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Assessing the Effects of Medical Marijuana Laws on Marijuana and Alcohol Use: The Devil is in the Details

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ABSTRACT

This paper sheds light on previous inconsistencies identified in the literature regarding the relationship between medical marijuana laws (MML) and recreational marijuana use by closely examining the importance of policy dimensions (registration requirements, home cultivation, dispensaries) and the timing of them. Using data from our own legal analysis of state MMLs, we evaluate which features are associated with adult and youth recreational use by linking these policy variables to data from the National Longitudinal Survey of Youth (NLSY97), the Youth Risk Behavior Survey (YRBS) and the Treatment Episodes Data System (TEDS). Our analyses control for state and year fixed effects, using within state policy changes over time to estimate the effect on changes in our outcome variables using a difference-in-differences approach. We find that while simple dichotomous indicators are generally not associated with marijuana use, specific dimensions of MMLs, namely home cultivation and legal dispensaries, are positively associated with marijuana use in each data set. Moreover, these same dimensions are tied to binge drinking and fatal alcohol automobile accidents as well. The findings have important implications for states considering legalization of marijuana, as regulating access to and promotion of dispensaries may be key for reducing the harms associated with these policies.

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I. INTRODUCTION

In November 2012, Colorado and Washington state legalized possession of one ounce or less of marijuana for recreational use by adults (those 21 years or older), and both states are developing guidelines to enable production and sale. At least twelve other states are considering similar policies and arguments for and against these policies are mounting based largely on a thin and conflicting scientific literature of the effects of medical marijuana laws and decriminalization policy on marijuana use and harms. Medical marijuana laws have received particular attention during the legalization debate because of their hypothesized impacts on access to marijuana and perceived harmfulness among key populations, particularly youth (Friese and Grube, 2013; Thurston, Leiberman and Schmiege, 2011). Moreover, many state medical marijuana policies now include provisions for the retail sale of marijuana for medicinal purposes. In parts of some cities like Los Angeles CA and Denver CO, medical marijuana dispensaries are popularly thought to outnumber Starbucks coffee shops (NPR, 2009; The Atlantic Wire 2011). A clear understanding of the impact of medical marijuana laws--particularly aspects relevant for broader legal regulated markets--is imperative for developing coherent public policies pertaining to legalization.

Average levels of marijuana consumption are higher in states with medical marijuana laws (MMLs). In 2004/05, for example, household survey respondents in states with medical marijuana laws were 92% more likely to report using marijuana in the last 12 months than those in non-medical marijuana states (Cerdá et al., 2012). For youth aged 12-17 over the period 2002-2008, prevalence of marijuana use was 25% greater in states with MMLs compared to those states without a MML (Wall et al., 2011). However, just because marijuana use is higher in states that have these laws does not mean that the laws created higher use rates. States with higher prevalence rates may be more likely to pass these initiatives in the first place. Indeed, several studies have shown that there is no statistical relationship (and at times a slight negative relationship) between these laws and recreational use of marijuana when other factors are

accounted for (Harper et al., 2012; Gorman and Huber, 2007). However, other studies examining different years of data and other states show that there remains a positive association between the laws and use for certain populations (Anderson et al., Forthcoming; Cerdá et al 2012).

The purpose of this paper is to carefully examine the impact of medical marijuana laws on marijuana use in the general population and among youth. While a few similar efforts exist (Anderson et al, Forthcoming; Cerdá et al 2012), we are the first to consider how specific medical marijuana provisions regulating cultivation and distribution affect use. We demonstrate the drawbacks of treating medical marijuana laws generically, showing that specific modes of regulation differentially influence consumption, a finding which sheds new light on the inconsistent findings of prior work. More specifically, using a differences-in-differences analysis applied to data from the Youth Behavioral Risk Surveillance System (YRBS), National Longitudinal Survey of Youth (NLSY), and Treatment Episode Data Set (TEDS), we show that access to dispensaries or home cultivation may increase marijuana consumption, including among youth, even while other forms of medical marijuana legalization appear to reduce consumption. The effects are not consistent across all measures of use in our data sets, suggesting that sampling limitations may also explain some of the disparate past findings regarding the effects of medical marijuana. Our results suggest that the use of a simple dichotomous indicator for legalized medical marijuana in policy research may mask important heterogeneous effects of these laws. Moreover, the measured effects of medical marijuana may be affected by the timing over which policies are being examined, the states being considered in the analysis, and the representativeness of the data drawn from those states.

The remainder of the paper proceeds as follows. In Section II we provide background on medical marijuana laws and these laws' key dimensions. We also summarize the limited research examining the impact of these laws, paying particular attention to past studies' years of analysis and hence their source of legal variation. Section III provides a theoretical framework

for thinking about how medical marijuana laws might influence consumption in the adult population as well as among youth. In Section IV we discuss our data sources, and then present the results from our analyses of the impact of these laws on marijuana use in Section V. Section VI extends our analysis to consider related outcomes, specifically alcohol abuse and fatal automobile accidents. We conclude in Section VII with a summary of our findings and its implications for both medical marijuana policy and legalization proposals.

II. BACKGROUND

As of January 1, 2012, 17 states and the District of Columbia had policies recognizing the medicinal value of marijuana and providing a legal defense for patients who used marijuana under the recommendation of a physician. Many early adopting states (those adopting between 1996 and 2000) did so through voter referendum, with such referenda providing little specific guidance about acceptable sources of supply for marijuana. Since then, policies governing medical marijuana, such as the allowance of dispensaries and requirements of patient registration systems, have evolved in fits and starts in response to often competing legislative, administrative, and judicial actions.

Table 1 shows the evolution of certain key dimensions of MML laws across different states through the end of 2011. Specific dimensions considered are whether states require patient registry systems, whether states have allowances for general “pain” rather than just specific medical conditions, whether states legally allow dispensaries, and whether states allow for home cultivation.

Beyond demonstrating which states employ various regulatory approaches, Table 1 also shows that only two early-adopting states (Hawaii and Colorado) have not changed any of these key dimensions relating to access, availability and norms since their policy was initially adopted. Most states, even later adopters, have refined their state policies since initial passage, in

particular with reference to dispensaries. Dispensaries have emerged to a very modest extent in states like Washington and Michigan that do not formally allow dispensaries, and such emergence often precedes a subsequent change in policy. Moreover, in states where dispensaries have been formally protected by state laws (e.g. Colorado and California), the number of dispensaries has exploded, particularly since the 2009 announcement by the U.S. Attorney General that the Justice Department would end raids on distributors who are in compliance with state medical marijuana laws (Ogden, 2009).

Marijuana dispensaries, as well as the competition and commercialization that can emerge with them, can impact recreational use of marijuana through a number of avenues: increased consumer access, normalizing the behavior and lowering perceptions of risk, and – if competition emerges – possible price reductions. However, previous analyses of the effects of MML laws do not consider their specific provisions, and therefore by default treat all laws as if they have the same impact on recreational use. It is perhaps unsurprising that various studies have found substantially different effects of medical marijuana laws on use given that laws have been measured based only on whether a broad policy is adopted. The fact that the literature ignores important changes over time in elements of state policies that impact access has contributed to the lack of consistent results in analyses of the policies.

Many early studies of medical marijuana laws find no significant impact of marijuana use on consumption, but none of the early laws had formal allowances for dispensaries or systematically regulated supply. For example, Khatapoush and Halfors (2004) use a pre-post design for the period 1995-1999 to assess the impact of California's medical marijuana law adopted in 1996. Using data from over 15,000 telephone surveys of young adults in 41 communities, they assess whether California's law affected perceived availability and harmfulness, approval of marijuana, or past-month recreational use among Californians as compared to residents of ten other non-MML states. The only significant difference in outcomes is in perceived harm, which fell more in California over time than in other states. While California

had higher use rates of marijuana than other states, the average difference in trends did not change. They conclude that California's medical marijuana law had no significant impact on recreational marijuana use among young adults.

