Impacts of Changing Marijuana Policies on Alcohol Use in the United States

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Abstract

Background—Marijuana policies are rapidly evolving. In the United States, recreational use of marijuana is now legal in four states and medical marijuana is legal in 23 states. Research evaluating such policies has focused primarily on how policies affect issues of price, access to, use, and consequences of marijuana. Due to potential spillover effects, researchers also need to examine how marijuana policies may impact use and consequences of alcohol.

Methods—The current paper is a critical review of articles evaluating alcohol outcomes associated with marijuana decriminalization, medical marijuana legalization, and non-medical or recreational marijuana legalization. We identified articles and reports through (1) online searches of EBSCO host database including Academic search premier, Econlit, Legal collection, Medline, Psych articles, and PsycINFO, as well as PubMed and Google Scholar databases; (2) review of additional articles cited in papers identified through electronic searches; and (3) targeted searches of state and local government records regarding marijuana law implementation. We reviewed studies with respect to their data sources and sample characteristics, methodology, and the margin of alcohol and marijuana use, timing of policy change, and the aspects of laws examined.

Results—The extant literature provides some evidence for both substitution (i.e., more liberal marijuana policies related to less alcohol use as marijuana becomes a substitute) and complementary (i.e., more liberal marijuana policies related to increases in both marijuana and alcohol use) relationships in the context of liberalization of marijuana policies in the United States.

Conclusions—Impact of more liberal marijuana policies on alcohol use is complex, and likely depends on specific aspects of policy implementation, including how long the policy has been in place. Further, evaluation of marijuana policy effects on alcohol use may be sensitive to the age

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group studied and the margin of alcohol use examined. Design of policy evaluation research requires careful consideration of these issues.

Keywords

marijuana; cannabis; policy; legalization; alcohol

"Marijuana policy is nothing if not complicated (Chokshi, 2014)." This opening sentence in a Washington Post article prior to the November 2014 elections in the United States (US) summarized the changing climate surrounding marijuana. Starting with Oregon in 1973, eleven US states reduced criminal penalties for possession of small amounts of marijuana during the 1970s. However, these policies varied widely across states (for review see Pacula et al., 2003) with the common denominator being no specific minimum jail or prison sentence for first-time possession of small amount of marijuana. The issue of heterogeneity across the so-called "decriminalization" policies has only increased over time but, as of 2015, 19 US states are considered to have some form of marijuana decriminalization policy.

United States Drug Enforcement Agency scheduling recognizes marijuana as a "Schedule I" drug, meaning there is no accepted medical use in the US. Nonetheless, in 1996 California adopted "medical marijuana" laws allowing use of marijuana to treat a variety of medical conditions, despite federal laws that prohibit marijuana use and possession (Annas, 2014). In 1998, Alaska, Oregon, and Washington followed, as did Maine in 1999 and a number of other states since 2000. Currently, 23 of the nation's 50 states, as well as the District of Columbia and US territories of Guam and Puerto Rico, allow use of marijuana for medical purposes.

Moreover, in 2012, Washington and Colorado legalized marijuana use and possession for non-medical or recreational purposes (hereafter referred to as recreational marijuana laws) for those over 21 years of age, and established regulations governing production, distribution, and sale of marijuana in retail stores (Pardo, 2014). Alaska, Oregon, and the District of Columbia passed their own laws related to recreational use in 2014.

These state-level marijuana policies raise public health and economic concerns because they can have implications not just for marijuana use and consequences, but also for use and consequences of alcohol and other substances (Pacula and Sevigny, 2014). Changes in alcohol use, in particular, are of great concern because the majority of the adults in the US use alcohol and alcohol consumption, especially excessive alcohol use, is extremely costly: between 2006 and 2010, it was responsible for an average of almost 88,000 deaths per year (Stahre et al., 2014), and in 2006 alone it amounted to a median state-cost of 2.9 billion dollars (Sacks et al., 2013). Understanding the impact of marijuana-related legislation on alcohol use is crucial to estimating costs and benefits to society, as well as guiding the design of prevention and intervention efforts (e.g., Caulkins et al., 2012; Kilmer et al., 2010).

Many proponents of marijuana legalization view marijuana as less harmful than alcohol. Proponents also emphasize that even if marijuana legalization increases marijuana use, costs of treating marijuana dependence and related problems are smaller than the potential savings

in criminal justice system spending stemming from legalizing marijuana (e.g., Gieringer, 2009). Additionally, if marijuana and alcohol are *substitutes* and increases in marijuana use result in <u>*decreased*</u> alcohol use, this could lead to a great reduction in individual and societal alcohol-related costs due to improved workplace productivity and reductions in healthcare costs and traffic accidents (Centers for Disease Control & Prevention, 2014).

Yet, the cost of changes in marijuana legislation could increase dramatically if marijuana and alcohol are *complements* and changes in marijuana policy lead to <u>*increases*</u> in *both* marijuana and alcohol (e.g., Pacula and Sevigny, 2014). Further, the costs of a complementary increase in marijuana and alcohol use may be more than additive since those who report using alcohol and marijuana tend to use them at the same time (Subbaraman and Kerr, 2015). Simultaneous use has been shown to be more risky and dangerous than use of alcohol or marijuana alone. For example, those who use marijuana and alcohol together have the highest rates of unsafe driving (e.g., Downey et al., 2013a; Ronen et al., 2010; Subbaraman and Kerr, 2015; Terry-McElrath et al., 2014). Clearly, understanding the impact of marijuana-related policies on alcohol use is of paramount public health and safety importance.

In the first section of this review, we provide a summary of the existing knowledge about the relationship between marijuana and alcohol in general, and in the context of well-established alcohol-related policies in particular. We then apply these perspectives to a comprehensive review of publications focused on the impact of marijuana-related policies on alcohol use including the effects of decriminalization, medical marijuana legalization (MML), and findings and future directions from the initial evaluation of recreational marijuana legalization (RML) policies. We conclude with areas for future research that can inform our understanding of how population levels of alcohol use and consequences may be influenced by more liberal marijuana policies.

Why might marijuana and alcohol be substitutes in the context of marijuana policy changes?

The propensity to substitute intoxicants depends on the similarity of anticipated effects of the intoxicants (Moore, 2010). For decades, alcohol and marijuana have been the two most commonly used intoxicants in the United States (e.g., Substance Abuse and Mental Health Services Administration, 2014). Neuroscience research indicates that marijuana and low-dose alcohol use share neuro-pharmacologic effects of reward and sedation (e.g., Heishman et al., 1997), which could lead to alcohol and marijuana being substitutes, particularly for occasional, low-consumption users (Wen et al., 2015). An individual chooses an intoxicant not only on the basis of the desired effects of the drug but also based on the expected costs (i.e., price, health, legal and social consequences). If marijuana and alcohol share their intoxicating effects, one might expect a heightened interchangeability among these substances in the context of marijuana policy changes that lead to lowered cost (be it legal, social or financial) of marijuana use. Decriminalizing or legalizing marijuana could lead to greater availability and lower costs for marijuana use due both to lower monetary price and lower likelihood of legal consequences. This is likely to lead to increases in marijuana use, and a number of studies document this effect (for review see Chu, 2014). If costs of

marijuana use decrease and costs of alcohol use do not, some individuals may decide to substitute marijuana for alcohol, achieving similar intoxication effects at a lower price. Thus, decriminalizing or legalizing marijuana could lead to increases in marijuana use, but decreases in alcohol use. This substitution hypothesis is consistent with findings from some econometric studies that policies designed to limit alcohol use, such as those that increase the minimum legal drinking age or raise alcohol tax rates, have the unintended consequence of increasing the prevalence of marijuana use (e.g., Crost and Guerrero, 2012; DiNardo and Lemieux, 2001).

