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ABSTRACT

The Public Health Effects of Legalizing Marijuana

Thirty-six states have legalized medical marijuana and 14 states have legalized the use of marijuana for recreational purposes. In this paper, we review the literature on the public health consequences of legalizing marijuana, focusing on studies that have appeared in economics journals as well as leading public policy, public health, and medical journals. Among the outcomes considered are: youth marijuana use, alcohol consumption, the abuse of prescription opioids, traffic fatalities, and crime. For some of these outcomes, there is a near consensus in the literature regarding the effects of medical marijuana laws (MMLs). As an example, leveraging geographic and temporal variation in MMLs, researchers have produced little credible evidence to suggest that legalization promotes marijuana use among teenagers. Likewise, there is convincing evidence that young adults consume less alcohol when medical marijuana is legalized. For other public health outcomes such as mortality involving prescription opioids, the effect of legalizing medical marijuana has proven more difficult to gauge and, as a consequence, we are less comfortable drawing firm conclusions. Finally, it is not yet clear how legalizing marijuana for recreational purposes will affect these and other important public health outcomes. We will be able to draw stronger conclusions when more post-treatment data are collected in states that have recently legalized recreational marijuana.

JEL Classification: I1, H7, K42

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1. *Introduction*

Figure 1 shows the number of articles related to the public health consequences of legalizing marijuana appearing in economics journals and leading public policy, public health, and medical journals during the period 2013-2020. Only 4 articles on this topic were published in 2013. By the next year, the total count had more than doubled. By 2020, there were over 140 published articles relating to the legalization of marijuana and public health.[1]

Clearly, interest in the public health consequences of marijuana legalization, at least among academics, is not waning, nor does it seem likely to wane any time soon. One reason for this continued interest is that policymakers and voters have been very active on the marijuana legalization front. During the period 2010-2020, 23 state medical marijuana laws (MMLs) went into effect and 12 state recreational marijuana laws (RMLs) went into effect. According to recent public-opinion polls, two out of three Americans favor the legalization of marijuana (Gurley 2019; Lopez 2019).[2] Given this level of support, it seems likely that more states will legalize marijuana in upcoming years. Several U.S. senators have recently said that they will push to pass a marijuana reform bill in 2021 to end the federal prohibition. (Nunley 2021).

Another reason why this literature has been growing so rapidly is that a wide variety of public health outcomes are readily available at the state-year level. Moreover, measuring MMLs (and, to a lesser extent RMLs) appears, at first blush, to be straightforward: the use of marijuana for medical purposes is either legal or it is not, allowing researchers to estimate standard difference-in-differences regression models without having to contend with the fact that not all MMLs are created

[1] The counts in Figure 1 are based on the journals listed in Combes and Linnemer (2010), the *American Journal of Health Economics*, *American Journal of Public Health, Pediatrics*, *Health Affairs*, *JAMA*, *JAMA Internal Medicine*, *JAMA Psychiatry*, and *JAMA Pediatrics*.

[2] Americans also now perceive marijuana as less harmful than alcohol and most other drugs (De Pinto 2019). Support for legalizing marijuana has been steadily growing since the late 1990s (Jones 2019).

equal. When deciding which studies to include in this review and which results are credible, we pay special attention to whether the authors carefully thought about how best to measure legalization and its effects. We also pay close attention to how much identifying variation is available. Too often in this literature, only a few policy changes can be leveraged, raising the possibility of spurious or non-generalizable estimates.

Producing accurate, unbiased estimates of the effects of marijuana legalization is of obvious importance to the making of sound policy. For instance, although the initial push to legalize the use of marijuana for medicinal purposes was not in response to the opioid epidemic, several studies have produced credible evidence of a negative relationship between MMLs and deaths involving opioids (Bachhuber et al. 2014; Powell et al. 2018), and politicians across the ideological spectrum have referred to these studies when explaining their support for legalizing both medical and recreational marijuana (Sfondeles 2018; Wang 2018; Taylor 2019). Not only do published estimates appear to inform the complicated process of crafting policy, but decisions at the state and local levels ultimately determine whether legalization affects just a small portion of the population—for instance, those who are suffering from cancer or diseases that affect the immune system (e.g., multiple sclerosis)—or whether it means that everyone over 21 years of age gains access.

If producing accurate estimates is important, then interpreting and conveying these estimates to a wider audience is equally important. Most policymakers have never heard of a difference-in-differences regression model, have no idea what an event study is, and do not care whether state-specific linear time trends were included on the right-hand side of the estimating equation. They count on the academic community to effectively communicate which studies should be taken seriously and which should be ignored. Given the large (and growing) number of studies on the legalization of marijuana, and the fact that many of these studies appear in the medical and public health literatures (which place less emphasis on credible causal identification strategies), the role of interpreter has taken on added significance.

We begin our review of the literature by providing readers with some background information and institutional details on MMLs and RMLs. We then discuss the effects of legalization on consumption and price. The subsequent six sections correspond to what we consider to be the most pressing public health issues related to legalization. Specifically, based on published research and a handful of notable (and publicly available) working papers, we try to gauge the effects of legalization on the following outcomes:

1. Youth marijuana use
2. The use of other substances, including alcohol, opioids, and tobacco
3. Mental health
4. Traffic fatalities
5. Workplace health
6. Crime

For each of these outcomes, we provide a table summarizing results from the relevant publications.[3] These tables include information on the data and identification strategy used, the main findings, and any important heterogeneity by type of law (e.g., MML vs. RML) or affected group (e.g., teenagers vs. adults). Our goal is to, as best we can, avoid phrases such as "the evidence

[3] In the tables provided below, we generally avoid listing unpublished working papers, but make the following three exceptions: Dills et al. (2017), Hollingsworth et al. (2020), Smart and Doremus (2021). Our sense is that these papers have already proven to be as influential as many of the published works we cite. Smart and Doremus (2021) is an updated version of the previously circulated paper by Smart (2015).

is inconclusive" and the "jury is still out" while still being careful not to overreach. The final section summarizes what we know and provides direction for future research.

2. *Background*

California became the first state to legalize medical marijuana in 1996, when voters passed the Compassionate Use Act. Under this Act, patients, upon recommendation from a physician, can possess and cultivate marijuana for medicinal use without fear of being arrested or fined. Patients also have the option of designating a "primary caregiver," who can legally possess and cultivate marijuana on their behalf.

Since 1996, 35 additional states and the District of Columbia have legalized medical marijuana. The strictest MMLs prohibit home cultivation and require that patients have a serious health condition (e.g., Alzheimer's, cancer, HIV/AIDS, or multiple sclerosis); the only legal rout to obtaining marijuana is through state-licensed dispensaries, which are highly regulated and limited in number. The laxest MMLs permit home cultivation, allow patients to register based on medical conditions that cannot be objectively confirmed (e.g., chronic pain or nausea), and place fewer restrictions on dispensaries.

Colorado and Washington passed RMLs in November 2012, but the first recreational dispensaries in these states did not open until 2014 (Bush 2014; Ingold 2014). To date, a total of 15 states and the District of Columbia have passed RMLs, and voters in several other states appear poised to legalize the use of marijuana for recreational purposes (McNamara 2020). In Table 1, we report the effective dates for MMLs and RMLs adopted through 2021. Unlike MMLs, RMLs do not require a doctor's recommendation, nor do they require registration with state authorities; possession of a limited amount of marijuana (e.g., one or two ounces) by anyone 21 years of age or older is legal and purchases of marijuana can be made at recreational dispensaries simply by showing proof of age; residence within the state is not required. All but three RMLs allow marijuana to be grown at home.[4]

2.1. *The role of marijuana dispensaries and how (not) to measure their effect*

Dispensaries are an important feature of the medical and recreational marijuana landscape, but researchers have struggled with how to measure their influence.[5] Anderson et al. (2013) used data at the state-year level and a simple MML indicator (equal to 1 if the state had passed a MML and equal to 0 otherwise) on the right-hand-side of a difference-in-differences (DD) regression. This approach was criticized by Pacula et al. (2013, 2015), who, instead of using a single indicator, distinguished between MMLs that explicitly allowed dispensaries and those that did not. Pacula et al. (2013) argued that the opening of "legally protected" dispensaries facilitated access to, and the use of, marijuana. Subsequent researchers have taken up this same argument, including Pacula and Sevigny (2014), Powell et al. (2018), and Hollingsworth et al. (2020).

Our view, however, is that focusing on the legal status of dispensaries is almost guaranteed to produce misleading estimates. Comparing the medical marijuana programs in Colorado and New Jersey, both of which were coded by Pacula et al. (2013) as having legally protected dispensaries, illustrates the problem with adopting this focus.

Before the "Colorado green rush" in the summer of 2009, two dozen medical marijuana dispensaries were operating in Colorado, serving approximately 5,000 patients (Warner 2009); two years later, hundreds of new dispensaries had opened and almost 120,000 patients were registered

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[4] In Illinois, New Jersey, and Washington, home cultivation of recreational marijuana is prohibited. In Washington, D.C., home cultivation is allowed, but its RML prohibits the exchange of money, goods, or services for marijuana; transfers of up to an ounce of marijuana, however, are legal.

[5] The term "dispensary" refers to stores that are only allowed to sell to qualified medical marijuana patients and to stores that sell marijuana for recreational use.

with the state (Schuermeyer et al. 2014).[6] By the end of 2014, immediately before recreational sales began, medical marijuana patients in Colorado were being served by roughly 300 to 400 dispensaries (Schuermeyer et al. 2014; Mitchell 2018).

In New Jersey, enrollment in the medical marijuana program was initially restricted to patients suffering from a specific, "debilitating" illness and the scale of the program was much smaller than in Colorado.[7] The first New Jersey dispensary opened in December of 2012. Two years later, only two dispensaries were in operation and fewer than 4,000 patients were registered with the state; three years later, 5 dispensaries were in operation and fewer than 7,000 patients had registered.[8] In 2017, the year before the medical marijuana program was expanded (Corasaniti 2018), there were still only 5 dispensaries operating in New Jersey, serving a total of 24,000 registered patients.

Lumping the Colorado and New Jersey medical marijuana programs into one category (i.e., dispensaries legally protected) plasters over their stark differences in scale. It also ignores the fact that quasi-legal dispensaries (often called clinics, clubs, co-ops, collectives, or compassion centers) became commonplace in states such as Michigan, Montana, Oregon, and Washington after the Ogden memorandum was issued in October of 2009 (Haskell 2010; Johnson and Korn 2010; Keeping 2010; Rosevear 2010; Volz, 2010; Martin 2011; Crombie 2012; Smith 2020).[9] All of these

[6] Data on registered medical marijuana patients comes from the Colorado Department of Public Health and Environment (https://www.colorado.gov/pacific/cdphe/medical-marijuana-statistics-and-data).

[7] According to rules promulgated in November of 2011 by the New Jersey Department of Health and Senior Services, qualifying conditions included amyotrophic lateral sclerosis (Lou Gehrig's disease), cancer, HIV/AIDS, glaucoma, multiple sclerosis, seizure disorder, and severe muscle spasms.

[8] Data on registered medical marijuana patients comes from the New Jersey Department of Health (https://www.nj.gov/health/medicalmarijuana/).

[9] Under federal law, it is illegal to use, possess, cultivate, or sell marijuana. However, the Ogden memorandum, issued on October 19, 2009, directed United States attorneys not to "focus federal resources…on individuals whose actions are in clear and unambiguous compliance with existing state laws providing for the medical use of marijuana" (United States Department of Justice Archives 2017).

states were coded by Pacula et al. (2013) as not providing legal protections to dispensaries, yet their enrollment rates (i.e., registered medical marijuana patients per 100,000 population) were much higher than in states with state-licensed dispensaries such as Connecticut, Delaware, and New Jersey (Williams et al. 2016).[10] It is difficult to believe that access to marijuana (and, by extension, diversion from the medicinal to the recreational markets) was somehow more restricted in Montana--where, at its height, almost 3 percent of the population participated in the medical marijuana program--than in New Jersey. Even after the 2017 expansion of its medical marijuana program, only 0.6 percent of New Jersey residents were registered patients (Maziarz 2019).