Gorman and Huber (2007) use data from a slightly longer time period (1995-2003), but restrict their analysis to data in just four early adopting states (California, Colorado, Oregon, and Washington) and look for structural breaks in state-specific quarterly counts of arrestees and marijuana-involved emergency department (ED) episodes following medical marijuana adoption. The authors find that initial passage of medical marijuana laws did not measurably change either indicator of marijuana use. However, they note that they have a very short post-reform time period for Colorado, which was the only state formally allowing dispensaries included in the study.

Harper, Strumpf and Kaufman (2012) examine a later period of policy change, looking over the period 2003-2008 at MML adoption's impact on adolescent self-reported marijuana use and perceived harmfulness using aggregated National Survey on Drug Use and Health (NSDUH) state data. First replicating and then improving upon an earlier descriptive study by Wall et al., (2011), Harper et al. (2012) use a difference-in-differences approach with year and state fixed effects to control for time-stable unobserved heterogeneity at the state level. They find that state MMLs have no statistically significant effect on perceived harmfulness among 12-17 year olds over the time period 2002-2008. When they expanded their sample with an extra year of data and more carefully looked at impacts of these laws across various age groups (12-17 year olds; 18-25 year olds, and 26+), they found no statistically significant impact of the state MML policy on any age group.

The importance of considering differences in responses to these policies by age was also underscored in a study by Anderson and Rees (2011), which identified impacts of the MML policies using NSDUH aggregated data during a period when just three states adopted new policies: Rhode Island (RI), Vermont (VT) and Montana (MT). This work shows similar results of

no statistically significant effect on minors (aged 12-17), but positive effects of the policies on older young adults. They find the law in Montana and Rhode Island increased use for those 18 years and older.

Anderson, Hansen, and Rees (2012) use a similar difference-in-differences approach to Harper et al. (2012), but employ a much longer panel of data from the 1993-2009 Youth Risk Behavior Survey (YRBS). In general, models making use of both the state and national YRBS data (which represents respondents in 9^{th}-12^{th} grade, so ages of 13- 17) show no statistically significant effect of the MML policy on thirty day prevalence of use. In fact, in some specifications, the authors find the policies are negative and statistically significant. However, because YRBS participation varies across years, the authors only have eight MML states with pre- and post-policy adoption data in each of the national and state samples. The Anderson et al. (2012) paper is unique in its efforts to replicate findings in a variety of other data sets and in considering different margins of use. Additional analyses are conducted making use of individual longitudinal data from the National Longitudinal Survey of Youth 1997 (NLSY97) and the 1992-2009 Treatment Admissions Data Set (TEDS) and findings using these data were consistent with the YRBS analysis.

Chu (2012) uses data from 1988-2008 and a differences-in-differences analysis to consider the effect of MML on two other proxies for use—marijuana arrests and marijuana rehabilitation treatments. In contrast to other studies, Chu finds evidence of a strong effect of legalization on both outcomes, with increases in admissions observed among juveniles as well as adults. While Chu's use of administrative data arguably alleviates some concerns related to self-reporting, a drawback of this analysis is that it confounds any direct impact of MML on use with concomitant responses of law enforcement or health care providers to legal change.

All these prior studies treat MMLs as a homogenous set of laws. This paper, in contrast, recognizes that not all medical marijuana policies are homogenous and that important policy

dimensions are not static.[1] We use variation in the timing of the core elements of MML policy shown in Table 1 to assess whether particular forms of regulation are more relevant for use. We also consider whether a more nuanced analysis of the attributes of these laws can explain the apparent inconsistent findings to date regarding the effects of these laws on use. Moreover, like Anderson et al. (forthcoming), we consider multiple measures of use, allowing us to consider both overall prevalence and patterns of use for different subpopulations of interest. Considering different margins of use is potentially valuable in light of national data showing relatively little change in thirty-day prevalence rates of marijuana use during the 2000s, but large increases in near-daily use, particularly among juveniles (SAMHSA, 2012).

III. THEORETICAL FRAMEWORK

To the extent that medical marijuana laws influence either (a) the perceived harmfulness of marijuana or (b) social availability of marijuana through home cultivation or dispensaries, they can indirectly influence demand by shifting a taste parameter of the utility function or changing the full price an individual faces for using marijuana. If we let *M* represent marijuana consumption, *O* represent a vector of other substance use (e.g. alcohol), and *C* represent a general composite consumption good, we can write the individual's maximization problem as follows[2]:

(1) $Max_{\{C, M, O\}}\ U(C) + bV(M, O)$

subject to:

(2) $Y = C + P_M M + P_O O$

[1] Other studies have been published evaluating the impact of these laws on particular populations employing less rigorous sample designs or methods (Thurstone, 2011; Cerdá et al 2012; Friese and Grube, 2013). In general, they too have found conflicting results. Given the methods are less rigorous than those discussed here, we simply note that these studies contribute to the general point of conflicting evidence in the literature.

[2] The current static analysis ignores the influence of habit formation on demand for marijuana and other illicit substances. There is some empirical evidence that marijuana is habit forming (e.g. Pacula, 1998); however, research suggests that about 1 in 10 users who ever use the drug will actually become dependent, a relatively small fraction of the user group (Hall et al, 2001). Hence this additional level of complexity is omitted from the current model.

(3) $b = f(H_i, A_i, \gamma_i, Z, \varepsilon)$ *for* $i = M, O$.

Following other models of substance use, utility is presumed to be separable in the consumption of drugs and all other goods. Hence, U and V in equation (1) are subutility functions, where $U' > 0$, $U'' < 0$, $V_i > 0$ and $V_{ii} < 0$ for $i = M, O$.[3] The vector b represents individual-level factors that influence the marginal utility of consuming marijuana and other substances, as is indicated by equation (3). The marginal utility of consuming marijuana and other substances is a function of the individual's perceptions regarding the harm of using specific substances (H_i), the social availability of the drug (A_i), the legal risks associated with consuming each drug (γ_i), individual observable characteristics, such as age or marital status (Z), and unobservable factors that influence an individual's "tastes" for drugs (ε), such as thrill-seeking behavior. It is assumed that the individual error term, ε, is *i.i.d.* with a mean of zero.

Equation (2) specifies the individual's budget constraint, with Y representing the individual's income and P_M and P_O representing the monetary price of marijuana and other substances consumed, respectively. Because marijuana is generally illegal to use and is believed to impose negative health consequences to the individual (Hall, 2009; Hall and Degenhardt, 2009), the monetary price of purchasing marijuana does not represent its full cost to the user. Additional costs include the health risks (H_M) and legal risks (γ_M) of consuming the substance. However, these additional costs are not typically paid for through market transactions and therefore represent nonpecuniary aspects of the full price.[4] They cannot therefore be represented through the budget constraint and are instead represented as individual-specific shift parameters to the marginal utility of consuming marijuana. Higher

[3] An implicit restriction imposed by the use of separable utility functions is that marijuana or other substance use is not allowed to increase the marginal utility of consuming other goods, such as leisure time. This is likely to be a rigid assumption that should be explored in future research.

[4] The monetary price of marijuana or any illicit drug reflects only those costs and risks borne by the seller in the black market. The actual monetary price charged will likely differ from consumer to consumer, based on the seller, the ability of the buyer to judge quantity and quality, and the history between the buyer and seller. For more about prices in drug markets see Caulkins (1994, 1995).

nonpecuniary costs are presumed to lower the marginal utility of consuming marijuana, or $\partial b / \partial H < 0$ and $\partial b / \partial \gamma < 0$.

