**0.14**†	Yes
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)	(0.08)	
Age 12-20: *%Pr(Marijuana Initiation)*	0.14	**1.43*****	0.04	**1.15*****	0.05	**1.24*****	**1.51*****	**0.46**†	No
	(0.14)	(0.19)	(0.18)	(0.17)	(0.17)	(0.23)	(0.22)	(0.26)	
	0.28	**0.55**†	0.08	**1.84*****	0.18	0.23	**1.42*****	**0.32***	Yes
	(0.25)	(0.30)	(0.25)	(0.29)	(0.45)	(0.30)	(0.40)	(0.17)	
Age 21+: *%Pr(Marijuana Abuse/Dep.)*	**1.16*****	**2.27*****	**0.43*****	**0.28****	0.01	0.0001	**0.59****	**0.32**†	No
	(0.11)	(0.15)	(0.13)	(0.09)	(0.09)	(0.14)	(0.22)	(0.18)	
	0.31*	**2.64*****	**1.02*****	**1.67*****	0.19	-0.76	**0.32***	**0.58***	Yes
	(0.16)	(0.17)	(0.15)	(0.13)	(0.20)	(0.73)	(0.16)	(0.25)	
Age 21+: *#Binge Drinking Days*	0.08	**0.38*****	**0.08****	0.01	**0.11*****	-0.05	**0.05**†	**0.10****	No
	(0.13)	(0.03)	(0.03)	(0.02)	(0.0-2)	(0.04)	(0.03)	(0.03)	
	0.09	**0.45*****	**0.28*****	0.01	**0.23*****	-0.03	0.03	**0.14****	Yes
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.06)	
Age 21+: *%Pr(Marijuana while Drinking)*	**--**‡	**--**‡	**7.52***	**0.44*****	**0.42*****	**1.83*****	**1.54*****	**0.62****	No
			(3.89)	(0.11)	(0.12)	(0.17)	(0.22)	(0.20)	
	--‡	**--**‡	5.02	1.73	**1.44*****	**1.35*****	**1.84*****	**0.89**†	Yes
			(4.47)	(2.81)	(0.37)	(0.22)	(0.29)	(0.54)	

Note: †p<0.10, *****p<0.05, ******p<0.01, *******p<0.001;
Standard errors in parentheses are clustered at the state level;
Baseline predicted means in square brackets are calculated as the average of predicted probabilities/counts when setting VT_{MML}~DC_{MML} or $MML_{s,t}$ to 0 and leaving the other covariates as the observed values;
‡ *%Pr(Marijuana while Drinking)* is not included in NSDUH 2004 and 2005 surveys, while the MMLs in Vermont and Montana both came into effective in 2004. Thus we cannot estimate the effect of VT_{MML} or MT_{MML} on *%Pr(Marijuana while Drinking)*;
§ $\rho_s\, t$ represents state-specific linear trend.

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