2.2. *Alternative methods of distinguishing between MMLs*

Researchers interested in distinguishing between types of MMLs have to contend with the fact that there is simply no data on quasi-legal dispensaries in early adopting states such as Michigan, Montana, Oregon, and Washington. We do not know precisely when the first dispensaries opened in these states, nor do we know how many patients they served or how much product was dispensed, let alone how much was diverted to the recreational market.

Anderson et al. (2013) responded to this lack of data by distinguishing between two types of medical marijuana states: those that prohibited collective cultivation, also known as "group growing," and those that did not. These authors argued that by limiting caregivers to one patient and prohibiting them from establishing clinics, clubs, or collectives, states in the first category could

[10] Williams et al. (2016) compared enrollment rates as of October 2014 in "non-medical" versus "medicalized" programs. The first category included states such as California, Colorado, Oregon, Michigan, Montana, and Washington; the second category was entirely composed of programs that established licensed dispensaries (Connecticut, Delaware, Illinois, New Jersey, and Washington D.C.). These authors found that enrollment rates in medicalized programs were, on average, one-twentieth of those in nonmedical programs (58 per 100,000 population versus 1,030 per 100,000 population).

more readily enforce possession limits and identify illegal suppliers.[11] They found that the (negative) relationship between MMLs and traffic fatalities was strongest in states that permitted collective cultivation.[12] Smart and Doremus (2021) took a similar tack when estimating the effects of MMLs on youth marijuana use, distinguishing between states that allowed caregivers to serve multiple patients and those that did not.

Powell et al. (2018) distinguished between states that passed MMLs before 2010 and those that legalized medical marijuana during the period 2010-2013, arguing that the Ogden memo encouraged state lawmakers in the later-adopting states to impose stricter regulations. In practice, the pre- and post-2010 distinction roughly corresponds to the collective cultivation distinction used by Anderson et al. (2013). Every state that Anderson et al. (2013) described as allowing collective cultivation passed their MML prior to 2010; every MML adopted from 2010 to 2013 prohibited home cultivation.[13]

There is much less heterogeneity across RMLs than MMLs. All but three recreational marijuana states (Illinois, New Jersey, and Washington) allow home cultivation. In Washington, more than a year passed between the passage of the law and when the first recreational dispensaries opened. By contrast, existing medical marijuana dispensaries in Illinois were allowed to sell to

[11] Specifically, Anderson et al. (2013) categorized 6 states (Alaska, Hawaii, Maine, New Jersey, New Mexico, and Vermont) and the District of Columbia as prohibiting collective cultivation or prohibiting home cultivation altogether. Eight states were put in the collective cultivation category (California, Colorado, Michigan, Montana, Nevada, Oregon, Rhode Island, and Washington). Williams et al. (2016) described the programs in Alaska, Hawaii, Maine, New Mexico, and Vermont as "non-medical," but 2014 enrollment rates in these states were lower than in California, Colorado, Michigan, Oregon, and Washington. Enrollment rates in Montana plunged in 2011 after SB 423 was enacted, which replaced Montana's Medical Marijuana Act with "new requirements for cultivation, manufacture, and possession of marijuana for use by people with debilitating medical conditions" (O'Connell 2012, p. 1).

[12] Sabia et al. (2017) found that the (negative) relationship between MMLs and body weight was strongest in states that permitted collective cultivation.

[13] Home growing is allowed in Massachusetts under "specific hardship cases," but as of October of 2014, there were fewer than 200 certified patients in the entire state (https://www.mass.gov/lists/medical-use-of-marijuana-program-monthly-dashboards#2014-dashboards-).

recreational customers immediately after the law went into effect on January 1, 2020 (Berg 2020). Clearly, it is important to distinguish between when the law came into effect and the official start of sales in recreational marijuana states. However, given that home cultivation is allowed in all but three of these states, the possibility that supply increased before recreational sales began should not be dismissed.

3. *Legalization, Consumption, and Price*

3.1. *Marijuana Consumption*

In theory, the legalization of marijuana should increase both its supply and demand, unambiguously leading to an increase in consumption. Estimating the effect of legalization on consumption is, however, complicated by data availability. At least three national surveys provide estimates of marijuana use among American teenagers over time (Monitoring the Future, the National Survey on Drug Use and Health, and the Youth Risk Behavior Survey), but only two, the National Survey on Drug Use and Health (NSDUH) and, more recently, the Behavioral Risk Factor Surveillance System (BRFSS), ask adults about their marijuana use.

Studies using NSDUH data to estimate of the effect of legalization on the use of marijuana by adults include Harper et al. (2012), Wen et al. (2015), and Hollingsworth et al. (2020). It should be noted, however, that the Substance Abuse and Mental Health Services Administration (SAMHSA) is not allowing access to the pre-2002 NSDUH microdata due to a change in survey design, precluding researchers from examining the effects of legalization in early-adopting states such as California, Colorado, Oregon, and Washington.[14] Presumably, the effect of legalizing

[14] Starting in 2002, NSDUH respondents were compensated $30, leading to a marked increase in participation rates. Due to this development and a change in sample weighting procedures, SAMHSA claims that data collected from 2002 and beyond cannot be validly compared to pre-2002 data (Substance Abuse and Mental Health Data Archive n.d.).

medical marijuana on adult use was larger in these states than in later-adopting states with stricter, more medicalized programs and fewer patients.

Adopting a DD approach and state-level data from the NSDUH's Small Area Estimation (SAE) files for the period 2002-2009, Harper et al. (2012) found no evidence of a relationship between MMLs and marijuana consumption among adults. By contrast, using a similar empirical approach and data from the SAE files for the period 2001-2017, Hollingsworth et al. (2020) found that MMLs were associated with a 4 to 7 percent increase in past-month adult marijuana use, while recreational sales were associated with a 30 percent increase in past-month adult marijuana use. Finally, using data from the restricted-access individual-level NSDUH data for the period 2004-2012, Wen et al. (2015) found that MMLs were associated with a 14 percent increase in past-month adult marijuana use.

In 2016, BRFSS surveys began including a marijuana use question in their "optional module," which states can elect to use.[15] States, however, have been allowed to tack on their own "state-added" questions to the survey for over a decade (Everson et al. 2019), which are not edited or evaluated by the CDC (Office of Disease Prevention and Health Promotion 2020). Using BRFSS data at the individual-month level, Ambrose et al. (forthcoming) examined the effect of recreational dispensaries on marijuana use among adults in Washington state. They found that a 33 percent reduction in driving time to the nearest recreational dispensary (e.g., from 30 to 20 minutes) was associated with a 5 percent increase in the probability of past-month marijuana use among individuals ages 18 and over. For young adults (i.e., 18- through 26-year-olds), a 33 percent reduction in driving time was associated with a 9 percent increase in the probability of past-month marijuana use.

[15] As of 2019, only 13 states asked BRFSS respondents about their marijuana use (Everson et al. 2019).

As an alternative to self-reports, Chu (2014) used data on arrests for marijuana possession as an outcome, which are available at the city level from the FBI's Uniform Crime Reports (UCR). Among male adults for the period 1988-2008, he found that MML-adoption was associated with a 9-12 percent increase in the ratio of marijuana to total arrests and a 14-16 percent increase in the ratio of marijuana to drug-possession arrests.[16]

Conyers and Ayres (2020) leveraged a unique natural experiment to assess the effects of medical marijuana dispensaries on marijuana overuse. In August of 2012, licenses for medical marijuana dispensaries in Arizona were allocated based on the results of a lottery conducted by the Department of Health Services. Lottery winners were allowed to open a dispensary, while losers were forced to wait. Conyers and Ayres (2020) found that emergency department (ED) visits involving marijuana went up among residents living nearby newly opened dispensaries. After 4 years, ED visits involving marijuana were 45 percent higher among residents of zip codes with newly opened dispensaries as compared to residents of zip codes without. The authors noted, however, that residents could have traveled between zip codes to purchase marijuana, which likely biased this estimate toward zero.

3.2. *Price*

The effect of legalization on the price of marijuana depends on whether the supply response is larger than the demand response (or vice versa). Anderson et al. (2013) examined the effect of MMLs on state-level prices using data from *High Times* magazine for the period 1990-2011. Each issue of *High Times* contains a section, "Trans High Market Quotations," in which readers from across the country provide information (e.g., price, amount purchased, and strain) on their marijuana

[16] Chu (2015) found similar results when he focused on the period 1992-2011.

purchases. These authors found that MML adoption was associated with a 25-30 percent reduction in the median per-ounce price of high-quality marijuana (e.g., high-grade Californian sinsemilla) in the 4th full year after legalization, which suggests the supply response to legalization outweighs the demand response. Anderson et al. (2013), however, only observed an average of 7.5 purchases per state-year and could not distinguish between illegal transactions and sales made at medical marijuana dispensaries.[17]

The reduction in price documented by Anderson et al. (2013) is consistent with complaints from law enforcement authorities of large-scale diversion from the medicinal to the recreational market in early-adopting states (Wagner and Dolan 2012; Light et al. 2015; Wong et al. 2016; Flaccus 2018).[18] There is no evidence, at least to our knowledge, of large-scale diversion in late-adopting states with strict controls on dispensaries, growers, and patients.

4. *Legalization and Youth Marijuana Use*

During the 1970s, 12 states decriminalized marijuana, reducing criminal sanctions for possessing small amounts of marijuana intended for personal consumption (Model 1993). Although early research produced little evidence that decriminalization affected youth marijuana use, these

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[17] The *High Times* data do not distinguish between purchases from dispensaries and purchases from dealers on the street, but it is not clear whether law enforcement treated these types of purchases differently. According to Hunt and Miles (2015, p. 177):

> While laws in the early years were clear about home cultivation, they were silent or ambiguous about the legality of obtaining marijuana from third-party vendors, such as dispensaries or collective arrangements. The silence in the laws made the lines between legal medical markets and illegal recreational markets blurry, and the ambiguity led to significant confusion and attention by law enforcement.

Anderson et al. (2013) compared *High Times* price data for 2011-2012 with price data posted online by 84 dispensaries across 7 states. In California, Michigan, Nevada, and Washington, the prices charged by dispensaries were statistically equivalent to those reported in *High Times*. In Arizona, Colorado, and Oregon, the prices charged by dispensaries were significantly lower than those reported in *High Times*.

[18] There is also evidence that the potency of marijuana seized by law enforcement officials increased in these states (Sevigny et al. 2014).

studies were generally based on research designs that cannot be considered credible from a causal perspective.[19] More recently, using data from Monitoring the Future for the period 1977-2015, Dills et al. (2017) found no evidence to suggest that decriminalization encourages marijuana use among teenagers.[20]

Today, marijuana use among 8th and 10th graders appears to be on the rise, and organizations such as the American Academy of Pediatrics (AAP) are concerned that legalization is contributing to this phenomenon (Zimlich 2019). Even as support for legalizing marijuana for medicinal and recreational purposes grows (De Pinto 2019; Dezenski 2020), the AAP remains firm in its opposition, citing evidence that marijuana use adversely affects adolescent brain development, particularly areas of the prefrontal cortex, which control judgment and decision-making (AAP 2015, Zimlich 2019).

Table 2 summarizes the literature attempting to gauge the relationship between marijuana legalization and youth marijuana use. With one exception, the studies described in Table 2 employ a DD empirical strategy, where identification is based on within-state variation in legalization.[21] Half of the 12 studies listed in Table 2 used data from the Youth Risk Behavior Surveys (YRBS), four used data from the National Survey on Drug Use and Health (NSDUH), two used data from the National Longitudinal Survey of Youth 1997 (NLSY97), two used data from the Treatment Episode Data Set (TEDS), and one used data from Monitoring the Future (MTF). Among the survey-based data sets (YRBS, NSDUH, NLSY97, and MTF), the YRBS is arguably preferred because of its

[19] See MacCoun et al. (2009) for a review of these studies.