Why might marijuana and alcohol be complements in the context of marijuana policy changes?

Opponents of decriminalization or legalization of marijuana suggest that liberalization of laws would be associated with increases in marijuana use, as well as increased alcohol use. Partial support for this view comes again from pharmacologic studies that show that the plasma THC (tetrahydrocannabinol) levels increase if alcohol is consumed simultaneously (e.g., Downey et al., 2013b; Lukas and Orozco, 2001), resulting in reports of more pleasurable subjective mood effects of marijuana (Lukas and Orozco, 2001). Thus, the quest for a "better high" might lead individuals to combine the use of both substances. This might be particularly the case for regular users and at higher end of the alcohol consumption continuum (Wen et al., 2015). In addition, marijuana use might impair judgment or decision-making capacity, leading to greater alcohol use than intended; create situations where individuals have more opportunities to combine marijuana and alcohol use to enhance the effects of both substances; or lead individuals to develop more permissive attitudes toward substance use in general (e.g., Kilmer, 2014). Complementarity is also supported by etiology research that has found a positive relationship between marijuana and alcohol use (e.g., Fergusson and Horwood, 2000; Kandel et al., 1992; Lynskey et al., 2003; Morral et al., 2002). Finally, some econometrics studies (e.g., Chaloupka et al., 1999; Saffer and Chaloupka, 1999; Williams et al., 2004) on the effects of alcohol-related policies on marijuana use also point to the plausibility of complementary effects. For example, using data from the National Household Survey of Drug Abuse (NHSDA, now known as the National Survey on Drug Use and Health, NSDUH), higher alcohol prices were related to both lower alcohol and marijuana participation (Saffer and Chaloupka, 1999). Other research using NHSDA data has found that an increase in the price of alcohol or tobacco was associated with lower probability of marijuana use among youth but not adults (Farrelly et al., 1999).

Materials and Methods

The current review was conducted utilizing online search databases, including EBSCO host that includes Academic Search Premier, Econlit, Legal Collection, Medline, PsycINFO, Psych Articles, as well as PubMed and Google Scholar. The primary search terms algorithm included medical/non-medical/recreat*/decrim* and polic*/law/legislation/legal and marijuana/marijuana/pot/weed/THC and alcohol/ethanol/etoh/drink*. Additional searches in all search engines were conducted using the terms spillover/complement*/substit*. These

searches yielded 751 articles. Only articles examining policy changes in the U.S. were included in the review of marijuana law changes on alcohol use. We also excluded articles not written in English, published in a peer-reviewed journal, or relevant to the topic. Figure 1 summarizes the search algorithm and results. Upon reading literature from identified searches, additional articles and government reports were identified and evaluated for relevance to understanding impact or association of marijuana legalization or policies on alcohol use. This search yielded 2 additional articles describing studies relevant to the topic area. In summary, articles were included in the review if they addressed the topic through including at least one outcome measure of alcohol use related to at least one aspect of change in, association with, or difference between marijuana policies. Articles that focused only on the impact of marijuana policies or laws on marijuana use were not included. Table 1 summarizes the studies along 6 key dimensions: the sample, the age groups examined, the type of marijuana policy, and the dimensions of the policy evaluated as well as the operationalization of marijuana and alcohol use. The following section discusses the findings with respect to the potential impacts of different types of marijuana legislation (decriminalization, MML, and RML) on alcohol.

Impact of Marijuana Policies on Alcohol Use

Decriminalization of marijuana possession—Decriminalization of marijuana continues to be an umbrella term for a wide range of statutes across US states varying across dimensions such as classification of the possession offense, the applicability of the reduced penalties to subsequent offenses, and specification of maximum fine or minimum jail time (Pacula et al., 2003). However, the general term refers to reduced criminal penalties for marijuana possession.

As shown in Table 1, our search identified eight studies describing effects of marijuana decriminalization on alcohol use. Model (1993) examined drug-related emergency room visits from 1975-1979 using the Drug Abuse Warning Network (DAWN) data. She found cities within states with changes in marijuana policy toward or including decriminalization showed increases in emergency room visits related to marijuana but a decrease in the number of visits mentioning other drugs including alcohol. Model was not, however, able to examine episodes involving alcohol only because that data was not recorded by DAWN. Studies using Monitoring the Future (MTF) data have yielded mixed results. On one hand, using the 1982-1989 from MTF, Chaloupka and Laixuthai (1997) reported that high school seniors living in states with decriminalization of marijuana policies used alcohol less frequently and were less likely to engage in heavy drinking than adolescents in states with stricter marijuana policies, although once the monetary price of marijuana was included, this relationship was somewhat attenuated. On the other hand, DiNardo and Lemieux (2001) used state-aggregated MTF data from 1980 through 1989 and found no statistically significant relationship between decriminalization and marijuana or alcohol use. Saffer and Chaloupka (1999) pooled three years (1988, 1990, and 1991) of NHDSU data and examined changes in the number of days of past month alcohol use and two dichotomous indicators of marijuana use – any use in the past month as well as in the past year – in the context of marijuana decriminalization. The results indicated that decriminalization was associated

with increases in prevalence of both past month and past year marijuana use but was not associated with alcohol use. However, in a sample of twelfth graders from the 1982 National Longitudinal Survey of Youth (NLSY) study, Yamada, Kendix, & Yamada (1996) found decriminalization was not significantly associated with marijuana use but was associated with less alcohol use, including lower likelihood of becoming a frequent drinker.

Using data on a sample of males from 1984 and 1988 NLSY surveys, Thies & Register (1993) report mixed findings for the impact of marijuana decriminalization on alcohol use. While decriminalization was not associated with marijuana use at either time point, it was associated with higher prevalence of any alcohol use in the 1984 data and lower prevalence of problem alcohol use in the 1988 data. While controlling for legal sanctions for possession of small amounts of marijuana in addition to other measures of state control of drug use, this study did not control for the variation in price of alcohol and marijuana. Pacula (1998) extended the analyses using the NLSY 1984 data to include both the monetary and legal cost of using alcohol and marijuana. In these analyses, the state decriminalization was positively associated with prevalence of alcohol, although there was no relationship between decriminalization status and the prevalence or the conditional quantity of marijuana use.

Finally, Williams and colleagues (2004) pooled data from 1993, 1997 and 1999 waves of the College Alcohol Study (CAS), a nationally representative study of full-time students attending 4-year colleges, to examine the interplay between substance use policies and college students' alcohol and marijuana use. While the results of the study generally indicate a complementary relationship between alcohol and marijuana, the relationship between alcohol- and marijuana-related policies was not symmetrical. Marijuana-related legal sanctions were not related to past month prevalence of alcohol use but alcohol-related policies such as college ban on alcohol were negatively related to both alcohol and marijuana use.

Medical marijuana legislation

Medical marijuana legislation (MML) in the US permits the sale and use of marijuana for medical purposes under widely varying degrees of regulation across and within states (e.g., Pacula et al., 2014). As shown in Table 1, our search identified 6 studies describing effects of medical marijuana legislation on alcohol use.