The influence of medical marijuana laws (*MedMJ*) on perceived harm (H_M) and social availability (A_M) can be incorporated into this model by noting that these parameters are themselves a function of several additional factors. The individual's perceptions of the risk of using marijuana on an occasional or regular basis is likely to be a function of the individual's own information set of the health benefits and risks of marijuana, the prevailing social norms regarding the use of marijuana , and other individual personality factors that influence the individual's receptivity to these different information sources. The presence of medical marijuana laws is presumed to reduce perceptions of harm from regular marijuana use by providing a medical justification for its use, thus causing marijuana to be seen more for its positive attributes and less for the negative ones. This implies that $\partial H_M / \partial (MedMJ) < 0$.

The social availability of marijuana to the individual can similarly be written as a function of several other factors, including the individual's exposure to peers and/or family members who use marijuana and the prevailing social norms regarding use of marijuana. To the extent that medical marijuana laws expose youth to more adults and/or peers who use the substance or to the extent that these laws enable home cultivation by friends, family and/or peers, these laws are likely to increase its social availability. This implies that $\partial A_M / \partial (MedMJ) > 0$.

Ideally, we would like to estimate a system of models that enable us to simultaneously evaluate demand equations associated with the maximization problems described in equations (1)-(3) as well as the perceived harm and perceived availability. The problem is that sufficient data do not exist for us to capture all the relevant domains and uniquely identify each of the mechanisms. Moreover, measures of general access and perceived harm are often not available for an individual's immediate peer group and hence are proxied through aggregated

measures at a school or state level. Thus, we estimate here a reduced form of the model given by:

(4) $M = M\{P_M, P_O, Y, H(MedMJ), A(MedMJ), \gamma_M, Z; \varepsilon\}$

The model is first estimated with state aggregated measures of consumption so as to generate models that are consistent with previous studies, and then where our data permits, we also estimate individual level demand equations.

IV. DATA AND EMPIRICAL SPECIFICATION

To study the association of medical marijuana laws and its different dimensions on utilization, we employ a variety of data sets. In an ideal world, the results from each data set should provide complementary evidence and provide validation of findings. However, for reasons that will be described in greater detail below, each has its strengths and weaknesses that lead to uncertainty regarding the reliability of findings from particular data sets.

4.1: National Longitudinal Survey of Youth (NLSY97).

The NLYSY97 provides individual-level data on a host of outcomes, including detailed information on marijuana and alcohol use over the past 30 days. In our analysis, we were able to use data from 1997-2009. The NLSY only follows a single cohort consisting of a population between the ages of 12 and 17 in 1997. This cohort is resurveyed in each survey year. A limitation of this type of data, especially when compared to repeated cross-sections which are resampled, is that the sample is constantly aging. Consequently, the NLSY97 sample is a different age when studying the effects of policies in late-adopting states compared to the age of those when early adopting state policies are evaluated. It is also not representative at the state-level. However, our analysis will study *changes* in individual-behavior, reducing concerns that this affects the validity or interpretation of our estimates. The primary advantage of the data is the richness of the outcome variables, which includes the number of days in the previous 30

days in which the individual used marijuana, and the fact that individual unobservable factors can be accounted for through fixed effects.

4.2. *Youth Risk Behavior Surveillance (YRBS) System*.

The YRBS System surveys middle and high school students on a host of risky behaviors, including alcohol and drug use. The data are repeated cross-sections, available biennially for 1991-2011. State participation is not consistent so it is common for a state to provide data in one wave but not the next. Many states require permission to access their state's YRBS data from the CDC and previous studies have noted difficulties and delays in receiving data from all states (Anderson et al., 2012). These data provide individual-level information. However, aggregated state-year statistics are available from the CDC without state-level permission using their Youth Online application (http://apps.nccd.cdc.gov/youthonline). We use these state aggregated data for our analysis. The individual-level files do not provide much demographic information that can be used in our regression analysis and the same individuals are not re-interviewed over time so little is lost using these aggregated numbers. Using these data allows us to maximize the number of state-years covered. Our final YRBS dataset include the fraction of high school students in state-year that have used marijuana (alcohol) in the previous 30 days.

4.3. Treatment Episode Data Set (TEDS).

The TEDS provides demographic and substance abuse characteristics of admissions to alcohol and drug treatment facilities. The data include the substance or substances that the individual is being treated for. The TEDS only includes treatment centers which receive public funding. Assuming that the prevalence of public funding for treatment centers is not systematically related to medical marijuana law adoption, this coverage issue should not bias our results since we will be including state fixed effects in our analysis. Furthermore, the data

note whether an individual is referred by the criminal justice system. We will use this variable to check whether changes in enforcement of marijuana laws, indicated by changes in referrals to treatment from the criminal justice system, affect our results.

The TEDS provides annual data on individual level admissions for the period 1992-2009. State reporting is relatively consistent in the TEDS. The outcome variable for the TEDS analysis is the number of treatment episodes in which marijuana (alcohol) is the primary substance of abuse.

We show in Table 2 the states in which we have pre and post policy implementation data for each of the data sets used in our analysis (YRBS, NLSY and TEDS), in addition to the NSDUH, which has been used by other researchers. Table 2 demonstrates that the effects of medical marijuana laws are identified off of changes in outcomes in different states across the various data sets, due to the coverage limitations of each data source. Capturing the true effects of medical marijuana laws across a broad set of states may require triangulating across multiple data sets rather than relying on a single data set.

In the NLSY, there is fairly good inclusion of individuals across many states that adopt a policy within the survey window. However, because the NLSY is a longitudinal survey, state policies mostly change when respondents are older than 19 years of age, well past the average age of marijuana initiation in the US (SAMHSA, 2012). The NLSY thus captures behavioral effects among late initiates or established users. The sensitivity to policy changes for these two groups could arguably be different than that of young adults (18-24) or youth in general. The state YRBS, as noted by Anderson et al (2012), has good coverage for many states that adopt policies and consistently evaluates impact on school-age children. However, important early adopting states like California and Washington are missing from the sample. Because of changes in the sampling frame of the NSDUH survey, state aggregate measures are only available from 2002 forward. Thus, studies making use of these data completely miss policy impacts in early adopting states. Moreover, to include early adopters in the control group, we

must assume that no refinements to the early policies occurred after 2002; otherwise, the simple difference-in-differences approach might be biased. The TEDS data, however, do not suffer from these sorts of problems as the data have been systematically collected since before any state policies were adopted. However, the TEDS data capture use behavior on a much different margin than simple prevalence estimates do, so it is entirely possible that patterns observed in TEDS data would not necessarily replicate across more general measures of use.

Keeping in mind these caveats, we show in Table 3 the mean values of each of our measures of marijuana and alcohol use in our primary data sets. Consistent with what has been reported elsewhere, we find higher rates of marijuana use among individuals living in states that have adopted MMLs than in states that do not have these policies. This is broadly true across all data sets. However, we find no consistent alcohol use patterns across our data sets, perhaps because of age differences across our samples. For the NLSY and TEDS data—which include people of older ages—average alcohol use is also higher in states with MML policies. In the YRBS, which only includes 12-17 year olds, alcohol use rates are generally lower in states that have MML policies. The fact that there are important differences in simple descriptive statistics for each of these data sets suggests that considering multiple data sources and controlling for unobservable state factors will be important for the analysis.

4.4 Empirical Specifications

For all data sets, we use state-level changes in medical marijuana policy to identify the relationship between that policy and a measure of marijuana (alcohol) utilization. We perform a difference-in-differences analysis including state and year fixed effects in all regressions.