[20] Unlike previous researchers, Dills et al. (2017) also leveraged policy variation from a second wave of decriminalization, which began with Nevada in 2002. Currently, 26 states have decriminalized the possession of marijuana (NORML 2021).

[21] Table 2 does not list studies that only report results from single-state analyses (e.g., Lynne-Landsman et al. 2013; Cerdá et al. 2017; Miller et al. 2017; Dilley et al. 2019) or are based on random-effects regression models (e.g., Hasin et al. 2015; Cerdá et al. 2020).

relatively large state-year cell sizes and the extended time period for which it is available. Starting in 1991 and still ongoing, the YRBS allows researchers to estimate the effects of MMLs adopted in the mid- to late 1990s. A disadvantage to using the YRBS is that it does not contain information on high school dropouts.[22]

Consistent with the results of a meta-analysis conducted by Sarvet et al. (2018), there is little evidence to support the hypothesis that MMLs have increased youth marijuana use on either the intensive or extensive margins.[23] In fact, some researchers have found a negative association between MMLs and youth marijuana use. For instance, using data from the YRBS for the period 1999-2015, Coley et al. (2019) found that MML adoption was associated with a 9 percent decrease in the odds of past-month marijuana use among teens. Using NSDUH data for the period 2002-2009, Harper et al. (2012) found that MMLs were associated with an 8 percent decrease in past-month marijuana use among teenagers.

A recent working paper by Smart and Doremus (2021) provides the only credible evidence of which we are aware that MMLs can lead to increased use among teenagers. Using data from the NSDUH for the period 2002-2013, these authors leveraged the fact that, after the Ogden memorandum was issued, dispensaries proliferated and registration rates soared in medical marijuana states with "loose production limits," defined as those that allowed caregivers to serve multiple patients. Marijuana use among 12- through 17-year-olds also increased in these states after the Ogden memorandum was issued. As noted above, the Ogden memorandum, issued in 2009,

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[22] The TEDS is collected annually by state substance abuse agencies and is based on admissions to publicly funded drug treatment facilities, providing researchers information on individuals on the margin of excessive consumption (Pacula et al. 2015). A downside to the TEDS is that admissions could, in part, reflect endogenous changes in enforcement and referrals from the criminal justice system.

[23] Sarvet et al. (2018, p. 113) included studies in their meta-analysis that are based on state random-effects regression models but acknowledged that models controlling for state fixed effects are "more rigorous."

deprioritized the prosecution of medical marijuana users and producers.[24] Smart and Doremus (2021) found no evidence that MML adoption affected youth marijuana use.

Three papers described in Table 2 explore the relationship between RMLs and youth marijuana use. Drawing on YRBS data for the period 1993-2017, Anderson et al. (2019) found that RMLs were associated with an 8 percent decrease in the odds of any marijuana use among high school students and a 9 percent decrease in the odds of frequent marijuana use among high school students.[25] These results are consistent with the argument that it is more difficult for teenagers to access marijuana when drug dealers are replaced by licensed dispensaries that require proof of age.

Using YRBS data for the period 1999-2017, Coley et al (forthcoming) found no evidence of a relationship between RMLs and past-month marijuana use, although RML adoption was associated with a small reduction in the frequency of use. By contrast, using NSDUH data for the period 2001-2017, Hollingsworth et al. (2020) found that legalizing recreational marijuana was associated with a 13-15 percent increase in past-month marijuana use among 12- through 17-year-olds.[26]

It is, however, important to keep in mind that the estimates such as those reported by Anderson et al. (2019), Hollingsworth et al. (2020), and Coley et al. (forthcoming) are based on limited geographic and temporal variation in RML adoption. Researchers will have to wait until

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[24] Marijuana use among 12- through 17-year-olds decreased in states with loose production limits after the Cole memorandum was issued on June 29, 2011. Smart and Doremus (2021, p. 8) observed that "in the months leading up to and following the [Cole] memo, the Drug Enforcement Administration stepped up raids on medical marijuana producers."

[25] Anderson, Rees, and Sabia (2020) produced similar, although less precise, estimates of the association between the opening of the first recreational dispensary and marijuana use among high school students. Specifically, they found that the start of recreational sales was associated with a 5 percent decrease in the odds of any marijuana use, and a 14 percent decrease in the odds of frequent marijuana use.

[26] See also Ambrose (2020), who found that proximity to a recreational marijuana dispensary was unrelated to youth marijuana use in Washington state. Hao and Cowan (2020) found no evidence that RML adoption by Colorado and Washington affected youth marijuana use in bordering states. Using data from the National College Health Assessment survey for the period 2008-2018, Bae and Kerr (2020) found a positive association between RMLs and marijuana use among undergraduates ages 18 through 26.

more years of post-legalization data become available before drawing firm conclusions about the relationship between RMLs and youth marijuana use.

5. *Legalization and the Use of Alcohol, Opioids, Tobacco, and Other Substances*

Opponents of legalization often refer to negative externalities associated with marijuana consumption (e.g., crime or traffic accidents) when making a case for prohibition. In the presence of such externalities, utility maximizing individuals will consume more marijuana than is socially optimal. However, the legalization of marijuana may also affect the consumption of other substances, some of which impose substantial costs on society (Miron and Zwiebel 1995). The policy-relevant question is empirical because theory alone cannot determine whether marijuana is a complement to or a substitute for other substances.

5.1. *Alcohol*

Early empirical studies on the relationship between marijuana and alcohol produced mixed results. Pacula (1998a) and Williams et al. (2004) found a negative association between state beer taxes and marijuana consumption, suggesting complementarity. By contrast, Chaloupka and Laixuthai (1997) and Saffer and Chaloupka (1999) found that marijuana decriminalization reduced the consumption of alcohol, suggesting the two goods are substitutes. All of these studies, however, relied on cross-sectional policy variation, which could simply reflect unobserved factors at the state level such as preferences and attitudes.[27]

[27] Early studies in the tobacco literature relied on cross-sectional cigarette tax variation and, consequently, greatly overstated the effect of taxes on smoking behavior (DeCicca et al. forthcoming). Relying on cross-sectional variation to estimate the effects of decriminalizing or legalizing marijuana likely produces equally misleading results.

The legalization of marijuana represents a well-defined natural experiment and, as such, has afforded researchers an opportunity to further explore the relationship between marijuana and alcohol.[28] Table 3 summarizes the literature on marijuana legalization and alcohol consumption. Of the 12 studies described in Table 3, seven used survey data on self-reported alcohol consumption (Anderson et al. 2013; Wen et al. 2015; Sabia et al. 2017; Johnson et al. 2018; Andreyeva and Ukert 2019; Dragone et al. 2019; Alley et al. 2020), four used alcohol sales data (Anderson et al. 2013; Baggio et al. 2020; Veligati et al. 2020; Miller and Seo forthcoming), two used data on alcohol-related hospital admissions (Kelly and Rasul 2014; Conyers and Ayres 2020), and one used data on alcohol-related traffic fatalities (Anderson et al. 2013).[29]

The survey-based studies provide strong evidence of substitutability between marijuana and alcohol.[30] For instance, using data from the Behavioral Risk Factor Surveillance System and DD regression models, Anderson et al. (2013) and Sabia et al. (2017) found that MMLs are associated with sharp reductions in past-month alcohol use and binge drinking. Using a similar empirical strategy and data from the National College Health Assessment-II for the period 2008-2018, Alley et al. (2020) found that RML adoption leads to a 6 percent decrease in binge drinking among college students. Leveraging the distance to the Washington state border in a DD spatial regression discontinuity design, Dragone et al. (2019) found that the legalization of recreational marijuana reduced binge drinking among NSDUH respondents by roughly 20 percent.

Estimates based on alcohol sales data are generally consistent with those based on self-reported alcohol consumption. Drawing upon Nielsen retail scanner data for the period 2006-2015

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[28] Other studies have used the minimum legal drinking age to test whether marijuana and alcohol are substitutes or complements (DiNardo and Lemieux 2001; Crost and Guerrero 2012; Crost and Rees 2013).

[29] The study by Anderson et al. (2013) is discussed below in Section 7.

[30] Hollingsworth et al. (2020) also provided evidence of a negative relationship between the legalization of marijuana for medicinal purposes and alcohol consumption.

and focusing on contiguous-border county pairs, Baggio et al. (2020) found that MMLs reduced retail sales of alcoholic beverages by 12 percent. Miller and Seo (forthcoming) used Nielsen scanner data from Washington state to estimate a flexible demand system at the county-month level. These authors found that legalizing recreational marijuana led to a 5 percent decrease in alcohol sales.[31]

Finally, Kelly and Rasul (2014) and Conyers and Ayres (2020) used data on alcohol-related hospital admissions. Kelly and Rasul (2014) explored what happened when Lambeth, a borough of London, experimented with marijuana "depenalization." Under the Lambeth experiment, which took effect in July of 2001 and lasted for one year, possession of small quantities of marijuana was no longer a prosecutable offense. These authors found large reductions in alcohol-related hospital admissions among male 15- through 24-year-olds, providing evidence that this group treated alcohol and marijuana as substitutes. There was no evidence that depenalization had an effect on hospital admissions among older males. Conyers and Ayres (2020) found no evidence that the opening of medical marijuana dispensaries in Arizona affected emergency department visits involving alcohol.[32]

5.2. *Opioids*

The opioid epidemic, a uniquely American phenomenon, can be thought of as being divided into two stages. In the first stage, which lasted through 2010, prescription anti-pain medications

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[31] Relatedly, using data form the Consumer Expenditure Interview Survey for the period 2005-2018, Lu (2020) found a positive relationship between RML adoption and household expenditures on alcohol. This result, however, was sensitive to the inclusion of state-specific linear time trends. In general, there is no consensus in this literature as to whether state-specific trends belong on the right-hand side of the regression model. For instance, Wen et al. (2015) included them in all of their estimations, while Powell et al. (2018) and Hollingsworth et al. (2020) did not. We recognize the possibility, raised by Wolfers (2006) and others, that the state-specific trends are using up exogenous variation in treatment. Given this possibility, we view estimates based on a standard DD regression model with state-specific liner trends as lower bounds.

[32] Using state-level data on poisoning mortality from the Center for Disease Control's Wide-ranging Online Data for Epidemiologic Research, Smart and Doremus (2021) found a negative relationship between the share of adults registered as medical marijuana patients and alcohol-related poisoning deaths among 45- through 64-year-olds. See also Wang et al. (2019), who found that RMLs reduced internet search volume and advertising effectiveness for alcohol.

such as OxyContin and Vicodin were responsible for the majority of deaths (Dart et al. 2015); in the second stage, heroin- and fentanyl-related deaths surged (Iwanicki et al. 2018), quickly overtaking mortality attributable to prescription opioids and prompting lawmakers across the country to consider the adoption of alternative policies, including the legalization of recreational marijuana (Sfondeles 2018; Voelker 2018; Wang 2018; Taylor 2019).[33]

In Table 4, we summarize the literature on marijuana legalization and the use of opioids. Bachhuber et al. (2014) were the first researchers to propose a link between MMLs and the abuse of prescription opioids. Using a DD regression model and data at the state-year level for the period 1999-2010, they found that MML adoption was associated with a 25 percent reduction in opioid-related mortality. When state-specific linear trends were included on the right-hand side of the regression, MML adoption was associated with an 18 percent reduction. These results suggest that marijuana and opioids are being treated as substitutes, at least by some segment of the population.

The study by Bachhuber et al. (2014) has been quite influential, and estimates produced by subsequent scholars seem to reaffirm their basic result.[34] For instance, Bradford and Bradford (2016, 2017, 2018) and Bradford et al. (2018) explored the association between MMLs and prescription opioids. We will focus on Bradford and Bradford (2018) because it was published in a well-regarded economics journal (*Journal of Law and Economics*) and illustrates the shortcomings of the other three, which were published in the medical/public health literature. All of the papers used similar empirical strategies and came to similar conclusions.