Evidence of substitution effects to alcohol—Anderson and colleagues (2013) examined the relationship between MML, traffic fatalities and alcohol consumption in 15 states, using multiple sources of data including Fatal Accident Report System (FARS), Behavioral Risk Factor Surveillance System (BRFSS), and alcohol industry data on sales, while also linking data obtained from advertisements in a *High Times*, a magazine for marijuana users, on changes in prices of marijuana. They found that MML was associated with (1) a significant drop in the price of potent marijuana; (2) a decrease in per-capita sales of beer; (3) reduced total alcohol consumption, particularly among young adults; and (4) a decrease in alcohol-related traffic fatalities. Solomonsen-Sautel and colleagues (2014) also examined FARS data. Using data from 1994-2011 for Colorado and 34 states without medical marijuana, they looked at changes occurring after mid-2009 when Colorado, due to

both federal and state law changes, experienced a large increase in medical marijuana commerce. Differences between the pre-commercial time period in Colorado (1994 to mid-2009) and post-commercialization period (late-2009 to 2011) indicated that commercialization of medical marijuana in Colorado was related to increases in the proportion of drivers in a fatal motor vehicle crash who tested positive for marijuana. There were no significant changes, however, in the proportion of drivers who tested positive for alcohol relative to states without medical marijuana. The differences in findings between Anderson & Rees (2014) and Solomonsen-Sautel et al. (2014) with respect to traffic fatalities involving alcohol likely stem from Anderson's study including multiple MML states, whereas Solomonsen-Sautel's study focused on Colorado's MML only. In addition, Anderson & Rees modeled the effect of initial passage of the medical marijuana legislation (which, for example, occurred in 2000 in Colorado) whereas Solomonsen-Sautel and colleagues focused on the proliferation of medical marijuana dispensaries.

Our review uncovered two additional studies that explicitly examined evidence of substitution focusing on marijuana-using adult samples of marijuana users within the MML context, though these studies do not examine the impact of MML policies, per se. Reiman (2009) surveyed 350 adult customers of a medical marijuana dispensary in Berkeley, CA. She found that 40% of patients reported using marijuana as a substitute for alcohol. The reasons for substitution included less severe side effects, better symptom management, and less withdrawal potential than alcohol, illicit or prescription drugs. Richmond and colleagues (2015) used data collected between 2012-2013 at Denver Health Medical Center to examine differences in marijuana and other substance use between patients in Colorado with and without state medical marijuana cards who have reported marijuana use in the past 90 day. Patients with state-issued marijuana cards had higher frequency of marijuana use and lower use of other substances, including alcohol, providing tentative evidence of substitution relationship between marijuana and alcohol.

Evidence of Complementary Effects—Pacula and colleagues (2013) found evidence that effects of MML on alcohol use depend on particular aspects of MML. Using data from Youth Risk Behavior Survey (YRBS), NLSY97 and Treatment Episodes Data System (TEDS), they examined the impact of different dimensions of MML across states on marijuana and alcohol use. Consistent with Anderson and colleagues (2013), they found that a dichotomous indicator of any MML vs. none was negatively associated with self-reported alcohol use. However, when accounting for differences in the dimensions of MMLs across states, the study showed that individuals living in states with MMLs allowing for dispensaries had a higher likelihood of past month marijuana use as well as alcohol use in the full sample (i.e., including all age groups) of NLSY. Similarly, they found evidence of the complementary relationship between alcohol and marijuana in the full sample analyses of the TEDS data where states with MML dispensaries had higher rates of both marijuana and alcohol treatment admissions, pointing to potential complementarity at the high-end of marijuana and alcohol misuse. However, the complementary relationship between alcohol and marijuana was not evidenced in the sub-sample analyses of those under the age of 21. They also found that a provision for medical marijuana dispensaries was important for alcohol-related fatalities. This study replicated Anderson et al.'s (2013) findings that states

with any type of MML policies had fewer alcohol-related fatalities according to FARS, but those states allowing for medical marijuana dispensaries specifically had higher alcohol-related fatalities. Pacula and colleagues found that a patient registry requirement was associated with both lower likelihood of past month marijuana as well as alcohol use in the full sample of NLSY. However, the patient registry provision was positively associated with the number of alcohol treatment admissions in the TEDS data, which suggests the effects of MML policy may differ along the alcohol use-to-disorder continuum.

In a comprehensive evaluation of the effects MML on substance use based on NSDUH data, Wen and colleagues (2015) compared participants from ten states that legalized medical marijuana between 2004 and 2012 with eight states that legalized medical marijuana prior to 2004 as well as the rest of the US states that did not have any MML by the end of 2012. The data were analyzed separately for youth and adults, and different levels of drinking and marijuana use were considered. To assess the frequency, intensity and problem use, five marijuana use outcomes and four alcohol-related outcomes were examined. The study also examined two measures of concurrent use of alcohol and marijuana. Moreover, the study also examined the variation in the timing of the effects of MML, using different time-leads and lags around the dates of MML legislation in their analysis models, and the dimensions of MML heterogeneity specified by Pacula and colleagues (2013). The results, largely consistent across the different specifications, revealed that while MML was not associated with any level of underage drinking among youth (12-20 year-olds) nor the overall past month quantity of alcohol drinks among adults (21+), MML was positively associated with increases in frequency of binge drinking and the probability of simultaneous use of alcohol and marijuana among those of legal drinking age. Finally, the study examined the issue of timing of the policy effect, estimating contemporary as well as six-months, one- and two-year time leads and lags. The results suggest that there are both contemporary effects of MML adoption that influence the changes in the probability of past month marijuana use as well as delayed policy effects on marijuana abuse/dependence among those over the age of 21. Overall, this study suggests there may be complementary effects between marijuana and alcohol among adults but not youth, and these effects may only be evident at higher levels of alcohol use, as well as in the form of increases in simultaneous use of marijuana and alcohol in the context of MML.

Recreational marijuana legalization

Implementation of the new recreational marijuana laws and development of legal recreational marijuana markets in Washington State and Colorado are still unfolding. Legislation passed in both states in 2012, but sale of recreational marijuana in state-regulated stores did not begin until January of 2014 in Colorado and July of 2014 in Washington. As of 2015, RML markets were growing in both states but had not yet matched MML markets in terms of amount of marijuana sold (Washington State Department of Revenue, 2015).

In Washington, understanding the associations between recreational marijuana legalization and alcohol use is complicated by recent change in laws regulating the sale of alcohol. In fall 2011, Washington voted to privatize the sale of hard liquor (Initiative 1183), which

previously had only been available for onsite consumption in bars or restaurants or through state-run liquor stores. Likely due to this law change, there was a 13% increase in retail sales in fiscal year 2013 compared to the prior year; thus, it may be hard to isolate the effects of marijuana legalization on alcohol use in Washington from the effects of the change in alcohol policy (Washington State Office of Financial Management, 2015).

Data from Colorado and Washington on alcohol sales (Colorado Department of Revenue, 2014; Washington State Department of Revenue, 2015) and alcohol-related crime (Denver Department of Safety Public Information Standards, 2014; Drug Policy Alliance, 2014) and traffic accidents (Colorado Department of Transportation, 2015; Washington Traffic Safety Commission, 2014) indicate no dramatic, immediate changes post-RML.

Similarly, adolescent survey data from the two states show changes in alcohol use consistent with longer term trends (Colorado Department of Public Health and Environment, 2013; Washington State Health Youth Survey, 2015). A recent study of a community sample of 238 students in Washington found two cohorts experiencing the law change in Washington at different ages differed in the relative likelihood of using marijuana versus alcohol (Mason et al., 2015), with the cohort that had experienced the law change prior to their 9th grade data collection being relatively more likely to use marijuana compared to their likelihood of using alcohol. Although based on a convenience sample and looking at the effects of legislation soon after passage rather than after full implementation, this study provides a blueprint for modeling the relative likelihood of marijuana and alcohol use as a test of substitution effects.