For the NLSY, we have data at the individual level and thus we estimate logistic regression models of self-reported marijuana use as a function of medical marijuana policies, beer and cigarette taxes, state fixed effects, year fixed effects and a variety of individual factors including gender, race/ethnicity, age, and educational attainment.

In the YRBS, we use state aggregated prevalence rates and study the relationship between the fraction of students using marijuana in the past 30 days and MML. We model this relationship through the use of a Poisson regression, which provides consistent estimates when the expected value of the outcome variable is modeled correctly (Silva and Tenreyro 2006), and which permits us to easily adjusted standard errors to account for overdispersion. We estimate

(5) $$y_{st} = \exp(\alpha_s + \gamma_t + X'_{st}\delta + \beta \times MML_{st})\epsilon_{st}$$

The TEDS analysis uses the same specification. The outcome variable is the number of admissions in the state-year.

Controls that are included in these models include dimensions of medical marijuana laws, a vector of state time-varying factors (including age distribution within the state, proportion that are male, proportion that are criminal justice referral for the state, the median income within the state, beer taxes, cigarette taxes and the state unemployment rate), state fixed effects and year dummy variables.

The information on medical marijuana laws come from our own original examination of the legal statutes and subsequent regulations pertaining to medical marijuana within the states. State policies were reviewed by legal scholars, economists and policy analysts at RAND before coding decisions for each dimension. In the case of registration requirements, our variable is set equal to one in those states that require patients to register with a state or local authority. States that simply recommend registration are coded as zeros as are states that do not make any mention of a patient registry. States that provide legal protection for dispensaries are those that either (a) explicitly allow dispensaries by either state statute or agency rule making, or (b) recognize the existence of dispensaries or cooperatives in their rules and regulations and are silent to their legality. States in which dispensaries are known to exist (e.g. Michigan or Washington State) but for which there is no legal protection in legal statutes or agency regulations are coded as if dispensaries are not allowed to exist. This is due in part to the fact

that we have no official date in which we can attribute the emergence of these dispensaries but also because it is unlikely that the proliferation of dispensaries beyond a few targeted jurisdictions is unlikely due to the uncertainty of legal protections. Finally, home cultivation is a dichotomous indicator set equal to one if the state provides legal protection for patients and/or their caregivers to grow their own plants for medicinal purposes.

Information on state demographic variables and unemployment rates are available from the Bureau of the Census and the Department of Labor, respectively. Information on beer taxes and cigarette taxes were provided by the ImpacTeen Project and updated with information from the NIAAA Alcohol Policy Information System (APIS) and CDC State Tobacco Activities Tracking and Evaluation (STATE) systems. All standard errors in our analysis are adjusted for clustering at the state-level.

V. RESULTS

Coefficient estimates from our difference-in-difference models of the proportion of students who use marijuana (YRBS) and logistic models of thirty day prevalence and near daily use of marijuana in the NLSY are presented in Table 4. The top part of the table provides results for youth in both data systems (those < 18 in the YRBS and those < 21 in the NLSY). The bottom part of the table provides estimates from identical models run on the adults in the NLSY. In all columns labeled "(1)", we show results from models that simply include the MML policy variable as a single dichotomous indicator, consistent with how it has been evaluated in previous studies. In columns labeled with a "(2)" we then add to these specifications the three primary dimensions of these marijuana policies that have changed over time and are believed to impact access: patient registries, allowances for dispensaries, and home cultivation. We exclude "pain" as a relevant domain due to its collinearity with these other policy dimensions when state fixed effects are included. In columns labeled with a "(3)", we remove the MML

dichotomous indicator and show simply the impact of each of the three policy dimensions of the medical marijuana laws, allowing us to better understand the degree to which certain dimensions are truly robust and independent of the medical marijuana allowance. This is particularly important because in the YRBS we cannot estimate a model that includes the three dimensions of the MML law simultaneously with the dichotomous indicator as several states are perfectly identified when all of these variables are included given we estimate models with state fixed effects (due to the timing of law changes within states and the timing of the data collection). This serves as an important reminder that the inclusion/exclusion of particular states over a given time period within a single data system has important implications on interpreting results from that data system and why replication of findings in other data systems is important. For the YRBS, we can only show a version of the model that includes the three policy dimensions without the dichotomous policy variable (labeled with a "(3)"). .

When we focus on results of just the MML dichotomous indicator (looking across columns labeled with a "(1)"), we see that regardless of whether we use the NLSY or YRBS or if we look at simple past month prevalence or heavy use of marijuana, we find no positive statistically significant association between the dichotomous policy MML variable and any of these measures of use for youth or the full NLSY sample. There is simply no evidence that the passage of the medical marijuana policy positively influences the prevalence of marijuana use among youth or adults. In one case, past month use in the full NLSY sample (including adults), we find a negative and statistically significant association between the simple dichotomous policy variable and use, suggesting that medical marijuana laws are associated with lower prevalence rates of marijuana in the general population. The result is only marginally significant at the 10% level, however, and is highly sensitive to model specification. So a general conclusion that there is no significant effect of these policies on general prevalence rates or heavy marijuana use rates among youth and adult populations seems reasonable based on findings from these two data sources.

However, it is entirely possible that such a finding is due to potentially offsetting effects of particular dimensions of these specific laws. Indeed, when we incrementally include the three medical marijuana dimensions to the model that includes MML laws (all columns labeled with a "(2)"), we begin to see some interesting and important differences from prior estimates in the literature. Interestingly, with respect to the simple MML dichotomous indicator, there is general support for the same conclusion reached when it was entered alone with one exception. We now find a positive, larger and statistically significant effect of the dichotomous MML indicator on youth use in the past 30 days in the NLSY. None of the other three policy dimensions are statistically significant in this specification, however, and the finding is sensitive to other variables included in the model, so we do not take a lot of stock into this finding for the MML variable itself.

As can be seen in the third columns of the top half of Table 4, we get findings that are generally consistent with those reported for the NLSY columns 2 when we include the three policy dimensions in the model without the MML variable, with the exception of the home cultivation variable. While neither youth past month prevalence or heavy marijuana use are associated with patient registries or dispensaries, we get an odd and inconsistent finding with respect to home cultivation. In the YRBS, we see a negative and marginally significant association between home cultivation and youth marijuana use, which further investigation has shown to be highly sensitive to particular states being included or dropped from the sample. Indeed, in the NLSY data, which includes three additional states (New Jersey, Oregon, Washington state), but drops Alaska, we find that the home cultivation has no statistically significant effect on past month prevalence but a positive and significant effect on youth heavy marijuana use. The inconsistency of the finding across data sets is most likely driven by the differences in states included in each of these samples. Thus, the proper interpretation generally, is difficult to say and something we explore a bit further in the TEDS data shortly.

In the full NLSY sample, we get perhaps a stronger indication of the importance of the different policy dimensions, at least perhaps for adults. In the model of past month prevalence, the MML variable becomes statistically insignificant in column (2) when the three policy dimensions are added into the model. But, we also find that past month prevalence of marijuana use is lower in states that require a patient registry system but higher in states that provide legal protection of dispensaries. These results do not simply reflect a collinearity with the MML dichotomous variable, as they remain significant in column (3) when the MML law is taken out, nor do they reflect a collinearity between themselves, as models entering these variables individually generate similar results for each variable independently.[5] The findings for adults suggest that any potentially protective effect medical marijuana policies might have for adults is offset by the positive impact medical marijuana dispensaries have on recreational use. It is interesting, however, that these same policy dimensions are not at all associated with self-reported heavy use in the full NLSY sample. In models predicting heavy use in the past month for the full NLSY sample, only home cultivation is marginally significant (as was the case for the youth sample), and its significance is reduced when the MML dichotomous measure is taken out.