Bradford and Bradford (2018) used data at the physician level for the period 2010-2015 to examine the association between MMLs and prescribing to Medicare Part D participants. During

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[33] Drug overdose deaths involving opioids have increased more than five-fold since 2000, exceeding 65,000 by 2017 (Ahmad et al. 2019).

[34] As of March 2021, Bachhuber et al. (2014) has nearly 700 citations according to Google Scholar.

this period, 10 states and the District of Columbia adopted MMLs. The Arizona MML was the least strict among these. It was adopted in November, 2010 and tens of thousands of patients were quickly enrolled. The other 10 MMLs analyzed by Bradford and Bradford (2018) were relatively strict and the medical marijuana programs they created were small-scale: in 2015, only 38,000 patients were enrolled across these 10 programs. This same year there were, by comparison, 7,814,000 Medicare Part D participants in the 9 treated states and the District of Columbia, or more than 200 Medicare Part D participants per registered medical marijuana patient.[35, 36]

Bradford and Bradford (2018) found that MML adoption was associated with a 4-5 percent reduction in pain-related prescriptions under Medicare Part D. It is possible that the behavior of 38,000 medical marijuana patients could have been the sole driver of this reduction, but, given its magnitude, this strikes us as unlikely. Because Bradford and Bradford (2018) did not have access to enough years of data for an event-study analysis, we do not know whether the parallel trends

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[35] The Bradford and Bradford (2108) estimates were identified from MMLs adopted by Arizona, Connecticut, Delaware, D.C., Illinois, Maryland, New Hampshire, New York, Massachusetts, Minnesota, and New Jersey. By December of 2015, there were 88,000 medical marijuana patients registered in Arizona (https://azdhs.gov/licensing/medical-marijuana/index.php), while Arizona Medicaid Part D enrollment was approximately 790,000 (Hoadley et al. 2015). If we include Arizona in our calculations, there were 68 Medicare Part D participants per registered medical marijuana patients in 2015.

[36] Data on Medicare Part D enrollment come from Hoadley et al. (2015). The number of registered medical marijuana patients in Connecticut comes from the Connecticut Department of Consumer Protection (https://portal.ct.gov/DCP/Medical-Marijuana-Program/Medical-Marijuana-Statistics); the number of registered medical marijuana patients in Delaware comes from the Delaware Division of Public Health (https://www.dhss.delaware.gov/dhss/dph/hsp/medmarhome.html); the number of registered medical marijuana patients in Washington, D.C. comes from D.C. Health (https://dchealth.dc.gov/node/823802); the number of registered medical marijuana patients in Illinois comes from the Illinois Department of Public Health (http://dph.illinois.gov/topics-services/prevention-wellness/medical-cannabis/annual-report); the number of registered medical marijuana patients in Massachusetts comes from the Massachusetts Department of Public Health (https://www.mass.gov/doc/mmj-dashboard-december-2015/download); the number of registered medical marijuana patients in Minnesota comes from the Minnesota Department of Health (https://www.health.state.mn.us/people/cannabis/docs/about/update0416.pdf); and the number of registered medical marijuana patients in New Jersey comes from the New Jersey Department of Health (https://www.nj.gov/health/medicalmarijuana/). The New York medical marijuana program did not begin registering patients until December 23, 2015 (https://health.ny.gov/press/releases/2015/2015-12-23_patient_registration.htm). The New Hampshire medical marijuana program did not begin registering patients until November 24, 2015 (https://www.nhpr.org/post/why-long-wait-medical-marijuana-nh#stream/0). The Maryland medical marijuana program did not begin registering patients until April, 2017 (Wood 2017).

assumption held or whether the prescription "effects" became stronger over time as enrollment in these 11 medical marijuana programs grew.

Wen and Hockenberry (2018) and McMichael et al. (2020) provide additional evidence that the legalization of marijuana reduces opioid prescribing.[37] For instance, Wen and Hockenberry (2018) examined the association between MMLs and opioid prescribing among Medicaid recipients for the period 2011-2016. During this period, 8 states (Connecticut, Delaware, Illinois, Maryland, New Hampshire, New York, Massachusetts, and Minnesota) legalized medical marijuana. These authors found that MML adoption was associated with a 6 percent reduction in opioid prescribing among Medicaid recipients, while RML adoption was also associated with a 6 percent reduction in opioid prescribing. Carrieri et al. (2020) examined the effects of a 2016 Italian law permitting the cultivation of marijuana with low levels of THC ("light cannabis"). Exploiting temporal and geographic variation in when this new product became available across Italy, these authors found evidence of substitution away from prescription opioids.

Shover et al. (2019) revisited the link between MMLs and opioid-related mortality by replicating and then extending the Bachhuber et al. (2014) study. Specifically, Shover et al. (2019) confirmed the negative association between legalization and opioid-related mortality found by Bachhuber et al. (2014) for the period 1999-2010, but found that this association became positive when data for the years 2011-2017 were added to the analysis.[38]

[37] See also Ozluk (2017), who found that MML adoption was associated with a reduction in spending on prescription opioids among young adults.

[38] When Shover et al. (2019) included state-specific linear trends on the right-hand side of their regression, the negative association between MMLs and opioid-related mortality for the period 1999-2010 became statistically insignificant. Likewise, the positive association between MMLs and opioid-related mortality for the period 1999-2017 became statistically insignificant when state-specific linear trends were included. Powell et al. (2018) found a negative and statistically significant association between MMLs and mortality involving prescription opioids for the period 1999-2010. This association shrank and became statistically insignificant when three extra years of data (2011-2013) were included in the analysis. Powell et al. (2018) also examined the effect of MMLs on mortality involving prescription opioids and/or heroin. Again, these authors found evidence to suggest that this effect was strongest during the period 1999-2010. See also Smart and Doremus (2021), who found a negative relationship between medical marijuana market size and opioid-analgesic poisoning deaths among 45- through 64-year-olds.

This reversal in sign has several plausible explanations. It is possible that the negative association between MML adoption and opioid-related mortality is spurious and fragile. Another plausible explanation is that the reversal in sign is due to the changing nature of the opioid epidemic. Perhaps marijuana and prescription pain medications are substitutes, but marijuana and heroin are not. Finally, as noted above, MMLs adopted after the Ogden memo was released tended to be stricter and, according to Williams et al. (2016), more "medicalized." Given how few patients were typically enrolled in post-2010 medical marijuana programs, it would not be surprising if the association between MMLs and opioid-related mortality was markedly weaker during this period, although this does not explain why the association would become positive.

Using data at the county level, Smith (2020) examined the relationship between the opening of medical marijuana dispensaries and opioid-related mortality during the period 1999-2014. Importantly, Smith (2020) made an effort to identify the opening dates of quasi-legal medical marijuana dispensaries operating as clubs, collectives, and compassion centers in states such as Michigan, Montana, Nevada, Oregon, and Washington. He found that there was, on average, a 7-11 percent reduction in mortality involving prescription opioids when the first dispensary opened, a result that is consistent with the hypothesis that marijuana and prescription opioids are, on net, substitutes. The estimated effect of dispensary openings on mortality involving prescription opioids was largest among white non-Hispanic men. This latter result is particularly notable because Case and Deaton (2017) have documented a substantial increase in "deaths of despair" (i.e., deaths due to drugs, alcohol, or suicide) among white non-Hispanics without a college degree since 1998. Case and Deaton (2017, p. 399) argued that the substantial increase in deaths of despair among lesseducated white non-Hispanics means that polices designed to reduce opioid use are "an obvious priority."[39]

More evidence that legalization can help curb the opioid epidemic comes from Shover et al. (2019) and Chan et al. (2020). Both of these studies examined the association between RMLs and opioid-related mortality drawing on state-level data for the years 1999-2017. During these years, 8 states adopted RMLs (Alaska, Colorado, California, Maine, Nevada, Oregon, Massachusetts, and Washington), but the first recreational sales in California, Maine, and Massachusetts began after 2017, and the first recreational dispensary in Nevada opened on July 1, 2017, only 6 months before the end of the study period.

Shover et al. (2019) found that RML adoption was associated with a 14 percent decrease in opioid-related mortality. Although this estimate was not statistically significant at conventional levels, the lack of precision is not surprising given how few RMLs were adopted during the period under study. Chan et al. (2020) found that the legalization of recreational sales was associated with a 16-21 percent decrease in opioid-related mortality. Chan et al. (2020), however, excluded 23 states and the district of Columbia from their main analysis, making it difficult to compare their results to those of Shover et al. (2019).[40]

The obvious next step in this literature is to examine the relationship between RMLs and the use of opioids (as opposed to opioid-related mortality or the prescribing of opioids). The issue here

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[39] See also Chu (2015), who found evidence that MML adoption reduced admissions to substance abuse treatment programs for heroin. By contrast, Conyers and Ayres (2020) found that the opening of medical marijuana dispensaries in Arizona may have increased ED visits involving opioids among nearby residents.

[40] Moreover, Chan et al. (2020) reported separate RML implementation and sales estimates. The implementation estimates were consistently positive but generally not statistically significant. To obtain the effect of legalizing recreational marijuana on opioid-related mortality, the implementation and sales estimates reported by Chan et al. (2020) must be added together. With or without state-specific linear trends, the sum of the implementation and sales estimates is statistically indistinguishable from zero and equal to -0.04. The negative association between recreational sales and opioid-related mortality was robust to the inclusion of state-specific linear trends.

is lack of data. As far as we know, the only data source that could be used to investigate this question is the NSDUH and, for now at least, SAMHSA is putting onerous restrictions on researchers who want access to the individual-level NSDUH data. For instance, because the wording of the question on the use of prescription pain medications changed between 2014 and 2015 (and because the automated skip pattern leading to this question changed), SAMHSA insists that researchers conduct separate analyses for the periods 2004-2014 and 2015-2018.[41]

5.3. *Tobacco*

According to the CDC, smoking tobacco is the leading cause of preventable death in the world; on average, smokers die 10 years earlier than their non-smoking counterparts (Centers for Disease Control and Prevention 2020). By contrast, marijuana use has been linked to substantially lower mortality and morbidity risks, and marijuana is regularly used as a treatment for several serious health conditions (Hall et al. 2005; Fiz et al. 2011; Ware et al. 2010; Choi et al. 2019).

Evidence on the relationship between marijuana and tobacco comes from studies of cross-price effects (Pacula, 1998a, 1998b; Chaloupka et al. 1999; Farrelly et al. 2001; Anderson, Matsuzawa, and Sabia 2020). Pacula (1998a, 1998b) and Chaloupka et al. (1999) found a negative association between cigarette prices and youth marijuana use, but relied on cross-state variation, leaving their estimates potentially biased due to unobserved factors at the state level, such as anti-

41 SAMHSA regularly publishes estimates of marijuana and the abuse of prescription painkillers that are based on the NSDUH data. These estimates are available from the NSDUH's Small Area Estimation (SAE) files for two-year periods only (e.g., 2010-2011, 2012-2013), and are therefore of limited value to researchers. Wen et al. (2015), who had access to individual-level NSDUH data for the period 2004-2012, found no evidence that MMLs were related to the abuse of prescription painkillers. This result is not consistent with the negative association between MMLs and prescribing found by Bradford and Bradford (2016, 2017, 2018), Bradford et al. (2018), Wen and Hockenberry (2018), and McMichael et al. (2020), although it should be noted that there is evidence of NSDUH respondents systematically underreporting painkiller abuse and the use of illicit drugs such as cocaine, heroin, and marijuana (Gfroerer et al. 2012; Johnson 2014). Rates of alcohol, marijuana, and heroin use among teenagers in the NSDUH are lower than rates from other nationally representative data sets such as Monitoring the Future and the Youth Rick Behavior Surveys (Gfroerer et al. 2012).

smoking sentiment.[42] Using data from the National Household Survey on Drug Abuse (NHSDA) for the period 1990-1996 and leveraging within-state variation, Farrelly et al. (2001) found that raising cigarette taxes reduced the intensity of marijuana use among individuals 12-20 years of age. Using data from the YRBS for the period 1991-2017, Anderson, Matsuzawa, and Sabia (2020) found little evidence to suggest that marijuana use among teenagers was sensitive to cigarette taxes.