General conclusions

It is clear that more work is needed to fully understand how the marijuana policy changes affect alcohol use. Across the reviewed studies, we have found support for marijuana and alcohol as both substitutes and complements. There is evidence for substitution effects resulting from liberalization of marijuana laws for some aspects of alcohol consumption. From data sources capturing state variation in marijuana laws, the evidence for substitution includes the MML-associated declines in traffic fatalities and measures of total alcohol consumption among young adults (Anderson et al., 2013; Pacula et al., 2013) and in alcohol use, particularly among youth (Chaloupka and Laixutha, 1997). There is also some weaker evidence of substitution in the studies of community samples based on medical marijuana user self-report of substitution (Reiman, 2009), comparison of alcohol use among medical marijuana card holders compared to non-card-holding marijuana users (Richmond et al., 2015), and comparison of different age cohorts in Washington (Mason et al., 2015). With respect to complementary effects in which liberalization of marijuana laws results in increased use of both marijuana and alcohol use, the strongest support comes from studies of MML by Pacula et al. (2013) and Wen et al. (2015). These studies, using nation-wide data and examining variation across states, suggest that MML, particularly in less restrictive and regulated forms, is associated with increases in some margins of alcohol use among certain age groups. In particular, the Wen et al. study points to increases in heavy drinking and alcohol use combined with marijuana use among adults that can occur in the context of MML.

To gain a more complete picture of the effects of marijuana policy changes on other substance use, it is important to examine changes in overall prevalence, initiation, and regular use as well as to distinguish between casual or occasional users, heavy or regular users, and, if possible, those with abuse or dependence problems. The importance of such distinctions has been aptly demonstrated in the work of Wen and colleagues (2015) who reported the effects of MML on frequency of binge drinking but not on past month quantity of drinking. Also, Pacula and colleagues (2013) found that the effects of MML policy differed along the severity of alcohol use continuum, with MMLs that have patient registry requirement being related to lower prevalence of past month alcohol use but higher number of alcohol treatment admissions indexing a "problem" or "disordered" use. Furthermore, the studies by Wen et al. (2015) and Pacula et al. (2013) highlight that it is important to account for multiple key dimensions of MML including laws about patient registry, dispensaries, and home cultivation and decriminalization and price of marijuana, and therefore also the use of marijuana as well as alcohol. Regarding decriminalization, a similar point can be made about the need to better capture the heterogeneity in decriminalization policies. Studies should focus on different dimensions of marijuana decriminalization policies including variation in statutory penalties such as minimum jail time and maximum fines, among others (Pacula et al., 2003). No study to date has comprehensively evaluated the effects of these dimensions on both marijuana and alcohol use. Furthermore, as the review of studies on the effects of decriminalization on alcohol use demonstrated, these effects are sensitive to the inclusion of the monetary price of marijuana (e.g., Chaloupka & Laixuthai, 1997; Pacula, 1998). Therefore, studies assessing the potential substitution effects between marijuana and alcohol in the context of marijuana policy changes need to capture the changes in the legal and financial price of marijuana use.

Moreover, although all studies included in this critical review included some indicator of decriminalization or MML, researchers should be familiar with actual implementation of policies and account for delays between the date of the policy change and the implementation. For example, Maine and New Jersey medical marijuana dispensaries did not open until two years after they were legalized (Anderson and Rees, 2014). To assess whether the presence of medical marijuana dispensaries affects marijuana and other substance use, the researchers should account for both, the "de-jure" as well as the "de-facto" dimension of the policy change (Anderson and Rees, 2014; Salomonsen-Sautel et al., 2014). A number of studies have examined potential effects on substance use behavior shortly after the passage of legislation even though putative effects may take time to take hold due to delays with implementation of the law and fluctuations in pricing until stabilization. It is plausible that the difference in findings between the Anderson et al. (2013) and Salomonsen-Sautel et al. (2014) with respect to alcohol-related traffic accidents stems from differences in how the timing of effects of MML were evaluated.

Recommendations for future research

In the absence of randomized trials, no single design is ideal to examine potential effects of legislation on other substance use. Thus, findings from multiple designs can complement one another to provide a more complete picture of how policies may influence substance use over time.

One important study approach compares substance use outcomes between states that have enacted pro-marijuana legislation and those that have not. For conducting these between-state comparisons, the difference-in-difference (DD) approach may be a useful method, which accounts for unmeasured time-fixed state-level characteristics. Using national data that have sufficiently representative samples for multiple states, researchers can utilize DD methods to compare differences in the change in prevalence of marijuana and alcohol use from pre- to post-legislation among states that pass legislation to states that do not pass such legislation over the corresponding period. However, it is important for researchers to understand the nuances of the different policies and how these policies were implemented in order to account for the important dimensions of the policy change and their timing.

Yet, there are also important opportunities to utilize data collected from within a single state. Using state-representative repeated cross-sectional samples, investigators could use interrupted time-series approaches to assess whether passage of a marijuana-related policy is associated with deflections off prior trajectories of substance use outcomes over time. A notable limitation is that it is not possible to account for important concurrent or temporally proximal events that could also influence use (e.g., the privatization of liquor sales initiative 1183 in WA that went into effect in 2012), and thus it may be difficult to disentangle the true impact of policy changes.

In addition, similar to work conducted by Mason and colleagues (2015), within-state multiple prospective cohorts from a single research study that traverse the period of policy change at different ages could offer information as to potential spillover effects of legislation. Additionally, within-state studies may allow for studies of specific aspects of the law that vary over smaller-area geographies (e.g., counties) and how they are related to substance use outcomes.

There are other important research questions to explore in addition to whether policies affect use, including impact on risk factors such as individuals' perceived social norms and risks and harms of other substances and how policies may influence co-occurring and concurrent substance use. There may be also differential impacts of policies according to variables such as age, race/ethnicity, income, education, and gender. Using the MTF data from 1976-2013, Lanza and colleagues (2015) found that recently the rates of marijuana use have increased, particularly for male and African American students. In addition, they found that the strength of positive relationship between marijuana use and heavy episodic drinking has increased since 2008 for African American adolescents. While not tested in this study, some of these trends may be sensitive to changes in marijuana related policy. Additional research may guide public health practitioners in selecting relevant tested and effective programs that target marijuana-related risk factors or populations that experience higher levels of problems related to marijuana and alcohol use.

It is important that collection of data at the local, state and national level keeps up with the policy evaluation needs. This means that consistent information is collected over time to allow for time trend analyses. At the same time, however, data should be collected to capture the emerging trends in substance use such as "dabbing" (inhalation of a concentrated THC manufactured through butane extraction, Stogner and Miller, 2015) or the

simultaneous use of marijuana, alcohol and other substances. Finally, the existing datasets should be augmented with variables that allow for disentangling of alcohol and other substance use. For example, the revised DAWN database could include data on alcohol-only episodes for the full sample of patients, not just for underage drinkers, in order to allow for evaluation of effects of marijuana policy changes on alcohol use.

The studies reviewed here highlight that marijuana policies are complex and evolving, and characteristics of these policies have the potential to impact the use of marijuana as well as alcohol. As the current review documented, it is likely that the relationship between marijuana and alcohol varies for different segments of population, and the type and course of marijuana and alcohol use. In the context of legalization, understanding whether alcohol and marijuana are complements or substitutes influences the policy tools to be employed in order to improve public health. This is particularly important if marijuana and alcohol are complements and tools such as increased taxation and decreased availability of marijuana through state monopolization could be used to curb increases in use. Yet, such controlling policy tools should be approached cautiously given the possibility of empowering the illicit, unregulated market that may expose consumers to potentially greater harm. What is clear is that our current understanding of the impact of marijuana-related policy changes on alcohol use is limited, and further study that carefully considers the heterogeneity in marijuana policy and its implementation, as well as the full range of marijuana and alcohol outcomes and the characteristics of the users is needed. Who is up for the challenge?

Acknowledgments

References

Anderson DM, Hansen B, Rees DI. Medical marijuana laws, traffic fatalities, and alcohol consumption. Journal of Law and Economics. 2013; 56:333–369.