Overall, Table 4 suggests some interesting, albeit inconsistent, findings. In general, when examining simple thirty day prevalence rates among youth, neither the policy nor specific dimensions of the medical marijuana policies appear to provide a robust indication of an influence on use in either the NLSY or YRBS. The "inconsistency" in the home cultivation result is likely to be attributed to heterogeneity in the states being used for identification in each of the analyses rather than differences in behaviors examined. We find some important nuances for specific dimensions of the policy in the full NLSY sample, which includes adults. However, the fact that the past month use measure is influenced by these policy domains rather than heavy use raises some question as to whether the findings are indeed real, implying

[5] Results available upon request.

differential effects on these different margins, or again a reflection of specific states being included in the NLSY sample.

Although the findings are difficult to understand as a whole, there are a few important takeaways. First, we can replicate previous results from the literature in terms of null finding of the single dichotomous indicator for MML laws. Second, when we begin to consider specific elements of the laws that might influence behavior, we see that several of those elements are in fact associated with changes in patterns of use although not consistently so, as indicated by the findings for the full NLSY.

To more carefully assess how these policies affect heavy use, we show in Table 5 estimates for similarly specified difference-in-difference models using the TEDS data where the main outcome variable is primary marijuana treatment admissions. A very high proportion of marijuana treatment admissions are generated by law enforcement activities, much higher than that for alcohol and other individual drugs. So to verify that particular policies are indeed reflective of treatment need rather than just law enforcement activities, we present results for both total treatment admissions (the three columns labeled "All") and those that did not come through the criminal justice system (referred to as "Non-CJ"). We place greater weight in results identified from the non-criminal justice referrals, as they will more likely reflect true use behavior rather than law enforcement activities. In the top portion of Table 5, we look at the effects of the policies on all age groups and in the bottom portion of the table we again restrict the samples to only include those younger than 21.

Consistent with evidence presented by Anderson et al (2012), we find fewer primary marijuana treatment admissions in MML states than in non-MML states for individuals under the age of 21 as well as for the population as a whole, and our results are statistically significant. The effect sizes are in general larger for the non-CJ referrals than all treatment episodes, suggesting that simply having a MML policy does not lead to greater need for marijuana treatment or higher treatment episodes and may in fact be associated with fewer admissions.

When we add in additional information on particular dimensions of medical marijuana policies that can change over time, we see once again that not all medical marijuana policies are the same. In particular, Table 5 shows a persistently positive effect of medical marijuana dispensary allowances on marijuana treatment admissions, which is only statistically insignificant in the youth sample on all treatment admissions. The fact that the finding is statistically significant at the 1% level for both youth and adult among the non-criminal justice referrals to treatment suggests that the policy does in fact influence the need for treatment in both the youth and adult population. Thus, while medical marijuana policies overall might be associated with reduced treatment admissions, access to marijuana through dispensaries at least partially offsets the benefit of these laws and is associated with higher treatment admissions.

Moreover, we find in the models excluding criminal justice referrals that states that require patients to register have lower rates of marijuana treatment admissions for adults. The findings for youth are also negative, but do not reach traditional levels of significance. This differential pattern across adults and youth is similar to that observed in the NLSY data reported in Table 4 and may reflect the fact that registration systems are a deterrent for adults (as they legally are telling a state agency they use marijuana for medicinal purposes – a federal offense), but inconsequential for youth who are less likely to formally register anyway given the need for parental consent (whether registries are required or not).

Finally, in all models that include the MML dichotomous policy indicator, we find that home cultivation is also positively associated marijuana treatment admissions. The positive association disappears when the MML law is removed, however. This again was consistent with what was observed in the NLSY data, and in light of its replication here in the TEDS data where all 50 states are represented, is less likely to be dismissed as an artifact of the selective states in the NLSY. The inconsistency between columns when the MML law is included versus excluded we believe has to do with the fact that the home cultivation variable is the one

dimension of the MML laws we examine that changes the least within states over the time period we have data. Indeed, when you look at Table 1 and examine the home cultivation variable across states, it is the only policy dimension of the three included in the model that does not vary within state over time for the time period evaluated (up to 2009). The other two variables (patient registry and dispensaries) do in fact vary within state during the time period being evaluated in some states, meaning they will be less sensitive to the inclusion or exclusion of the main policy effect. What does that mean for interpretation of the home cultivation variable? When the MML policy is included, the home cultivation variable picks up cross-sectional variation in the deviation of policies that do and do not allow for home cultivation (there are five states that do adopt MML laws but do not allow for home cultivation). Without the main MML policy effect, the lack of variation in the MML policy over time means the home cultivation effect gets dominated by the main policy effect of having an MML, since two-thirds of the states with any MML policy also allow for home cultivation.[6]

These results provide an interesting perspective on the inconsistent findings in Table 4, as all 50 states are consistently represented in the TEDS data unlike the YRBS and NLSY and so the problem of "selective state" representation is not a problem in these TEDs analyses. In particular, the full sample NLSY findings showing a positive effect of dispensary allowances on thirty day prevalence rates (shown in Table 4) are verified here and presumed to be real even though the effect of the policy was not statistically significant among self-reported heavy users as we see a similar effect of dispensaries on treatment admissions for youth and adults in the TEDS non-CJ referrals. Similarly, the finding of a positive effect of home cultivation on heavy use in the full and youth samples of the NLSY, which was not supported in the YRBS data, is

[6] As not all states are represented in the NLSY and YRBS, the particular exclusion of some states might lead to greater collinearity in one data system than another. As indicated in Table 2, there are five states that adopt MML policies but do not allow for home cultivation: AZ, MD, NJ, WA and DC. Only MD is included in the YRBS sample, so home cultivation is going to be highly collinear with the MML policy variable in these data (which is why we could not run the model including dimensions plus the MML variable). In the NLSY, states having MML policies with and without home cultivation are both missing, so the collinearity will be similar to that observed in TEDS.

now verified in another sample of heavy users and is indeed robust, suggesting that home cultivation provisions are generally associated with more heavy use of marijuana. Requiring patients to register with the state, however, is clearly associated with reduced marijuana treatment admissions among adults in the TEDS, consistent with what was found in the NLSY, suggesting that this specific policy dimension could be effective at limiting access to those interested in using for recreational purposes.

VI. DISCUSSION & EXTENSIONS

The evidence thus far shows that the specific dimensions of MML laws appear to matter in terms of their impacts on recreational marijuana use and that some regulatory approaches influence consumption differentially. Use of a single indicator for these laws captures the net effect of a range of regulatory policies that vary across states, and can obscure some important underlying policy dimensions that influence the effect of a particular state's law because of the dimensions captured in it. What this also means is that depending on the time period and state laws being examined in a given sample, one can estimate very different policy effects. The sensitivity of findings to choice of sample and time frame can explain at least some of the inconsistency in existing published findings on the effects of MML laws on consumption.

These findings raise an important follow-on question; Do alternative regulatory approaches also differentially affect marijuana-involved public health outcomes? Although an examination of the full set of public health outcomes that might reasonably be affected by MML is beyond the scope of this paper, we are able to look at one particular public health outcome of significant interest: alcohol use. Given the abundant evidence that alcohol use is associated with a range of public health problems, an important channel through which these MML policies might affect public health is through modifying alcohol use behaviors. Moreover, as with the direct measures of marijuana use examined above, there are plausible scenarios under which

specific aspects of MML policy might have differential effects. In the analysis that follows, we examine not only direct consumption measures, but also alcohol-involved vehicle fatalities. This latter outcome furnishes an opportunity to assess whether the heterogeneity in impacts of various approaches to MML regulation can be observed when examining a consumption-related direct health outcome.