In Table 5, we summarize six studies on the relationship between marijuana legalization and tobacco use. Two of these studies found evidence that legalization for medicinal purposes reduces tobacco use (Choi et al. 2019; Anderson, Matsuzawa, and Sabia 2020),[43] one found evidence that recreational legalization reduces tobacco use (Miller and Seo forthcoming),[44] and the remaining three found no evidence of an association between legalization and tobacco use (Andreyeva and Ukert 2019; Alley et al. 2020; Veligati et al. 2020).

We view Choi et al. (2019), who drew on three separate data sets to estimate the relationship between MMLs and cigarette consumption among adults, as the highest quality study in this literature. Using DD regressions and data from the NSDUH, BRFSS, and the Current Population Survey Tobacco Use Supplements (CPS-TUS), Choi et al. (2019) found that MML adoption was associated with a reduction in cigarette use of 1 to 1.5 percentage points. These authors also found that MMLs reduced the number of cigarettes consumed conditional on already being a smoker. A supplementary synthetic control analysis produced results there were consistent with those obtained from the DD regressions.

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42 Pacula (1998a) estimated the effect of state cigarette taxes on youth marijuana use, while Pacula (1998b) and Chaloupka et al. (1999) estimated the effect of cigarette prices inclusive of taxes.

43 Anderson, Matsuzawa, and Sabia (2020) found that MML adoption was associated with reductions in both cigarette and marijuana use among teenagers, suggesting that teenagers treat these two substances as complements. Hollingsworth et al. (2020) found that the legalization of medical marijuana reduced tobacco consumption among both adolescents and adults.

44 Wang et al. (2019) found that RML adoption increased internet search volume and advertising effectiveness for tobacco.

5.4. *Other Substances*

The gateway hypothesis suggests that legalizing marijuana should, in a causal sense, increase the use of other, "harder" drugs. In Table 6, we summarize the literature on marijuana legalization and the use of hard drugs such as cocaine. We also summarize the literature on marijuana legalization and other drugs such as anti-depressives and sedatives.

Evidence on the relationship between MML adoption and the use of cocaine comes from Chu (2015) and Wen et al. (2015). These authors found that legalizing medical marijuana had no appreciable effects on admissions to substance abuse treatment for cocaine (Chu 2015) or self-reported cocaine use (Wen et al. 2015).[45] Similarly, Conyers and Ayres (2020) found no evidence that living near a medical marijuana dispensary affected cocaine-related ED visits.

Evidence on the relationship between legalizing marijuana for recreational purposes and the use of cocaine comes from Hollingsworth et al. (2020). Using NSDUH data for the period 2001-2017, Hollingsworth et al. (2020) found that RML adoption was associated with an increase in the use of cocaine, but this association was sensitive to specification choice. They concluded that, "[t]his fact coupled with the event study that shows a decaying effect following year three from adoption raises concerns about the validity of the cocaine estimates" (p. 18).

Kelly and Rasul (2014) examined what happened to hospital admissions involving hard drugs (cocaine, crack, crystal-meth, heroin, LSD, MDMA, and methadone) when Lambeth, a borough of London, "depenalized" possession of small quantities of marijuana. These authors found that, among men, hospital admission rates involving hard drugs increased by 40-100 percent when the Lambeth police temporarily stopped prosecuting marijuana possession cases. By contrast, there was no evidence that female drug use was sensitive to the depenalization of marijuana.

[45] Additional evidence on the relationship between legalizing marijuana and the use of cocaine comes from a recent working paper by Leung (2019). Using data from the Healthy Mind Study Questionnaires for the period 2009-2017, Leung (2019) found a negative association between MML adoption and cocaine use among college students.

Intriguingly, there is evidence that sales of over-the-counter sleep aids went down in Colorado with the opening of recreational dispensaries (Doremus et al. 2019), suggesting that marijuana is being used to relieve anxiety and treat insomnia. This result is consistent with those of Bradford and Bradford (2018), who found that MML adoption was associated with a 6-8 percent reduction in anxiety-related prescriptions and a 7-9 percent reduction in sleep-related prescriptions under Medicare Part D.[46]

Finally, Carrieri et al. (2020) examined the effects of a 2016 Italian law permitting the cultivation of marijuana with low levels of THC ("light cannabis"). Exploiting temporal and geographic variation in the availability of this product, these authors found strong evidence of substitution away from a variety of prescription drugs, including sedatives, anti-depressants, and anti-psychotics.

6. *Legalization and Mental Health*

Randomized control trials provide evidence that cannabinoids, compounds found in marijuana, can improve sleep quality and help alleviate the symptoms of posttraumatic stress disorder (National Academies of Sciences, Engineering, and Medicine 2017, pp. 121-124); animal studies show that, at low doses, synthetic cannabinoid injections can have a potent antidepressant effect (Jiang et al. 2005; Bambico et al. 2007). Although epidemiologists have shown that marijuana use is positively associated with the symptoms of depression, this association likely reflects self-medication or is due to difficult-to-measure confounders at the individual level such as personality (National Academies of Sciences, Engineering, and Medicine 2017, p. 289 and pp. 307-310).[47]

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[46] See also Ozluk (2017), who found that MML adoption was associated with less spending on prescription sedatives among the elderly.

[47] Consuming marijuana as a teenager is also associated with an elevated risk of developing psychosis and schizophrenia in adulthood (Levine et al. 2017; Ladegard et al. 2020).

Legalizing marijuana could, in theory, have indirect effects on mental health through the use of other substances. There is accumulating evidence that restricting where and when alcohol is sold can reduce suicides (Kõlves et al. 2020).[48] Obversely, gaining access to alcohol through, for instance, reaching the minimum legal drinking age is associated with an increase in the likelihood of committing suicide (Carpenter 2004; Carpenter and Dobkin 2009). If, as most studies based on well-defined natural experiments suggest, alcohol and marijuana are treated as substitutes (DiNardo and Lemieux 2001; Crost and Guerrero 2012; Anderson et al. 2013; Kelly and Rasul 2014; Baggio et al. 2020; Miller and Seo forthcoming), then legalizing marijuana could improve mental health and ultimately reduce suicides.

Table 7 summarizes the results of three studies on the relationship between legalizing marijuana and suicide. Anderson et al. (2014) obtained suicide counts at the state-year level from the National Vital Statistics System (NVSS) for the period 1990–2007. Estimating a DD regression model, they found that MML adoption was associated with an 11 percent reduction in suicides among male 20- through 29-year-olds, and a 9 percent reduction in suicides among male 30- through 39-year-olds. Estimated effects on female suicide rates, while of similar magnitude, were less precise and sensitive to specification changes such as controlling for state-specific linear time trends.

The Anderson et al. (2014) results were revisited by Grucza et al. (2015). Using NVSS data for the period 1990-2010 and a DD regression model, these authors found a negative and statistically significant association between MML adoption and suicides among male 20- through 39-year-olds. However, when they controlled for spending on mental health, rates of the uninsured, cigarette taxes, and various anti-tobacco policies, this association, although still negative, became

[48] The use of opioids is also associated with depression and suicidal behaviors (Scherrer et al. 2015; Davis et al. 2020), but, to our knowledge, there is no evidence of a causal link.

statistically insignificant at conventional levels.[49] These authors concluded that legalizing marijuana for medicinal purposes "does not appear to lead to changes in suicide rates" (Grucza et al. 2015, p. 71). Grucza et al. (2015) did not report estimates of the association between MMLs and suicides for the period 1990-2007.[50]

Bartos et al. (2020) used a synthetic control approach to examine the effect of California's MML, passed in 1996, on suicides. These authors found that, relative to its synthetic control, the suicide count in California fell after medical marijuana was legalized. Specifically, they found that legalization was associated with 399 fewer suicides per year, a reduction of approximately 11 percent.[51] In addition, Bartos et al. (2020) found that MML adoption was associated with fewer firearm-related suicides, but its relationship with non-firearm-related suicides, although negative, was not statistically significant at conventional levels.

Two recent working papers, which are not listed in Table 7, have used outcomes other than suicide to explore the effects of MMLs on mental health (Kalbfuß et al. 2018; Leung 2019). Drawing on BRFSS data for the period 1993-2015, Kalbfuß et al. (2018) examined MML adoption and the number of "not good" mental health days in the past month.[52] These authors found that MML adoption was associated with a 5 percent reduction in the number of "not good" mental health days. MMLs that allowed home cultivation and/or included pain as a qualifying condition

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[49] According to Anderson et al. (2014), legalizing medical marijuana was associated with a 3.5 percent reduction in the odds of suicide among male 20- through 29-year-olds (p-value = 0.39). Legalizing medical marijuana was associated with a 5.6 percent reduction in the odds of suicide among male 30- through 39-year-olds (p-value = 0.14).

[50] In an unpublished working paper, Singer et al. (2020) found that RML adoption was associated with a 5 percent reduction in the suicide rate among male 40- through 49-year-olds.

[51] In California, there were a total of 3,694 suicides in 1995 and 3,712 suicides in 1994 (Singh et al. 1996; Anderson et al. 1997).

[52] BRFSS respondents are asked, "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?"

were associated with larger reductions in the number of days respondents described their mental health as "not good."

Leung (2019) analyzed individual-level data on U.S. college students from the Healthy Mind Survey (HMS) for the period 2009-2017. HMS respondents are asked nine questions designed to screen for depression and gauge its severity; they are also asked seven questions designed to screen for several anxiety disorders, including post-traumatic stress disorder.[53] Leung (2019) found little evidence that MML adoption affected the mental health of HMS respondents. However, as noted above, MMLs passed in the post-Ogden period were stricter (more "medicalized") than those passed before; given that Leung's data began in 2009, the year in which the Ogden memo was issued, his null findings are perhaps not surprising.[54]

With the exception of Singer et al. (2020), none of the studies cited in this section considered the effects of RMLs. The next step in this literature is to estimate the effect of RML adoption on measures of mental health aside from suicides. Researchers might also leverage the opening and closing of recreational dispensaries to better understand how legalization affects mental health.

7. *Legalization and Traffic Fatalities*

Opponents of legalizing marijuana argue that it will lead to more traffic accidents and fatalities (Sabet 2013, pp. 72-76; Evans 2019). This argument is not without merit. Simulator experiments show that drivers under the influence of tetrahydrocannabinol (THC), the active

[53] Specifically, HMS respondents are given the Patient Health Questionnaire and the Generalized Anxiety Disorder Screener. In addition, they are asked whether they had suicidal thoughts in the past year and whether they had been diagnosed by a professional as suffering from a mental illness.

[54] See also Rylander et al. (2014), who examined the county-level association between medical marijuana patients and suicide rates in Colorado during the period 2004-2010. Because Rylander et al. (2014) did not find a positive and statistically significant association between these variables, they concluded that "[t]he legalization of medical marijuana may not have an adverse impact on suicide rates" (Rylander et al. 2014, p. 269).

ingredient in marijuana, have trouble "road tracking" (i.e., maintaining the correct road position), although these same studies provide evidence of compensatory decreases in speed (Hartman and Huestis 2013; Bondallaz et al. 2016; Vollrath and Fischer 2017); on-road experiments conducted under normal traffic conditions confirm that THC has a negative, albeit moderate, effect on driving performance (Robbe 1998; Ramaekers et al. 2000).