Anderson DM, Rees DI. The role of dispensaries: the devil is in the details. Journal of Policy Analysis and Management. 2014; 33:235–240. [PubMed: 24358532]

Annas GJ. Medical marijuana, physicians, and state law. The New England Journal of Medicine. 2014; 371:983–983. [PubMed: 25099473]

Caulkins, JP.; Hawken, A.; Kilmer, B.; Kleiman, MAR. Marijuana legalization: What everyone needs to know. New York: Oxford University Press; 2012.

Centers for Disease Control & Prevention. Excessive drinking costs U S $223.5 billion. 2014. Retrieved May 29, 2015, from the World Wide Web: http://www.cdc.gov/Features/AlcoholConsumption/

Chaloupka FJ, Laixutha A. Do youths substitute alcohol and marijuana? Some econometric evidence. 1997; 23:3.

Chaloupka, FJ.; Pacula, RL.; Farrelly, MC.; Johnston, LD.; O'Malley, PM. Do higher cigarette prices encourage youth to use marijuana? (NBER Working Paper No 6939). National Bureau of Economic Research; 1999. Retrieved May 29, 2015, from the World Wide Web: http://www.nber.org/papers/w6939

Chokshi, N. Where marijuana is legalized, decriminalized, or on the November ballot. Washington Post; 2014 Oct 13. Retrieved May 29, 2015, from the World Wide Web: http://

www.washingtonpost.com/blogs/govbeat/wp/2014/10/13/where-marijuana-is-legalized-decriminalized-or-on-the-november-ballot

Chu YW. The effects of medical marijuana laws on illegal marijuana use. Journal of Health Economics. 2014; 38:43–61. [PubMed: 25205609]

Colorado Department of Public Health and Environment. Marijuana: Overview of 2013 data from the Healthy Kids Colorado Survey. 2011. Retrieved May 29, 2015, from the World Wide Web: http://www.chd.dphe.state.co.us/topics.aspx?q=Adolescent_Health_Data

Colorado Department of Revenue. Annual Report: July 1, 2013–June 30, 2014. 2014. Retrieved May 29, 2015, from the World Wide Web: https://www.colorado.gov/pacific/sites/default/files/2014%20Annual%20Report1.pdf

Colorado Department of Transportation. National Traffic Highway Association, Fatality Analysis Reporting System Colorado historical fatal crash trends since 2002. 2015. Retrieved May 29, 2015, from the World Wide Web: https://www.codot.gov/library/traffic/traffic-manuals-guidelines/safety-crash-data/fatal-crash-data-city-county/Colorado_Historical_Fatalities_Graphs.pdf/view

Crost B, Guerrero S. The effect of alcohol availability on marijuana use: evidence from the minimum legal drinking age. Journal of Health Economics. 2012; 31:112–121. [PubMed: 22381404]

Denver Department of Safety Public Information Standards. [Retrieved Accessed May 29, 2015] Part 1: Crime in the city and county of Denver based on UCR standards. 2014. from the World Wide Web: http://www.denvergov.org/Portals/720/documents/statistics/2014/UCR_Citywide_Reported%20_Offenses_2014.pdf

DiNardo J, Lemieux T. Alcohol, marijuana, and American youth: the unintended consequences of government regulation. Journal of Health Economics. 2001; 20:991–1010. [PubMed: 11758056]

Downey LA, King R, Papafotiou K, Swann P, Ogden E, Boorman M, Stough C. The effects of cannabis and alcohol on simulated driving: Influences of dose and experience. Accident Analysis and Prevention. 2013a; 50:879–886. [PubMed: 22871272]

Downey LA, King R, Papafotiou K, Swann P, Ogden E, Boorman M, Stough C. The effects of cannabis and alcohol on simulated driving: Influences of dose and experience. Accident Analysis & Prevention. 2013b; 50:879–886. [PubMed: 22871272]

Drug Policy Alliance. Marijuana legalization in Colorado after one year of retail sales and two years of decriminalization. 2014. Retrieved May 29, 2015, from the World Wide Web: https://www.drugpolicy.org/sites/default/files/Colorado_Marijuana_Legalization_One_Year_Status_Report.pdf

Farrelly, MC.; Bray, JW.; Zarkin, GA.; Wendling, BW.; Pacula, RL. The effects of prices and policies on the demand for marijuana: Evidence from the National Household Surveys on Drug Abuse (NBER Working Paper 6940). National Bureau of Economic Research; 1999. Retrieved the World Wide Web: http://www.nber.org/papers/w6940

Fergusson DM, Horwood LJ. Does cannabis use encourage other forms of illicit drug use? Addiction. 2000; 95:505–520. [PubMed: 10829327]

Freisthler B, Gruenewald PJ. Examining the relationship between the physical availability of medical marijuana and marijuana use across fifty California cities. Drug and Alcohol Dependence. 2014; 143:244–250. [PubMed: 25156224]

Gieringer, D. Marijuana legalization could yield California taxpayers over $1.2 billion per year [CA NORML Web site]. 2009. Retrieved May 29, 2015, from the World Wide Web: http://www.canorml.org/background/CA_legalization2.html

Gruenewald PJ. The spatial ecology of alcohol problems: Niche theory and assortative drinking. Addiction. 2007; 102:870–878. [PubMed: 17523980]

Heishman SJ, Arasteh K, Stitzer ML. Comparative effects of alcohol and marijuana on mood, memory, and performance. Pharmacology, Biochemistry and Behavior. 1997; 58:93–101.

Kandel DB, Yamaguchi K, Chen K. Stages of progression in drug involvement from adolescence to adulthood: Further evidence for the gateway theory. Journal of Studies on Alcohol. 1992; 53:447–457. [PubMed: 1405637]

Kilmer B. Policy designs for cannabis legalization: Starting with the eight Ps. The American Journal of Drug and Alcohol Abuse. 2014; 40:259–261. [PubMed: 24853283]

Kilmer, B.; Caulkins, JP.; Midgette, G.; Dahlkemper, L.; MacCoun, RJ.; Pacula, RL. Before the grand opening: Measuring Washington state's marijuana market in the last year before legalized commercial sales. RAND; 2013. Retrieved May 29, 2015, from the World Wide Web: http://www.rand.org/pubs/research_reports/RR466.html

Kilmer, B.; Caulkins, JP.; Pacula, RL.; MacCoun, R.; Reuter, PH. Altered state? Assessing how marijuana legalization in California could influence marijuana consumption and public budgets No OP-315-RC. Santa Monica, CA: RAND; 2010.

Lanza ST, Vasilenko SA, Dziak JJ, Butera NM. Trends among U.S. high school seniors in recent marijuana use and associations with other substances: 1976-2013. Journal of Adolescent Health. 2015; 57:198–204. [PubMed: 26206440]

Light, MK.; Orens, A.; Lewandowski, B.; Pickton, T. Market size and demand for marijuana in Colorado. 2014. Retrieved May 29, 2015, from the World Wide Web: https://www.colorado.gov/pacific/sites/default/files/Market%20Size%20and%20Demand%20Study,%20July%209,%202014%5B1%5D.pdf

Lukas SE, Orozco S. Ethanol increases plasma Delta(9)-tetrahydrocannabinol (THC) levels and subjective effects after marihuana smoking in human volunteers. Drug and Alcohol Dependence. 2001; 64:143–149. [PubMed: 11543984]

Lynskey MT, Heath AC, Bucholz KK, Slutske WS, Madden PAF, Nelson EC, Statham DJ, Martin NG. Escalation of drug use in early-onset cannabis users vs co-twin controls. JAMA. 2003; 289:427–433. [PubMed: 12533121]

MacCoun, RJ.; Reuter, P. Drug war heresies: Learning from other vices, times, and places. Cambridge, UK: Cambridge University Press; 2001.