There is tremendous concern regarding the potential impact of marijuana legalization policies in Washington State and Colorado on alcohol consumption, particularly among high risk users. The economics literature regarding the relationship between alcohol and marijuana remains uncertain. Early studies examining the relationship between alcohol and marijuana relying on information on state beer taxes and marijuana decriminalization policy suggest that alcohol and marijuana are economic substitutes (Chaloupka and Laixuthai, 1997; Saffer and Chaloupka, 1999; DiNardo & Lemieux, 2001). Subsequent studies that incorporate measures of the monetary price of marijuana suggest that the two goods are economic complements (Pacula, 1998; Farrelly et al.,1999; Williams et al., 2004; Pacula et al., 2010). However, two recent studies making use of the regression discontinuity in drinking at age 21 generate completely opposite findings (Yörük & Yörük, 2011; Crost and Guerrero, 2012; Crost and Rees, 2013). Thus, the question of the unintended impact of liberalizing marijuana policies on alcohol related harm remains a critical unresolved question.

Two studies to date have looked specifically at the question of the impact of medical marijuana laws on drinking and in particular alcohol-related fatalities (Anderson & Rees, 2011; Anderson et al., 2013). Both studies show that alcohol use and alcohol related automobile fatalities are negatively associated with these policies, suggesting that the laws have the positive effect of reducing alcohol related harm. However, both studies rely on a single dichotomous indicator of medical marijuana laws. Thus, it is important to reassess these findings in light of our results above.

We begin by assessing the impact of these policies in the survey data we previously examined for marijuana. Table 6 shows the results of identical models of self-reported alcohol use in the past 30 days from both the YRBS and NLSY data. We also include in the final two columns information from the TEDS treatment data, showing the impact of these policies on per capita rates of treatment admissions where alcohol is the primary substance of abuse. Unlike the case for marijuana, alcohol treatment admissions are not as heavily influenced by criminal justice treatment referrals and there is little risk that marijuana policy enforcement would dramatically impact the proportion of people referred to treatment from the criminal justice setting with alcohol as the primary substance of abuse. Thus, we only present results for all treatment admissions in which alcohol is the primary substance of abuse. Again, as was done in Table 4, we report results for youth (those under the age of 21) of each survey/data set in the top, and compare those results to analyses for the full survey/data population in the bottom portion of the table. It is important to keep in mind that the YRBS sample (ages 12-17) is considerably younger than the NLSY sample (which ages from a range of 12-17 and stays in the youth sample until age 20), and hence rates of alcohol use are lower in the YRBS (as shown in Table 3).

When we simply include the single dichotomous indicator of a MML law in analyses using each of these data sets, we generally find no statistically significant relationship between the policy and alcohol use. This is consistent with our results for marijuana, as shown in Tables 4 and 5. When additional policy dimensions are included as explanatory variables, we again get some disparate findings across age groups and data sets. It is important to keep in mind, again, that identification of state policy effects is being assessed off of different state policies across these data sets. Only the TEDS data comprehensively assesses the effects of changes in all the states, but only heavy alcohol consumption requiring treatment is reflected in these data.

There are few consistent findings when looking across the top panel of Table 6, which shows the association between various MML policy dimensions and youth alcohol use. In

general, the inclusion of the additional policy domains does not lead to an increase in the statistical significance of the MML policy variable for youth (similar to Table 4, but not Table 5). However, the specific policy dimensions differ considerably in their effects on alcohol use across the three data sets. Patient registries, which were not statistically important in any of the youth marijuana models shown previously, are negative and statistically significantly associated with past month alcohol use reported in the NLSY and only the NLSY. Given the lack of a significant effect of this variable on any of the youth marijuana use models presented earlier, and in particular the TEDS data, it is not clear how much meaning one should place on this finding.

We see in the alcohol treatment admissions in TEDS that dispensaries have a positive and statistically significant impact on primary alcohol treatment admissions, which is consistent with findings in Table 5 for marijuana admissions. However, findings for the YRBS suggest that dispensaries reduce self-reported alcohol use among those younger than age 18 in the past month. The fact that this result does not hold for the NLSY, which includes more states with changes in medical marijuana laws as well as a higher rate of alcohol use, and that a similar significant finding was not identified for past month marijuana use in the YRBS data, suggests to us that this negative finding in the YRBS is probably just spurious correlation caused with another unobserved attribute of the states included in the data. The negative and significant effect of the home cultivation variable on past thirty day use in the YRBS is also believed to be spurious, as we do not find the same result in the NLSY when we limit these analyses to a subset of the data on the same age group. In the NLSY data we see a consistent pattern of a positive effect of the home cultivation variable on alcohol use for youth even when the MML law is not included. Similarly we see a positive effect on alcohol primary treatment episodes, but the results are not significant at conventional levels.

When we look at the bottom half of Table 6 showing alcohol results for the adults, we see a pattern of specific policy dimensions associated with use that is very similar to that shown for marijuana, particularly in the NLSY sample. MML dichotomous measures are negatively

associated with self-reported alcohol use, patient registry requirements are negatively associated with alcohol use and dispensaries are positively associated with alcohol use. These findings are all consistent with what we observed for marijuana in the NLSY data and supported in the TED marijuana admissions, suggestive of a complementary relationship between alcohol and marijuana among adults. However, when we look at the results for patient registries in the alcohol treatment admissions, we now see a switch in the association between patient registry requirements and alcohol treatment admissions, becoming positive and statistically significant. What is surprising is that none of the other policy dimensions change in the alcohol treatment model, only patient registries. All the other policy dimensions suggest the impact on heavy alcohol use as on heavy marijuana use (suggesting economic complementarity with respect to these dimensions), but for a reason that is readily apparent to us, this one policy dimension changes. The inconsistency between the NLSY finding and TEDS finding can be easily explained by the fact that the NLSY data captures alcohol use at a very different margin (any alcohol use) than that of the TEDS data (heavy use in need of treatment), suggesting there is a heterogeneous effect of these policies along the distribution of drinkers.

In general looking across the adolescent and adult alcohol measures, there are a few broad conclusions that can be drawn. First, when policy elements of the MML laws are also included, the simple dichotomous indicator of having a MML policy becomes negative and statistically significant at a very high level in specifications for adults but not for youth. We did not observe similarly large effects in the marijuana models (Table 4) although other researchers have identified a negative relationship using other years of data (Anderson et al., 2013). Thus, it is possible that broad medical marijuana policies do in fact generate lower marijuana use, and possibly alcohol use. However, all policies are not the same. Marijuana dispensaries are clearly an offsetting factor to any beneficial impact of these policies, as indicated both for alcohol consumption (Table 6) and marijuana consumption (Tables 4 and 5). The effects are stronger for adults than they are for youth, but they have effects on both marijuana consumption

and alcohol consumption. Moreover, we find that home cultivation generally has a positive association with both marijuana use and alcohol use, although this finding is sensitive to which state policies are assessed (as is indicated by the different results in the YRBS from the NLSY and even TEDS data). Finally, patient registry requirements, which were shown to be negatively related with marijuana use in Tables 4 and 5, are also negatively associated with self-reported alcohol use, but positively associated with alcohol treatment admissions. The differential effects of this policy, particularly in light of the clear negative effect it has on marijuana use, provides the strongest evidence of an inconsistent relationship between alcohol and marijuana for different segments of the using population.