As discussed above (in Section 5.1), there is strong evidence that legalizing marijuana discourages the use of alcohol, especially binge drinking (Anderson et al. 2013; Kelly and Rasul 2014; Sabia et al. 2017; Dragone et al. 2019; Baggio et al. 2020; Miller and Seo forthcoming). If driving under the influence of marijuana is safer than driving under the influence of alcohol, then the reduced-form effects of legalizing marijuana on traffic accidents and fatalities could, in theory, be negative.[55] Moreover, because alcohol is often consumed in public (e.g., restaurants and bars) while public marijuana consumption is generally illegal, legalization could improve road safety even if driving under the influence of marijuana is just as dangerous as driving under the influence of alcohol (Anderson et al. 2013).[56]

Table 8 summarizes the literature on marijuana legalization and road safety. Using state-level data from the Fatality Analysis Reporting System (FARS) for the period 1990–2010, Anderson et al. (2013) were the first researchers to estimate the effects of MML adoption on traffic fatality rates. These authors found that legalizing marijuana for medicinal purposes was associated with a 9-10

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[55] See the review by Sewell et al. (2009). These authors compared the effects of driving under the influence of marijuana with the effects of driving under the influence of alcohol. Legalization could also impact traffic safety through the use of other substances, including opioids.

[56] Specifically, Anderson et al. (2013, p. 359) argued that, because marijuana consumption typically takes place at home, "designating a driver for the trip back from a restaurant or bar becomes unnecessary, and legalization could reduce traffic fatalities even if driving under the influence of marijuana is every bit as dangerous as driving under the influence of alcohol." In Alaska, Colorado, and Oregon, marijuana can be consumed in licensed private clubs and "social lounges" (Mickelson 2019). As these clubs become more popular (or their legal status changes outside of Alaska, Colorado, and Oregon), the relationship between marijuana consumption and traffic fatalities could change.

percent reduction in traffic fatalities. MMLs were associated with larger negative effects on traffic fatalities involving alcohol,[57] traffic fatalities on the weekends, and traffic fatalities at night. Fatal crashes on weekends and at nights are more likely to involve alcohol than those that occur on weekdays and during daylight hours (National Center for Statistics and Analysis 2019).

The negative association between MMLs and traffic fatalities has been confirmed by Cook et al. (2020), who used an identification strategy similar to that used by Anderson et al. (2013). Specifically, Cook et al. (2020) used city-level data from the FARS for the period 2010-2017 to examine the effects of state MMLs and ordinances decriminalizing marijuana. These authors found that MML adoption was associated with a 9 percent decrease in fatal crashes, while decriminalization was associated with a temporary increase in traffic fatalities involving young male drivers.[58]

Aydelotte et al. (2017), who used data from Colorado and Washington for period 2009-2015 and a DD approach, found no evidence of a relationship between the legalization of recreational marijuana and traffic fatalities. These authors, however, defined the post-treatment period as beginning in 2013, before recreational sales in Colorado and Washington actually began. Recreational sales in Colorado began on January 1, 2014, while recreational sales in Washington began on July 8, 2014 (Bishop-Henchman and Scarboro 2016).

Two recent studies have used a synthetic control approach to examine the effects of RMLs in Colorado and Washington (Hansen et al. 2020a; Santaella-Tenorio et al. 2020). Since the first

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[57] Anderson et al. (2013) considered two separate measures of alcohol-related traffic fatalities: the traffic fatality rate where at least one driver involved had a BAC > 0 and the traffic fatality rate where at least one driver involved had a BAC ≥ 0.10. Their results were similar regardless of how the alcohol-related traffic fatality rate was defined.

[58] Using data from the FARS and a regression model with state random effects, Santaella-Tenorio et al. (2017) found that MMLs were associated with an 11 percent reduction in traffic fatalities. Ellis et al. (2020) found that the legalization of medical marijuana reduced auto accident premiums; this effect was larger in areas with higher levels of pre-legalization driving under the influence. Among high school students, Dills et al. (2017) found no association between MMLs and self-reported involvement in past-year traffic accidents. By contrast, Smart and Doremus (2021) found a positive association between the share of adults registered as medical marijuana patients in a state and traffic fatalities among 15- through 20-year-old drivers.

recreational dispensaries opened in these states, marijuana sales have soared (Boesen 2020). Using data from the FARS for the period 2000-2016, Hansen et al. (2020a) found no evidence that RMLs impacted total or alcohol-related traffic fatalities. These authors speculated that the growth in recreational marijuana sales could have come at the expense of black-market and medicinal sales, leading to their null result (Hansen et al. 2020a, p. 664). Santaella-Tenorio et al. (2020), who analyzed an additional year of post-treatment data, concluded that the Colorado RML increased traffic fatalities. Traffic fatalities in Washington also increased after recreational sales began but this increase was comparable to the increase in its synthetic control, leading Santaella-Tenorio et al. (2020, p. 1066) to conclude that the "adverse unintended effects of RCLs [recreational cannabis laws] can be heterogeneous." It should be noted, however, that Hansen et al. (2020a) and Santaella-Tenorio et al. (2020) did not use the same set of matching variables to create their synthetic controls, and synthetic control estimates can be quite sensitive to the choice of matching variables (Minard and Waddell 2019).

8. *Legalization and Workplace Health*

Increasingly, concerns are being raised over the potential impact of legalizing marijuana on workplace safety (Goldsmith et al. 2015; Parnes et al. 2018; Freedman 2020). The American College of Occupational and Environmental Medicine recently stated that legalizing marijuana comes with "huge public and workplace health implications" and that "marijuana can cause impairment which will interfere with safe and acceptable performance in the workplace" (Industrial Safety and Hygiene News 2019, para. 3 and 4).[59]

[59] Legalization also raises new challenges for employers who maintain drug testing policies. Unlike alcohol, it is difficult to determine whether employees or applicants are using marijuana on the job or at home, making outright bans on using marijuana attractive from an employer's perspective. However, in some states, medical marijuana patients are legally protected in the workplace and disciplinary actions against them are considered discriminatory (Freedman 2020).

It is difficult to sign the relationship between legalization and workplace safety *a priori*. Marijuana use impairs short-term memory function, information processing, hand-eye coordination, and reaction times, all of which could reduce workplace safety (Ramaekers et al. 2004; Hall and Degenhardt 2009; Hartman and Huestis 2013; National Institute on Drug Abuse 2019). If, however, legalization discourages the consumption of alcohol, opioids, and other substances, then it could improve workplace safety and reduce on-the-job injuries and fatalities (Anderson et al. 2013; Bachhuber et al. 2014; Chu 2015; McMichael et al. 2020). Alcohol consumption at work is associated with substantial increases in the risk of injury (Ohsfeldt and Morrisey 1997; Ramirez et al. 2013), while non-habitual opioid use slows reflexes and impairs cognitive functioning (Zacny 1995).

In Table 9, we review five papers on marijuana legalization and outcomes related to workplace safety and the health of employees. The first of these is by Ullman (2017), who drew upon data from the March Current Population Survey (CPS) for the period 1992-2012. Using a DD regression at the individual-year level, Ullman (2017) found that MML adoption was associated with an 8 percent reduction in the likelihood of missing work due to a health issue; estimated effects were larger in medical marijuana states with lax supply-side restrictions, among full-time workers, and among middle-aged males (the group most likely to hold a medical marijuana card). Using state-level data from the Census of Fatal Occupational Injuries for the period 1992-2015, Anderson et al. (2018) found a negative association between MMLs and workplace fatalities among individuals ages 25-44. Consistent with Ullman's (2017) results, Anderson et al. (2018) found larger estimated effects for 25- through 44-year-olds in MML states that listed pain as a qualifying condition or allowed collective cultivation.[60]

[60] Ullman (2017) coded Arizona, California, Colorado, Michigan, Montana, Nevada, Oregon, and Washington as states with lax MMLs. These correspond to 8 out of the 9 states listed by Anderson et al. (2018) as allowing pain as a qualifying condition *and* collective cultivation. According to Anderson et al. (2018), Rhode Island listed pain as a qualifying condition and allowed collective cultivation, but Ullman (2018) coded Rhode Island as a "strict" MML state.

Nicholas and Maclean (2019) explored the effect of MMLs on the self-reported health and labor supply of adults 51 years of age and older. Using data from the Health and Retirement Study for the period 1992-2012, these authors found that MML adoption was associated with less pain and better overall health. They also found that MML adoption increased the hours of work supplied by older adults who were already in the labor force, and that these effects were strongest for those with a preexisting health condition that would qualify for legal medical marijuana use.[61]

As an alternative to using data on workplace fatalities or self-reported health, Ghimire and Maclean (2020) used information on workers' compensation (WC) claims from the Annual Social and Economic supplement to the CPS, arguing that MMLs could affect WC claims through improving symptom management. With access to legal medical marijuana, an injured or sick worker "may be better able to treat symptoms and hence return to work more quickly or possibly not require a work separation to recuperate" (Ghimire and Maclean 2020, p. 420). Alternatively, if marijuana is an inferior treatment option or compromises the effectiveness of other, ongoing treatments, then WC claiming could increase with MML adoption. Consistent with the argument that marijuana can help with symptom management, these authors found that MMLs were associated with fewer WC claims and less income from WCs.[62]

To our knowledge, the only published research on RMLs in this area comes from Maclean et al. (2021), who estimated the effects of RML adoption on new applications and allowances for Social Security Disability Insurance (SSDI) and Supplemental Security Income (SSI).[63] Using data for the

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[61] Nicholas and Maclean (2019) found no evidence of an association on the extensive margin. Using data from the Current Population Survey Outgoing Rotation Groups, Sabia and Nguyen (2018) found no evidence that MML adoption was related to the employment, hours of work, or wages of working-age adults.

[62] In an unpublished working paper, Abouk et al. (2021) found that RML adoption was negatively associated with WC benefit receipt.

[63] SSDI gives benefits to disabled persons who worked in a covered job for at least 5 of the 10 years prior to application. SSI is a means-tested benefit that is available to low-income disabled or blind persons who do not meet the qualifications for SSDI or whose SSDI benefits are sufficiently low (Maclean et al. 2021).

period 2001-2019, these authors found that RML adoption increased applications for both SSDI and SSI, but had no appreciable effect on allowances. One possible explanation for this pattern of results is that post-RML SSDI and SSI applications are more likely to be identified as illegitimate by Social Security Administration case reviewers.

9. *Legalization and Crime*

Based on urine samples at the time of booking, marijuana is the most commonly used drug among arrestees in the United States (Pacula and Kilmer 2003; Baran 2011; Burke 2019).[64] More generally, there exists a strong positive association between marijuana consumption and criminal behavior (Bennett et al. 2008). This positive correlation has been interpreted as evidence of causality but could be due to unobserved factors at the individual level such as personality, risk tolerance, or time preferences. In an effort to isolate the effect of using marijuana on crime, researchers have generally relied on two approaches: (i) leveraging the legalization or decriminalization of marijuana as a well-defined natural experiment, or (ii) exploiting the spatial and temporal variation from openings and closings of marijuana dispensaries.

In theory, legalizing marijuana could shrink the black market and reduce its attendant violence or free up police resources, allowing law enforcement officials to reallocate their efforts toward reducing non-drug crime (Miron and Zwiebel 1995; Adda et al. 2014). Also, if legalization lowers the price of marijuana--and demand is sufficiently inelastic--then crimes committed to finance marijuana consumption could fall.[65] On the other hand, increased marijuana use could lead

[64] Self-reported data on past-month drug use from the NSDUH and the Arrestee Drug Abuse Monitoring (ADAM) Program confirm that marijuana is the most popular illicit substance among arrestees (Lattimore et al. 2014).