Mair C, Freisthler B, Ponicki WR, Gaidus A. The impacts of marijuana dispensary density and neighborhood ecology on marijuana abuse and dependence. Drug and Alcohol Dependence. 2015

Mason WA, Hanson K, Fleming CB, Ringle JL, Haggerty KP. Washington State recreational marijuana legalization: Parent and adolescent perceptions, knowledge, and discussions in a sample of low-income families. Substance Use and Misuse. 2015; 50:541–545. [PubMed: 25671633]

Model KE. The effect of marijuana decriminalization on hospital emergency room drug episodes: 1975–1978. Journal of the American Statistical Association. 1993; 88:737–747.

Moore SC. Substitution and complementarity in the face of alcohol-specific policy interventions. Alcohol and Alcoholism. 2010; 45:403–408. [PubMed: 20729529]

Morral AR, McCaffrey DF, Paddock SM. Reassessing the marijuana gateway effect. Addiction. 2002; 97:1493–1504. [PubMed: 12472629]

Pacula RL. Does increasing the beer tax reduce marijuana consumption? Journal of Health Economics. 1998; 17:557–585. [PubMed: 10185512]

Pacula, RL.; Chriqui, JF.; King, J. Marijuana decriminalization: What does it mean in the United States? (NBER Working Paper No 9690). National Bureau of Economic Research; 2003. Retrieved May 29, 2015, from the World Wide Web: http://www.nber.org/papers/w9690

Pacula RL, Hunt P, Boustead A. Words can be deceiving: A review of variation among legally effective medical marijuana laws in the United States. Journal of Drug Policy Analysis. 2014; 7:1–19. [PubMed: 25657828]

Pacula, RL.; MacCoun, RJ.; Reuter, P.; Chriqui, J.; Kilmer, B.; Harris, K.; Paoli, L.; Schaefer, C. What does it mean to decriminalize marijuana? A cross-national empirical examination. In: Lindgren, B.; Grossman, M., editors. Substance use: Individual behaviour, social interactions, markets and politics. North-Holland: Elsevier; 2005. p. 347-370.

Pacula, RL.; Powell, D.; Heaton, P.; Sevigny, EL. Assessing the effects of medical marijuana laws on marijuana use: the devil is in the details (NBER Working Paper No 19302). National Bureau of Economic Research; 2013. Retrieved May 29, 2015, from the World Wide Web: http://www.nber.org/papers/w19302

Pacula RL, Sevigny EL. Marijuana liberalization policies: Why we can't learn much from policy still in motion. Journal of Policy Analysis and Management. 2014; 33:212–221. [PubMed: 24358530]

Pardo B. Cannabis policy reforms in the Americas: A comparative analysis of Colorado, Washington, and Uruguay. International Journal of Drug Policy. 2014; 25:727–735. [PubMed: 24970383]

Reiman A. Cannabis as a substitute for alcohol and other drugs. Harm Reduction Journal. 2009; 6:35. [PubMed: 19958538]

Richmond MK, Pampel FC, Rivera LS, Broderick KB, Reimann B, Fischer L. Frequency and risk of marijuana use among substance-using health care patients in Colorado with and without access to state legalized medical marijuana. Journal of Psychoactive Drugs. 2015; 47:1–9. [PubMed: 25715066]

Ronen A, Chassidim HS, Gershon P, Parmet Y, Rabinovich A, Bar-Hamburger R, Cassuto Y, Shinar D. The effect of alcohol, THC and their combination on perceived effects, willingness to drive and performance of driving and non-driving tasks. Accident Analysis and Prevention. 2010; 42:1855–1865. [PubMed: 20728636]

Sacks JJ, Roeber J, Bouchery EE, Gonzales K, Chaloupka FJ, Brewer RD. State costs of excessive alcohol consumption, 2006. American Journal of Preventive Medicine. 2013; 45:474–485. [PubMed: 24050424]

Saffer, H.; Chaloupka, F. Demographic differentials in the demand for alcohol and illicit drugs. In: Chaloupka, J.; Grossman, M.; Bickel, WK.; Saffer, H., editors. The Economic Analysis of Substance Use and Abuse. University of Chicago Press; Chicago: 1999.

Saffer, H.; Chaloupka, F. Demographic differentials in the demand for alcohol and illicit drugs. In: Chaloupka, J.; Grossman, M.; Bickel, WK.; Saffer, H., editors. The Economic Analysis of Substance Use and Abuse. University of Chicago Press; Chicago: 1999.

Salomonsen-Sautel S, Min SJ, Sakai JT, Thurstone C, Hopfer C. Trends in fatal motor vehicle crashes before and after marijuana commercialization in Colorado. Drug and Alcohol Dependence. 2014; 140:137–144. [PubMed: 24831752]

Stahre M, Roeber J, Kanny D, Brewer RD, Zhang X. Contribution of excessive alcohol consumption to deaths and years of potential life lost in the United States. Preventing Chronic Disease. 2014; 11:E109. [PubMed: 24967831]

Stogner JM, Miller BL. Assessing the dangers of "dabbing": Mere marijuana or harmful new trend? Pediatrics. 2015; 136:1–3. [PubMed: 26077476]

Subbaraman MS, Kerr WC. Simultaneous versus concurrent use of alcohol and cannabis in the National Alcohol Survey. Alcoholism: Clinical and Experimental Research. 2015; 39:872–879.

Substance Abuse and Mental Health Services Administration. Results from the 2013 National Survey on Drug Use and Health: Summary of National Findings, NSDUH Series H-48, HHS Publication No (SMA) 14-4863. Rockville, MD: Substance Abuse and Mental Health Services Administration; 2014.

Terry-McElrath YM, O'Malley PM, Johnston LD. Alcohol and marijuana use patterns associated with unsafe driving among U.S. high school seniors: High use frequency, concurrent use, and simultaneous use. Journal of Studies on Alcohol and Drugs. 2014; 75:378–389. [PubMed: 24766749]

Theall KP, Lancaster BP, Lynch S, Haines RT, Scribner S, Scribner R, Kishore V. The neighborhood alcohol environment and at-risk drinking among African-Americans. Alcoholism: Clinical and Experimental Research. 2011; 35:996–1003.

Thies CF, Register CA. Decriminalization of marijuana and the demand for alcohol, marijuana and cocaine. The Social Science Journal. 1993; 30:385–399.

Truong KD, Sturm R. Alcohol outlets and problem drinking among adults in California. Journal of Studies on Alcohol and Drugs. 2007; 68:923–933. [PubMed: 17960311]

Washington State Department of Revenue. Spirits Tax. 2015. Retrieved May 29, 2015, from the World Wide Web: http://dor.wa.gov/Content/AboutUs/StatisticsAndReports/stats_SpiritsTaxes.aspx

Washington State Health Youth Survey. Healthy youth survey fact sheets. 2015 Apr 14. Retrieved May 29, 2015, from the World Wide Web: https://www.askhys.net/FactSheets

Washington State Office of Financial Management. Forecasting and Research Division. Washington state: Privatization of liquor: The impact of initiative 1183. 2015 Retrieved May 29, 2015, from the World Wide Web: Forecasting and Research Division. Washington state: Privatization of liquor: The impact of initiative 1183.