While the results presented thus far clearly suggest that not all medical marijuana policies are the same, we have not yet considered what may perhaps be the most significant public health outcome associated with the policy change: alcohol-involved traffic fatalities. Anderson et al (2013) demonstrate convincingly that medical marijuana policies have a negative and statistically significant association with alcohol related fatalities, providing perhaps the strongest evidence that these policies may in fact have positive health benefits. To assess whether those findings are sensitive to the policy dimensions considered, we replicate Anderson et al (2013) model using the same estimation strategy in the 1990-2009 Fatal Accident Reporting System (FARS). These data are collected by the National Highway Traffic Safety Administration and represent an annual census of all fatal injuries suffered in motor vehicle accidents in the United States, as known to police, emergency medical services, emergency departments and death certificates. Similar to Anderson and his colleagues, we estimate the rate of alcohol-involved fatal accidents for various groups (total fatalities, youth age 15-19 traffic fatalities and percent of alcohol involved fatalities) as a function of medical marijuana laws, a vector of state time-varying factors influencing driving practices (average vehicle miles traveled, seat belt laws, graduated drivers licenses, administrative license revocations), state time varying

alcohol policies (blood alcohol content, or BAC, laws and the beer tax), state specific fixed effects and year dummy variables.[7]

Results for similar models to Anderson et al (2013) are presented in Table 7. As there are a few differences in the recognition of medical marijuana laws on the books between our analysis and theirs (in particular the policies in Arizona and DC), we first construct a dichotomous indicator of MML policy that is consistent with the definition they use and replicate their results closely. Our results are broadly consistent although slightly smaller in magnitude to their estimates. We obtain very similar results when we instead use our own dichotomous measure of MML policies. In the third column, we then introduce the other policy elements as additional explanatory variables. We find that MML policies remain negatively associated with total fatal accident rates in the total population, but we again find that this negative relationship is partially offset in states that also allow dispensaries. This is consistent with evidence we showed in Table 6 that dispensaries leads to greater alcohol misuse, as indicated by the TEDS data. Moreover, the result becomes even stronger when we restrict the data to those less than 21. These results provide a powerful example of how important it is to consider the nuances of MML laws in assessing the general benefit or cost. Interestingly, we also find in the models excluding the MML composite measure that home cultivation is negatively associated with fatal alcohol-involved accidents. The fact that this variable is insignificant in the model including the MML composite measures suggests to us that it is again simply picking up the strong negative impact of the MML composite effect when this variable is excluded from the model.

VII. CONCLUSIONS

While it may be tempting to attempt to learn something about the possible effects of legalization on recreational marijuana use from the state experimentation with medical marijuana laws, it is clear from the analyses presented in this paper that not all medical

[7] Unlike Anderson et al, we use the same Poisson specification given by equation (5), as it is deemed to be a more appropriate model fit.

marijuana laws are not homogenous. There are important nuances to these policies that have differential effects on marijuana consumption and related public health harms. Contrary to expectations, we do find that certain types of MML policies are associated with reduced marijuana consumption. However, states that allow dispensaries and/or allow home cultivation can undermine any salutary effect of MML laws on marijuana consumption. Similarly, dispensary policies in particular offset the positive influence of MML laws on alcohol consumption. Marijuana dependence appears to be higher in states with more lenient access to medical marijuana. Measures that operate on supply channels--in particular home cultivation and state acceptance of dispensaries--are associated with higher levels of dependence. Importantly, they are also associated with higher admissions to treatment for alcohol abuse.

The results in this paper provide some additional insight to the inconsistent findings in the literature related to MML policies in general. Consistent with evidence shown by Anderson et al (2012), our analyses show that measured policy effects are sensitive to the specific states used to examine the impacts of policy change. We offer insight into that discussion by demonstrating why this is the case. MML policies are not homogenous, and they do change and get refined over time in important ways. Ignoring the heterogeneity across laws and key regulations related to access that change over time can lead to an impolite picture of the effects of these laws. The offsetting effects of particular policy dimensions on marijuana and alcohol use, dependence, and alcohol involved fatalities suggests these policies might influence use through a variety of different mechanisms, some that may be more relevant for particular populations than others. Further work is needed to assess whether these findings hold for other marijuana-related harms, as it is clear that measured effects are not consistent across different levels of use and different age groups.

Finally, the results should caution policy makers not to make simple inferences about the relationship between alcohol and marijuana solely based upon analyses of MML policies, particularly given the heterogeneity of these laws. Instead, a more careful consideration is

warranted that considers the particular states being evaluated and the dimensions of the medical marijuana laws those states represent.

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Table 1: Summary of State Medical Marijuana Laws as of Jan 1 2012

State	Year of Legislation/ Referendum/ Court Decision	Patient Registry Required?	Allowed for "Pain" ?	Home Cultivation ?	Dispensaries Allowed?
Alaska	1998 1999 2007	No Yes	Yes	Yes	No
Arizona	1996 2010	No Yes	Yes	No Yes	No Yes
California	1996 2003	No	Yes	Yes	No Yes
Colorado	2000 2010 2011	Yes	Yes	Yes	Yes
Delaware	2011	Yes	Yes	No	Yes
District of Columbia	1998 2010	No Yes	No	No	No Yes
Hawaii	2000	Yes	Yes	Yes	No
Maine	1999 2002 2009 2010 2011	No No Yes	Yes	Yes	No No Yes
Maryland	2003 2011	No	No Yes	No	No
Michigan	2008	No	Yes	Yes	No
Montana	2004 2011	No Yes	Yes	Yes	Ambiguous No
Nevada	2001 2003 2005	Yes	Yes	Yes	No
New Jersey	2009	Yes	Yes	No	Yes
New Mexico	2007	Yes	No	Yes	Yes
Oregon	1998 1999 2005 2007	No No No Yes	Yes	Yes	No
Rhode Island	2007 2009	Yes	Yes	Yes	No Yes
Vermont	2004 2007 2011	Yes	No Yes	Yes	No No Yes
Washington	1998 2007 2010 2011	No	Yes	No No No Yes	No

Note: For each state, the first year listed represents year of initial legalization. Other years listed indicate years with additional legal changes. In some cases, new laws did not alter any of the four policy dimensions listed in the table.

Table 2: Data Sets with Pre- and Post- Implementation Information on Medical Marijuana Policies Assessable as of May 2012

State	Year	NLSY	YRBS	NSDUH State Aggregates	TEDS
Alaska	1996		X		X
Arizona	2010				
California	1996				X
Colorado	2000	X	X		X
Delaware	2011				
District of Columbia	2010				
Hawaii	2000	X*	X		X
Maine	1999	X	X		X
Maryland	2003	X*	X	X	X
Michigan	2008	X*	X	X	X
Montana	2004	X*	X	X	X
Nevada	2001	X	X		X
New Jersey	2009	X*		X	X
New Mexico	2007	X*	X	X	X
Oregon	1998	X			X
Rhode Island	2007	X*	X	X	X
Vermont	2004	X*	X	X	X
Washington	1998	X			X

Notes: Asterisk for specific states in the NLSY indicates that cohort is passed age of primary initiation of marijuana by the time the state law passed.