[65] Anderson et al. (2013) found that MML adoption was associated with a 25-30 percent reduction in the median per-ounce price of high-quality marijuana in the 4th full year after legalization, suggesting that the supply response to legalization outweighs the demand response. Using data on over 23,000 marijuana transactions from priceofweed.com, Davis et al. (2016) estimated the price elasticity of demand to be between -0.67 and -0.79.

to more violent behavior directly through a psychopharmacological effect or indirectly through a "gateway" effect (Pacula and Kilmer 2003; Morris et al. 2014).[66]

Table 10 reviews the literature on marijuana legalization and crime.[67] Of the nine studies listed, three use data from the Uniform Crime Reports and estimate standard DD models in which state-level variation in MMLs is exploited (Morris et al. 2014; Huber III et al. 2016; Chu and Townsend 2019). None of these studies found evidence to suggest that MMLs have increased crime. Morris et al. (2014) found that MML adoption was associated with fewer robberies, larcenies, and burglaries, while Huber III et al. (2016) found that MML adoption was associated with fewer homicides and assaults. Chu and Townsend (2019) found little evidence to suggest that MMLs affected either property or violent crimes.[68]

Using a difference-in-difference-in-differences regression model and data at the county-year level from the UCR and Supplementary Homicide Reports (SHR) for the period 1994-2012, Gavrilova et al. (2019) compared the effect of legalizing medical marijuana in U.S. states on the Mexican border with its effect in non-border states.[69] By allowing production in the United States, MMLs could create competition for incumbent Mexican drug trafficking organizations (DTOs), reducing their revenues and disincentivizing them from investing in rent-protecting violent activity (Miron and Zwiebel 1995; Gavrilova et al. 2019). Consistent with this argument, Gavrilova et al.

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[66] Whether marijuana use heightens or inhibits aggression is up for debate, and likely depends on the characteristics of the user (Bushman 1990; Pacula and Kilmer 2003; Ostrowsky 2011).

[67] In related work, Klassen and Anthony (2019) found that the legalization of marijuana for recreational purposes reduced the amount of illicit cultivation in Oregon national forests.

[68] Within California, Chu and Townsend (2019) found that MMLs reduced both property and violent crimes by approximately 20 percent. Among Monitoring the Future respondents, Dills et al. (2017) found no evidence that MMLs affected self-reports of arson, property damage, or weapon carrying on school property. However, these authors found a positive relationship between MML adoption and self-reported petty crime.

[69] Gavrilova et al. (2019) also estimated models in which MML adoption was interacted with the distance of the county centroid to the U.S.-Mexico border.

(2019) found that MML adoption by states on the Mexican border was associated with a 13 percent reduction in violent crime. Using a DD and spatial regression discontinuity design and UCR data for the period 2010-2014, Dragone et al. (2019) estimated the effect of legalizing recreational marijuana in Washington on crime near the Washington-Oregon border. Their results suggest that Washington's RML led to a 15-30 percent reduction in rapes and a 10-20 percent reduction in thefts on the Washington side of the border relative to the Oregon side.[70]

With large amounts of high-grade marijuana and cash on hand, marijuana dispensaries provide criminals with a potentially lucrative target. Three studies listed in Table 10 rely on variation in dispensary openings or closings to estimate the relationship between having legal access to marijuana and crime (Brinkman and Mok-Lamme 2019; Burkhardt and Goemans 2019; Chang and Jacobson 2017). Using data from administrative records, Brinkman and Mok-Lamme (2019) and Burkhardt and Goemans (2019) estimated the effect of recreational marijuana dispensary openings on neighborhood-level crime in Denver, Colorado. Brinkman and Mok-Lamme (2019) found that the opening of a dispensary was associated with large reductions in nonviolent crime, while Burkhardt and Goemans (2019) found that dispensaries reduced hard drug- and alcohol-related crimes. Burkhardt and Goemans (2019) also found that dispensary openings were associated with an increase in vehicle break-ins within a mile of the dispensary's location.

Chang and Jacobson (2017) estimated the effect of a short-term mass closing of hundreds of medical marijuana dispensaries in Los Angeles, California. Contrary to the results reported in Burkhardt and Goemans (2019), Chang and Jacobson (2017) found that dispensary closures led to increased theft from vehicles in the area immediately around the dispensary. In a separate analysis, these authors found nearly identical effects related to restaurant closures, suggesting that a more

[70] Hansen et al. (2020b) found evidence that Oregon residents crossed the border to buy marijuana after recreational dispensaries opened in Washington, suggesting that Oregon counties on the Washington border may not be the appropriate control group.

general mechanism could be driving their observed dispensary estimates. Specifically, they hypothesized that retail establishments provide informal security through their customers and that "eyes upon the street" deter "dark alley" crimes (Chang and Jacobson 2017, p. 134).

Finally, Adda et al. (2014) explored what happened to crime when Lambeth, a borough of London, temporarily "depenalized" marijuana possession. These authors found that depenalization led to large increases in marijuana-related offenses (e.g., trafficking and intent to supply), but also that depenalization shifted police resources toward hard drug-related and nondrug crime, causing these offenses to fall by 9 percent.

10. *Conclusion*

In 2012, Colorado and Washington became the first states to legalize the use of marijuana for recreational purposes. At the time, there were several unknowns fueling the debate over legalization. Would it lead to more teenagers experimenting with marijuana? Would it encourage the use of alcohol? Would the opening of recreational dispensaries lead to more violent and property crimes? In the years since, researchers have worked diligently to answer these questions and considerable headway has been made. Meanwhile, new questions have come to the fore.

Youth marijuana use is the outcome that has perhaps received the most attention from researchers. Many of the studies appearing in public health and medical journals have employed identification strategies that economists would not deem credible from a causal perspective (e.g., Lynne-Landsman et al. 2013 and Dilley et al. 2019). Although their results have generally been consistent with the those produced using more sophisticated empirical strategies (Sarvet et al. 2018), we have chosen not to describe them. Their results could have just as easily gone the other way.

Table 2 lists a dozen studies that have employed a difference-in-differences (DD) design to examine the effects of medical marijuana laws on youth marijuana use. Almost without exception, and regardless of whether their focus was on early MMLs (Anderson et al. 2014) or MMLs passed after 2000 (Hollingsworth et al. 2020), there is little evidence that teenagers responded to the legalization of medical marijuana by increasing their consumption.

The evidence with regard to recreational marijuana and youth use is more equivocal. One study described in Table 2 provides evidence that RMLs reduced marijuana use among teenagers, although this estimated effect is modest in terms of magnitude (Anderson et al. 2019); two found no evidence of an effect (Hao and Cowan 2020; Coley et al. forthcoming); and one study found that legalizing marijuana for recreational purposes was associated with a substantial increase in past-month marijuana use among 12- through 17-year-olds (Hollingsworth et al. 2020). As more states legalize marijuana for recreational purposes and more years of post-treatment data become available in the Youth Risk Behavior Surveys, Monitoring the Future, and National Survey on Drug Use and Health, a clearer picture will presumably emerge.

One of the key unknowns in the debate leading up to Colorado and Washington passing their RMLs concerned the relationship between alcohol and marijuana (Escobedo and Spellman 2012; Johnson 2012; Livingston 2013). Although there was general agreement that, from a public health perspective, alcohol was the more harmful of the two substances, prominent experts argued that there was not enough evidence to determine whether they were substitutes or complements (Kilmer et al. 2010; Pacula and Sevigny 2014; Caulkins and Kilmer 2016).

Efforts to legalize medical and recreational marijuana have provided researchers with new opportunities to explore the relationship between alcohol and marijuana. The studies summarized in Table 3 generally support the hypothesis that young adults treat these two goods as substitutes. For instance, Anderson et al. (2013) and Sabia et al. (2017) found that legalizing medical marijuana reduced past-month alcohol use and binge drinking; Miller and Seo (forthcoming) found that legalizing recreational marijuana led to a 5 percent decrease in alcohol sales; and Kelly and Rasul

(2014) found large reductions in alcohol-related hospital admissions among male 15- through 24-year-olds after Lambeth, a borough of London, "depenalized" the possession of marijuana. These studies, which are described in Section 5.1, have, in our opinion, gone a long way towards settling the debate over whether alcohol and marijuana are complements or substitutes, at least among young adults.

The relationship between marijuana and opioids did not receive much attention from researchers and policymakers until the publication of Bachhuber et al. (2014). Bachhuber et al. (2014) found that that MML adoption was associated with a 25 percent reduction in opioid-related mortality, a result that made headlines (Healy 2014; Millman 2014). This result—coming when so many Americans were abusing, and being killed by, prescription opioids—also helped persuade key policymakers to support the legalization of marijuana (Sfondeles 2018; Wang 2018; Taylor 2019). Since the publication of Bachhuber et al. (2014), dozens of studies have examined the relationship between legalizing medical marijuana and various opioid-related outcomes, including mortality and prescribing. In general, they have found evidence of substitution (Powell et al. 2018; Carrieri et al. 2020; McMichael et al. 2020), but it is clear that more recent, "medicalized" MMLs have not had the same effect as those passed during the pre-Ogden period (Powell et al. 2018; Shover et al. 2019).

We reviewed only two studies examining the effect of legalizing recreational (as opposed to medical) marijuana on opioid-related outcomes (Table 4). Drawing on data for the years 1999-2017, during which time 5 states (Alaska, Colorado, Nevada, Oregon, and Washington), allowed the sale of recreational marijuana, both Shover et al. (2019) and Chan et al. (2020) found a negative association between RML adoption and opioid-related mortality. It is possible that RMLs will eventually help curb the opioid epidemic, but more time will have to pass (and more data will have to be collected) before any firm conclusions can be drawn.

In addition to reviewing the literature on the effects of marijuana legalization on alcohol consumption and opioid use, we summarized studies on tobacco use (Table 5) and the use of other substances (Table 6). In general, there is little evidence that legalization has encouraged the smoking of tobacco; if anything, it has discouraged its use. Similarly, an accumulating body of research suggests that MML adoption is associated with reductions in prescription medications for disorders such as depression, anxiety, and epilepsy.

Drivers under the influence of marijuana have trouble maintaining the correct road position (Bondallaz et al. 2016; Vollrath and Fischer 2017), but legalization could discourage drunk driving, which is unequivocally dangerous (Irwin et al. 2017). The legalization of marijuana could also affect road safety through other substances, including prescription opioids. Evidence from the reduced-form relationship between MMLs and traffic fatalities suggests that, on net, road safety improves when medical marijuana is legalized (Table 8). The best evidence on relationship between RMLs and road safety come from studies using a synthetic control approach (Hansen et al. 2020a; Santaella-Tenorio et al. 2020). However, this approach is sensitive to which matching variables are used (Minard and Waddell 2019), which could explain why these studies come to different conclusions: Hansen et al. (2020a) found no evidence that RMLs affected traffic fatalities in Colorado and Washington, while Santaella-Tenorio et al. (2020) concluded that Colorado's RML (but not Washington's RML) increased traffic fatalities. As more years of Fatality Analysis Reporting System data are made available from other recreational marijuana states, we will undoubtedly learn more about RMLs and road safety.

To date, only a small number of studies have examined the effects of legalizing marijuana on mental health and workplace safety. Their results are generally consistent with the argument that the public health consequences of legalizing marijuana are, on net, positive (Tables 7 and 9), but more work clearly needs to be done. In particular, we know little about the effects of legalizing marijuana on mental health outcomes other than suicide. Although the legalization of medical marijuana appears to reduce sickness-related absences and workplace injuries (Ullman 2017; Anderson et al. 2018; Nicholas and Maclean 2019), the precise mechanisms are unknown. Until these mechanisms are pinned down, it is premature to conclude that the legalization of recreational marijuana will have similar effects on workplace safety.

Finally, we reviewed nine studies on the relationship between legalization and crime (Table 10). Studies that examine the effect of MML or RML adoption provide strong evidence that legalization reduces non-drug crimes. For instance, Huber III et al. (2016) found that MML adoption led to fewer homicides and assaults, while Dragone et al. (2019) found that Washington's RML was associated with reductions in rapes and thefts. By contrast, studies of the effects of dispensary openings and closings have produced mixed results that require a more careful, nuanced interpretation. As the number of dispensaries grows, economists will want to gauge their localized effects on not only crime but also on the other outcomes reviewed. In general, there is a dearth of studies examining the effects of dispensaries, co-ops, and growers on neighborhood-level outcomes. We believe this is an area ripe for future researchers to explore.