Washington Traffic Safety Commission. Quarterly Crash Data. 2014. Retrieved May 29, 2015, from the World Wide Web: http://wtsc.wa.gov/research-data/crash-data/

Wen H, Hockenberry JM, Cummings JR. The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. Journal of Health Economics. 2015; 42:64–80. [PubMed: 25863001]

Williams J, Liccardo Pacula R, Chaloupka FJ, Wechsler H. Alcohol and marijuana use among college students: economic complements or substitutes? Health Economics. 2004; 13:825–843. [PubMed: 15362176]

Yamada T, Kendix M, Yamada T. The impact of alcohol consumption and marijuana use on high school graduation. Health Economics. 1996; 5:77–92. [PubMed: 8653193]
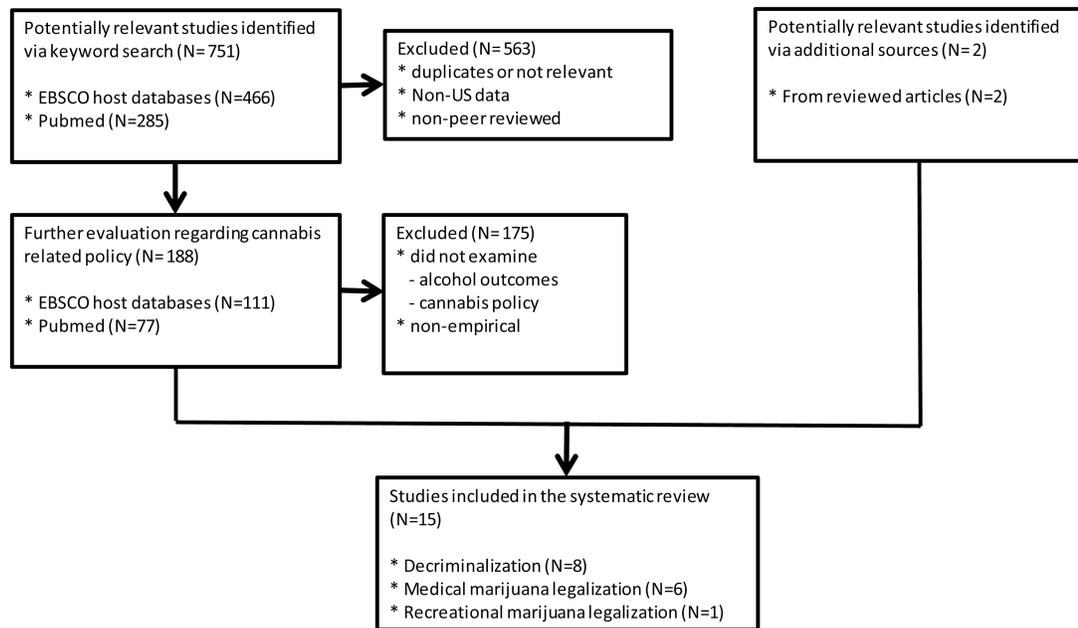
Figure 1. Flow diagram showing the search algorithm and the number of studies included and excluded from the systematic review

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Table 1

Summary of the Reviewed Studies

First Author (year)	Sample	Age group considered	Cannabis policy evaluated	Specific dimensions of the policy evaluated	Measures of Cannabis Use	Measures of Alcohol Use	Key findings
Chaloupka & Laixuthai (1997)	MTF 1982 and 1989 data	High-school Grade 12	Decrim	marijuana decriminalization, and price of marijuana	not examined	frequency of alcohol in PY, drinking in past 30 days, heavy drinking past 2 weeks	decriminalization associated with less frequent alcohol use and lower likelihood of heavy drinking; findings somewhat attenuated once controlling for monetary price of cannabis
Chaloupka & Laixuthai (1997) **continued**	FARS 1975-1988 data	age 18-20, 15-24	Decrim	decriminalized in the state of residence y/n	not examined	total fatality rate; night driver fatality rate; alcohol involved driver fatality rate	decriminalization associated with decreases in alcohol-related driver fatality rates among youth
Dinardo & Lemieux (2001)	MTF 1980-1989 data	High school; controls for >=18 years of age	Decrim	decriminalization	any PM cannabis use	any PM alcohol use	no statistically significant relationship between decriminalization and cannabis or alcohol use
Model (1993)	DAWN 1975-1977 data	All ages but controlling for % of 18-34	Decrim	decriminalized in the state of residence y/n, and the time elapsed since the enactment of the new law (up to 3 years ago)	Number of mentions in ER drug-related visits	# of mentions of ER drug-related visits not mentioning cannabis (not alcohol specific); alcohol is recorded in ER visit if used in conjunction with another illicit drug or with a prescription drug used for nonmedical purposes; alcohol-related episodes separately are not examined because data unavailable	decriminalization was associated with an increase in the number of ER cannabis episodes and decrease in the number of episodes mentioning other substances
Pacula (1998)	NLSY 1984 data		Decrim	marijuana decriminalization,	any PM cannabis use;	any PM alcohol use;	decriminalization associated with higher

First Author (year)	Sample	Age group considered	Cannabis policy evaluated	Specific dimensions of the policy evaluated	Measures of Cannabis Use	Measures of Alcohol Use	Key findings
				and price of marijuana and price of marijuana	number of times cannabis consumed in PM	number of drinks drunk in PM	prevalence of alcohol use but not related to cannabis use
Saffer & Chaloupka (1999)	NHSDA 1988, 1990, and 1991 data	age 12-20, age 21-30	Decrim	marijuana decriminalization, and price of marijuana	any PM cannabis use, any PY cannabis use	number of days in the past alcohol use	decriminalization associated with higher prevalence of PM and PY cannabis use but not related to alcohol use
Thies & Register (1993)	NLSY 1984 and 1988 data (but males only)	age 14-21	Decrim	marijuana decriminalization, enforcement index measuring state law enforcement of common crimes	any PM cannabis use and number of joints during the last month for cannabis users	any PM alcohol use, any binge drinking defined as 6 or more drinks of alcohol at one time and the amount each in the PM	decriminalization not associated with cannabis use in 1984 or 1989; but positively associated with any alcohol use in 1984 and negatively associated with problem drinking
Williams et al. (2004)	CAS 1993, 1997 and 1999 data	college students; separate analyses testing age interaction >=21 years of age	Decrim	marijuana decriminalization; and state-level maximum fine for possession of 1 oz of cannabis; also price of cannabis	PM and PY cannabis use	PM and PY alcohol use	no statistically significant relationship between cannabis-related policies and alcohol use but alcohol-related sanctions related to lower cannabis use; also negative relationship between monetary price of cannabis and both cannabis and alcohol use
Yamada et al. (1996)	NLSY 1982 data	High school Grade 12	Decrim	decriminalized in the state of residence y/n	Whether used marijuana in each of the ten months during the academic year	Used alcohol two or more days in the past week; number of drinks consumed in the prior week	Decriminalization was associated with lower probability of frequent drinking but no relationship with cannabis use
Anderson et al. (2013)	FARS 1990-2010 data	15-19; 20-29; 30-39; 40-49; 50-59; 60+ years of age	MML	passage of MML	not examined	Traffic fatalities overall; TF not involving alcohol; TF involving alcohol BAC>0; and BAC>=.10	MML is related to a significant decrease in TF from accidents involving BAC>=.10. Evidence of effects by age - MML related 16.7% decrease in TF of 20-29 yos. And some evidence of greater impact of MML on fatalities among males (trend).