Table 3: Sample Means of Measures of Marijuana and Alcohol Use for Each of Our Main Data Sets

	No MML		MML	
YRBS (1993-2009)	Mean	SE	Mean	SE
Percentage Using Marijuana in Last 30 Days	20.88	5.74	22.67	3.14
Percentage Using Alcohol in Last 30 Days	45.34	7.02	39.75	4.60
N	238		29	
NLSY (1997-2008)	Mean	SE	Mean	SE
Percentage Using Marijuana in Last 30 Days	14.89	35.60	16.75	37.34
Percentage Using Marijuana in At Least 16 of Last 30 Days	5.12	22.03	5.62	23.02
Percentage Using Marijuana in At Least 21 of Last 30 Days	4.07	19.76	4.53	20.79
Percentage Using Alcohol in Last 30 Days	52.68	49.93	59.64	49.06
Percentage Using Alcohol in At Least 16 of Last 30 Days	4.51	20.76	5.63	23.05
Percentage Using Alcohol in At Least 21 of Last 30 Days	2.22	14.75	2.78	16.45
N	78641		18072	
TEDS (1992-2008)	Mean	SE	Mean	SE
Marijuana Treatments per 1,000	0.89	0.53	1.24	0.53
Alcohol Treatments per 1,000	3.57	2.53	4.68	3.25
N	744		84	

Table 4: Impact of Medical Marijuana Laws on Recent and Heavy Marijuana Use in YRBS and NLSY Data Sets

	YRBS		NLSY < 21			NLSY < 21		
Data Set	(1)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Outcome	Used in the Past Month		Used in the Past Month			Heavy Use in the Past Month		
MML	-0.01		0.004	0.026***		0.003	0.003	
	(0.033)		(0.010)	(0.010)		(0.007)	(0.006)	
MML, Registry		0.057		-0.017	-0.017		-0.025	-0.025
		(0.049)		(0.013)	(0.013)		(0.009)	(0.009)
MML, Dispensaries		0.037		0.013	0.014		0.008	0.008
		(0.047)		(0.011)	(0.011)		(0.017)	(0.017)
MML, Home		-0.072*		-0.022	0.002		0.029**	0.033***
		(0.038)		(0.014)	(0.013)		(0.015)	(0.013)
State FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	267	267	46,321	46,321	46,321	46,321	46,321	46,321
			NLSY Full Sample			NLSY Full Sample		
Outcome			Used in Past Month			Heavy Use in the Past Month		
MML			-0.015*	-0.003		0.001	-0.019	
			(0.008)	(0.024)		(0.009)	(0.014)	
MML, Registry				-0.033**	-0.034**		-0.018	-0.02
				(0.012)	(0.013)		(0.012)	(0.012)
MML, Dispensaries				0.033***	0.033***		0.004	0.003
				(0.008)	(0.008)		(0.006)	(0.006)
MML, Home				-0.002	-0.005		0.051*	0.022
				(0.024)	(0.010)		(0.037)	(0.022)
State FEs			Yes	Yes	Yes	Yes	Yes	Yes
Year FEs			Yes	Yes	Yes	Yes	Yes	Yes
State covariates			Yes	Yes	Yes	Yes	Yes	Yes
N			96,713	96,713	96,713	96,713	96,713	96,713

Significance Levels: * 10%, ** 5%, *** 1%. Standard errors in parentheses adjusted for clustering at the state level. Controls included but not shown: ln(population), unemployment rate, age distribution, BAC limit, beer tax. NLSY analysis also includes age fixed effects.

Table 5: Impact of Medical Marijuana Laws (MML) on Treatment Admissions, Marijuana as the Primary Substance of Abuse/Dependence (TEDS, 1992-2009)

	All			Non-CJ		
	(1)	(2)	(3)	(1)	(2)	(3)
MML	-0.136***	-0.306***		-0.196***	-0.498***	
	(0.051)	(0.071)		(0.059)	(0.075)	
MML, Registry		-0.13	-0.128		-0.187**	-0.186**
		(0.105)	(0.103)		(0.106)	(0.103)
MML, Dispensaries		0.120**	0.118**		0.229***	0.224***
		(0.066)	(0.064)		(0.065)	(0.064)
MML, Home		0.233***	-0.059		0.397***	-0.075
		(0.080)	(0.057)		(0.071)	(0.052)
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes	Yes
N	877	877	877	877	877	877
Under 21						
MML	-0.150**	-0.352***		-0.152**	-0.434***	
	(0.062)	(0.071)		(0.070)	(0.084)	
MML, Registry		-0.204	-0.195		-0.207	-0.196
		(0.125)	(0.121)		(0.130)	(0.124)
MML, Dispensaries		0.109	0.108		0.396***	0.395***
		(0.086)	(0.083)		(0.086)	(0.083)
MML, Home		0.310***	-0.027		0.379***	-0.034
		(0.060)	(0.046)		(0.083)	(0.065)
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes	Yes
N	877	877	877	877	877	877

Significance Levels: * 10%, ** 5%, *** 1%. Standard errors in parentheses adjusted for clustering at the state level. Controls included but not shown: ln(population), unemployment rate, age distribution, BAC limit, beer tax.

Table 6: Impact of Medical Marijuana Laws (MML) on Alcohol Use in the YRBS, NLSY and Alcohol Treatment Admissions in the TEDS

	Under 21 Sample							
Data Set	YRBS		NLSY			TEDS		
Outcome	Use in the Past 30 Days		Use in the Past 30 Days			Number of Treatments		
	(1)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
MML	-0.036		0.009	-0.005		0.107	-0.122	
	(0.024)		(0.022)	(0.017)		(0.084)	(0.081)	
MML, Registry		0.067		-0.118***	-0.118***		0.069	0.069
		(0.041)		(0.029)	(0.029)		(0.149)	(0.148)
MML, Dispensaries		-0.071**		0.024	0.024		0.255***	0.254***
		(0.034)		(0.023)	(0.023)		(0.099)	(0.098)
MML, Home		-0.096***		0.108***	0.103***		0.188	0.074
		(0.036)		(0.027)	(0.021)		(0.150)	(0.131)
State FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	267	267	46,264	46,264	46,264	877	877	877
	Full Samples							
Data Set			NLSY			TEDS		
Outcome			Use in the Past 30 Days			Number of Treatments		
			(1)	(2)	(3)	(1)	(2)	(3)
MML			-0.021	-0.046***		0.047	-0.418***	
			(0.013)	(0.016)		(0.087)	(0.055)	
MML, Registry				-0.068***	-0.074***		0.248***	0.246***
				(0.021)	(0.023)		(0.065)	(0.070)
MML, Dispensaries				0.043***	0.041***		0.110**	0.102**
				(0.011)	(0.010)		(0.061)	(0.062)
MML, Home				0.055**	0.013		0.375***	-0.017
				(0.023)	(0.022)		(0.065)	(0.045)
State FEs			Yes	Yes	Yes	Yes	Yes	Yes
Year FEs			Yes	Yes	Yes	Yes	Yes	Yes
State covariates			Yes	Yes	Yes	Yes	Yes	Yes
N			96,261	96,261	96,261	877	877	877

Significance Levels: * 10%, ** 5%, *** 1%. Standard errors in parentheses adjusted for clustering at the state level. Controls included but not shown: ln(population), unemployment rate, age distribution, BAC limit, beer tax. NLSY analysis also includes age fixed effects.

Table 7: Impact of Medical Marijuana Laws on Alcohol Related Fatalities in 1990-2009 FARS

ln(Fatal Accident Rate)								
	All				21 and Under			
MML (AHR)	-0.076***				-0.138***			
	(0.028)				(0.039)			
MML (new)		-0.066***	-0.077**			-0.114***	-0.132***	
		(0.026)	(0.034)			(0.038)	(0.025)	
MML, Registry			-0.003	-0.006			-0.014	-0.019
			(0.051)	(0.052)			(0.074)	(0.075)
MML, Dispensaries			0.094**	0.093**			0.111**	0.108**
			(0.043)	(0.043)			(0.056)	(0.054)
MML, Home			0.007	-0.068*			0.018	-0.109*
			(0.049)	(0.037)			(0.056)	(0.057)
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1020	1020	1020	1020	1020	1020	1020	1020

Significance Levels: * 10%, ** 5%, *** 1%. Standard errors in parentheses adjusted for clustering at the state level. Controls included but not shown: ln(population), unemployment rate, age distribution, BAC limit, beer tax, and decriminalization status. Controls also included in the FARS analysis include: graduated driver's license, adminstrative license revocation, seatbelt laws, and average vehicle miles travelled.