First Author (year)	Sample	Age group considered	Cannabis policy evaluated	Specific dimensions of the policy evaluated	Measures of Cannabis Use	Measures of Alcohol Use	Key findings
Anderson et al. (2013) - **continued**	BRFSS 1993-2010 data	all; and 18-19; 20-29; 30-39; 40-49; 50-59; 60+ years of age	MML	passage of MML	not examined	PM use: any; 15+; 30+; 60+; Binge drank; 2+ Binges; Number of drinks	MML related to reduction in the probability of some forms on PM alcohol consumption in all age groups except the oldest (60+ yos): any and daily drinking among 18-19 yos; 60+ drinks and number of drinks among 20-29yos; 15+ drinks among 30-39 yos; binge drinking among 40-49 yos; 15+ and 30+ drinks among 50-59 yos binge drinking
Anderson et al. (2013) - **continued**	Cannabis price data from High Times 1990-2011 data	N/A	MML	passage of MML	price of low- and high-quality cannabis in a given state and year	N/A	MML related to 9.8% decrease in the price of high quality cannabis but the effect of MML on the price of cannabis was delayed - in the 4th full year after MML, there was a 24% decrease in the price of high-quality cannabis
Anderson et al. (2013) - **continued**	Alcohol sales from the Beer Institute in Brewers Almanac 1990-2010 data	N/A	MML	passage of MML	N/A	per capita sales of beer, wine and spirits in a given state and year	MML passage associated with lower beer sales; also, lower beer sales associated with lower traffic fatalities overall and those involving BAC>0 and >.10
Pacula et al. (2013) **(NBER working paper)**	FARS 1990-2009 data	<21 and total sample	MML	Laws concerning (1) registry, (2) home cultivation, (3) dispensaries, and (4) whether allow MM for non-specific pain. Exclude non-specific pain rules from analysis due to collinearity with other dimensions	not examined	FARS: rate of alcohol rated traffic accident fatalities	negative association between general MML indicator and alcohol related fatalities; positive association between dispensaries and fatalities
Pacula et al. (2013) **(NBER working paper) continued**	TEDS 1992-2008 data	<21 and total sample	MML	Laws concerning (1) registry, (2) dispensaries, (3) home cultivation, and (4) whether allow MM for non-specific pain. Exclude non-	Marijuana Treatments per 1,000;	Alcohol Treatments per 1,000;	in both <21 and full samples, MML associated with fewer marijuana admissions but dispensaries and home cultivation associated with more marijuana

First Author (year)	Sample	Age group considered	Cannabis policy evaluated	Specific dimensions of the policy evaluated	Measures of Cannabis Use	Measures of Alcohol Use	Key findings
							specific pain rules from analysis due to collinearity with other dimensions; no specific pain rules from analysis due to collinearity with other dimensions between specific pain rules from analysis due to collinearity with other dimensions MML and specific pain rules from analysis due to collinearity with other dimensions admissions for <21 or full sample; positive associations between alcohol admission and dispensaries in <21 sample and between alcohol admissions and dispensaries, registries and home cultivation in full sample
Pacula et al. (2013) (**NBER working paper) continued**	NLSY97 1997–2008 data	<21 and total sample (although NLSY sample 12-17 in 1997, so lack coverage of ages in a given year)	MML	Laws concerning (1) registry, (2) dispensaries, (3) home cultivation, and (4) whether allow MM for non-specific pain. Exclude non-specific pain rules from analysis due to collinearity with other dimensions	% use any marijuana past 30 days, % used marijuana 16+ days in past 30, % used 21+ in past 30	% use any alcohol past 30 days, % used alcohol 16+ days in past 30, % used 21+ in past 30	in the <21 sample, no association between MML and any or heavy marijuana use but positive association between home cultivation and heavy marijuana use; in the full sample, negative association between MML and PM marijuana use and between registries and PM marijuana use and positive association between dispensaries and PM marijuana use; no association between MML and alcohol use; positive associations between alcohol use and home cultivation in <21 and full samples and between alcohol use and dispensaries in full sample; negative association between alcohol use and registries in <21 and full samples
Pacula et al. (2013) (**NBER working paper) continued**	YRBS 1993–2009 data	High school Grades 9-12	MML	Laws concerning (1) registry, (2) dispensaries, (3) home cultivation, and (4) whether allow MM for non-specific pain. Exclude non-specific pain rules from analysis due to	% used marijuana in past 30 days	% used alcohol in past 30 days	no association between MML and PM marijuana use; negative association between home cultivation and PM marijuana use; no overall association between MML and alcohol use; negative associations between alcohol use and both

First Author (year)	Sample	Age group considered	Cannabis policy evaluated	Specific dimensions of the policy evaluated	Measures of Cannabis Use	Measures of Alcohol Use	Key findings
				collinearity with other dimensions collinearity with other dimensions			dispensaries and home cultivation
Salomonsen-Sautel et al. (2013)	FARS 1994-2011 data	all, controlling for proportion of drivers 21-24 years of age	MML	Commercialization of MM that took place after Ogden memo and changes in Colorado rules that involved lifting limit on number of patients a caregiver could aid.	Proportion of drivers involved in fatal crash testing positive for marijuana	Proportion of drivers involved in fatal crashes with BAC 0.08%	No evidence of the effects of medical cannabis commercialization on proportion of drivers testing positive for alcohol. Evidence of increase in proportion of drivers testing positive for marijuana after medical cannabis commercialization.
Wen et al. (2015)	NSDUH 2004-2012 data	Examined 12-20 and 21+ separately (although also looked at other possible cut points (18, 25, 30)).	MML	Examined MML as a dichotomous variable, but also ran models examining effects of laws on (1) non-specific pain, (2) patient registries, (3) retail dispensaries, and (4) home cultivation	1) any use in prior month, 2) 20+ days of use in prior month, 3) days of use in past 30 among users, 4) initiation in prior year, and 5) dependence in prior year according to DSM-IV criteria	1) number of drinks in PM, 2) frequency of binge drinking days in PM, 3) abuse/ dependence during PY according to DSM-IV criteria, 4) used both marijuana and alcohol and binge drank in prior month, and 5) used marijuana while drinking alcohol (i.e., on the same occasion) during prior month	For ages 12-20: no evidence of any effect on any measure of alcohol use; for ages 21+: no effect on number of drinks in PM or alcohol abuse/dependence, but more frequent binge drinking and higher likelihood of both marijuana use and binge drinking in PM and of simultaneous use of cannabis and alcohol. For specific dimensions of MML: no consistent effect of patient registry or allowance for retail dispensaries, consistent and significant effect of the "non-specific pain" provision on increasing marijuana use and binge drinking and simultaneous use of marijuana and alcohol.
Reiman (2009)	Users of a medical cannabis dispensary in Berkely, CA (N=350)	Ages 18 through 81 (mean = 39.4) years of age	N/A	N/A but within the context of MML	PM cannabis use, any and frequency	PM alcohol use, any and number of days, and treatment history	Over half of the participants were current drinkers. 40% reported substituting cannabis for alcohol.
Richmond et al. (2015)	SBIRT screened patients who reported cannabis use from health care	Ages 18 through 94 (mean age = 36.8) years of age	N/A	Whether a medical marijuana card holder	number of days using cannabis in the	ASSIST screen for severity of alcohol risk	Cardholders had higher frequency of cannabis use and lower odds of moderate/high risk of

First Author (year)	Sample	Age group considered	Cannabis policy evaluated	Specific dimensions of the policy evaluated	Measures of Cannabis Use	Measures of Alcohol Use	Key findings
	facilities in Denver, CO in study period (N=2030) facilities in Denver, CO in study period (N=2030)				PM and risky use		alcohol use than non-cardholders (i.e., those without access to state legalized medical cannabis)
Mason et al. (2015)	two cohorts from community sample of 238 students in Washinton State 2011, 2012	9th grade students, longitudinal	RML	passage of RML	any PM cannabis use	any PM alcohol use	cohort experiencing RML change prior to 9th grade data collection relatively more likely to use marijuana compared to likelihood of using alcohol than younger cohort that had not experienced the law change

Notes: MML= Medical Marijuana Legislation; RML= Recreational Marijuana Legislation; Decrim=Decriminalization of marijuana; PM=past month; PY=past year; TF=traffic fatalities; BAC=blood alcohol concentration; CAS=College Alcohol Study; DAWN=Drug Abuse Warning Network; FARS=Fatal Accident Report System; MTF=Monitoring the Future; NHSDA=National Household Survey of Drug Abuse; NLSY=National Longitudinal Study of Youth; TEDS=Treatment Episodes Data System; YRBS=Youth Risk Behavior Survey.