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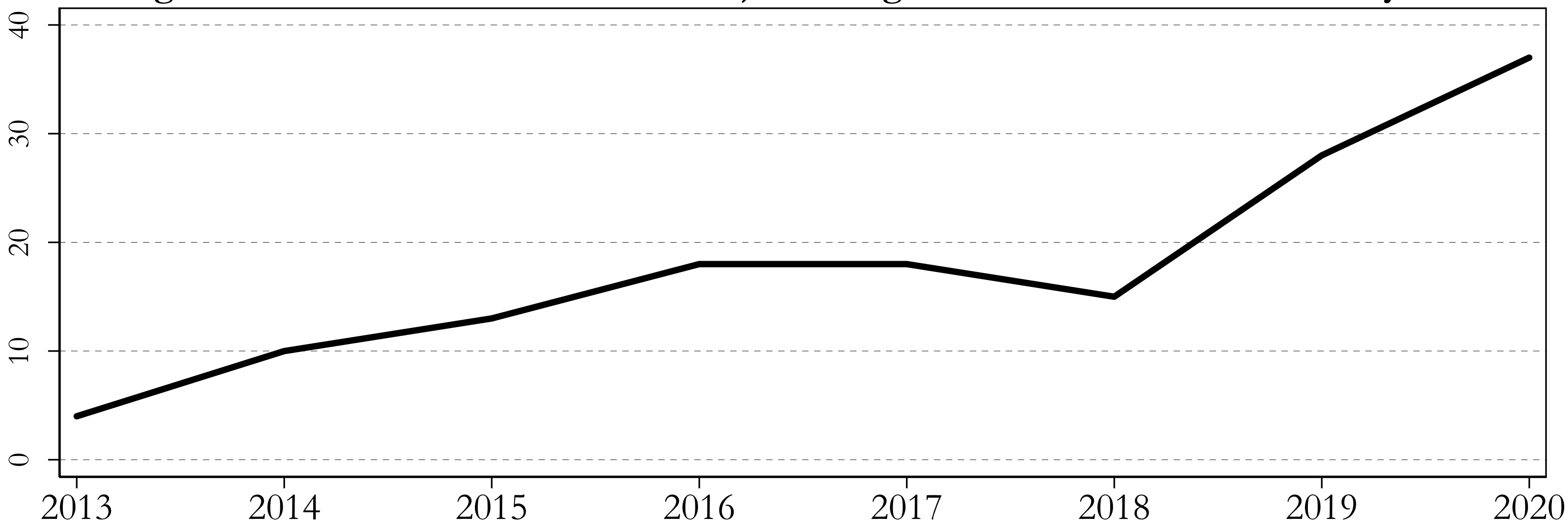
Figure 1. Publications Related to Marijuana Legalization and Public Health by Year



Notes: Yearly counts of publications related to marijuana legalization and public health are shown. In addition to articles in the journals listed by Combes and Linnemer (2010), articles published in the *American Journal of Health Economics*, *American Journal of Public Health*, *Health Affairs*, *JAMA*, *JAMA Internal Medicine*, *JAMA Pediatrics*, *JAMA Psychiatry*, and *Pediatrics* are included.

Table 1. Medical and Recreational Marijuana Laws, 1996-2021

	MML effective dates	RML effective dates	Recreational sales allowed
Alaska	3/4/1999	2/24/2015	10/29/2016
Arkansas	11/9/2016		
Arizona	4/14/2011	11/30/2020	
California	11/6/1996	11/9/2016	1/1/2018
Colorado	6/1/2001	12/10/2012	1/1/2014
Connecticut	8/20/2014[a]		
Delaware	6/26/2015[a]		
D. C.	7/30/2013[a]	2/26/2015	2/26/2015
Florida	7/26/2016[a]		
Hawaii	12/28/2000		
Illinois	11/9/2015[a]	1/1/2020	1/1/2020
Louisiana	8/6/2019[a]		
Maine	12/22/1999	1/31/2017	
Maryland	12/2/2017[a]		
Massachusetts	1/1/2013	12/15/2016	11/20/2018
Michigan	12/4/2008	12/6/2018	12/1/2019
Minnesota	7/1/2015[a]		
Mississippi	Not yet operational		
Missouri	10/17/2020[a]		
Montana	11/2/2004	1/1/2021	
Nevada	10/1/2001	1/1/2017	7/1/2017
New Hampshire	5/1/2016[a]		
New Jersey	12/6/2012[a]	2/22/2021	
New Mexico	7/1/2007		
New York	1/8/2016		
North Dakota	3/1/2019[a]		
Ohio	1/16/2019[a]		
Oklahoma	7/26/2018		
Oregon	12/3/1998	7/1/2015	10/1/2015
Pennsylvania	1/17/2018[a]		
Rhode Island	1/3/2006		
South Dakota[b]	Not yet operational		
Utah	3/2/2020[a]		
Vermont	7/1/2004	7/1/2018	
Virginia	10/17/2020[a]		
Washington	11/3/1998	12/6/2012	7/8/2014
West Virginia	8/22/2017[a]		

[a] Date on which first medical marijuana dispensary opened.
[b] South Dakota voters simultaneously approved the legalization of marijuana for medicinal and recreational purposes in November, 2020. However, on February 8, 2021, South Dakota's RML was determined by the state court as unconstitutional and therefore void and without effect (Clarkson and Soukhome 2021).

Table 2. Marijuana Legalization and Youth Marijuana Use

Study	Data Sources	Empirical strategy and identification	Results
Anderson et al. (2015), ***American Law and Economics Review*** Examines the effect of legalizing medical marijuana on teenage marijuana use.	Youth Risk Behavior Surveys (YRBS), 1993-2011 National Longitudinal Survey of Youth 1997 (NLSY97) Treatment Episode Data Set (TEDS), 1992-2009	YRBS analysis: Difference-in-differences (DD) regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends. NLSY97 analysis: DD regression at the individual-year level. Models include individual- and state-level covariates, individual and year fixed effects, and state-specific linear time trends. TEDS analysis: DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends.	YRBS analysis: With or without state-specific time trends, there is no evidence that MMLs increased the likelihood of marijuana use or frequent use among teenagers. NLSY97 analysis: With or without state-specific time trends, there is no evidence that MMLs increased the likelihood of marijuana use or frequent use among teenagers. TEDS analysis: With or without state-specific time trends, there is no evidence that MMLs increased admission rates involving marijuana among teens at publicly funded drug treatment facilities.
Anderson et al. (2019), ***JAMA Pediatrics*** Estimates the effects of legalizing medical and recreational marijuana on teenage marijuana use.	YRBS, 1993-2017	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects.	There is no evidence that MMLs increased the likelihood of marijuana use or frequent use among teenagers. RMLs are associated with an 8% decrease in the odds of any marijuana use and a 9% decrease in the odds of frequent teen marijuana use.
Choo et al. (2014), ***Journal of Adolescent Health*** Examines the association between legalizing medical marijuana and teenage marijuana use.	YRBS, 1991-2011	DD regression at the individual-year level. Models include individual-level covariates, state and year fixed effects.	There is no evidence that MMLs increased the probability of marijuana use among teens.

Coley et al. (2019), ***American Journal of Drug and Alcohol Abuse*** Examines the association between legalizing medical marijuana and the use of marijuana by teenagers. In addition, examines the association between decriminalization and teenage marijuana use.	YRBS, 1999-2015	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects.	MMLs are associated with a 9% decrease in the odds of marijuana use among teens. There is no evidence that MMLs affected frequent teen marijuana use. There is no evidence that marijuana decriminalization affects the likelihood of marijuana use or frequent use among teenagers.
Coley et al. (Forthcoming), ***Journal of Adolescent Health*** Estimates the effects of marijuana decriminalization, medical marijuana legalization, and recreational marijuana legalization on teenage marijuana use.	YRBS, 1999-2017	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects.	There is no evidence that marijuana decriminalization, MMLs, or RMLs affected the likelihood of marijuana use among teens. RMLs are associated with a small decrease in the frequency of marijuana use among current marijuana users.
Dills et al. (2017), NBER Working Paper Estimates the effects of medical marijuana legalization and decriminalization on marijuana use by teenagers.	Monitoring the Future, 1977-2015	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	There is little evidence that legalization or decriminalization affects teenage marijuana use.
Harper et al. (2012), ***Annals of Epidemiology*** Examines the association between legalizing medical marijuana and marijuana use by teenagers.	National Survey on Drug Use and Health (NSDUH), 2002-2009	DD regression at the state-year level. Models include state and year fixed effects.	MMLs are associated with an 8% decrease in any marijuana use among teens. There is no evidence that MMLs affect perceived riskiness of monthly marijuana use.

Hollingsworth et al. (2020), Working Paper Estimates the effects of legalizing medical and recreational marijuana on marijuana use among 12- through 17-year-olds.	NSDUH, 2001-2017	DD regression at the state-year level. Models include state-level covariates, state fixed effects, and region-by-year fixed effects.	MML adoption is associated with a 4-5% increase in past-month youth marijuana use, while RML adoption is associated with a 13-15% increase in past-month use. Recreational sales are associated with a 10% increase in past-year use.
Johnson et al. (2017), *Drug and Alcohol Dependence* Examines the association between legalizing medical marijuana and teenage marijuana use.	YRBS, 1991-2011	DD regression at the individual-year level. Models include individual-level covariates, state and year fixed effects.	MMLs are associated with a 7% reduction in the odds of marijuana use among teens. There is no evidence that MMLs affected frequent teen marijuana use. MMLs with more liberal provisions are associated with lower odds of teen marijuana use, while MMLs with higher possession limits and voluntary registration are associated with higher odds of use.
Pacula et al. (2015), *Journal of Policy Analysis and Management* Estimates the effect of legalizing medical marijuana on marijuana use among individuals under the age of 21.	NLSY97 TEDS, 1992-2011	NLSY97 analysis: DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects. TEDS analysis: DD regression at the state-year level. Models include state-level covariates, state and year fixed effects.	NLSY97 analysis: There is no evidence that MMLs affected the likelihood of marijuana use or frequent marijuana use among individuals under the age of 21. MMLs that require a patient registry system are associated with increased use, while MMLs that allow home cultivation are associated with decreased use. TEDS analysis: MMLs are associated with a 12% decrease in the admission rates involving marijuana among individuals under the age of 21 at publicly funded drug treatment facilities. MMLs that legally permit dispensaries are associated with more treatment admissions, while MMLs that allow home cultivation are associated with fewer treatment admissions.

Smart and Doremus (2021), Working Paper Estimates the effects of legalizing medical marijuana and the size of the medical marijuana market on youth marijuana use.	NSDUH, 2002-2013	Linear trend-break models at the state-year level, focused on the periods following the Ogden and Cole memorandums. Models include state-level covariates, state and year fixed effects. The authors also estimate DD regressions at the state-year level, where the share of adults registered as medical marijuana patients in state *s* during year *t* proxies for the size of the medical marijuana market. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends.	The linear trend-break analysis produces evidence that marijuana use among 12- through 17-year-olds increased after the Ogden memorandum was issued, but fell after the Cole memorandum was issued. The DD analysis produces evidence of a positive association between medical marijuana market size and past-month marijuana use among 12- through 17-year-olds. There is no evidence, however, that MML adoption affects youth marijuana use.
Wen et al. (2015), ***Journal of Health Economics*** Examines whether legalizing medical marijuana affects the use of marijuana by 12- through 20-year-olds.	NSDUH, 2004-2012	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	There is no evidence that MMLs affected past-month marijuana use among 12- through 20-year-olds. MMLs are associated with a 5% increase in the probability of past-year marijuana initiation among 12- through 20-year-olds.

Table 3. Marijuana Legalization and the Use of Alcohol

Study	Data Sources	Empirical strategy and identification	Results
Alley et al. (2020), *Addictive Behaviors* Examines the association between legalizing recreational marijuana and alcohol consumption among college students.	National College Health Assessment-II (NCHA-II), 2008-2018	Difference-in-differences (DD) regression at the individual-year level. Models include individual- and institution-level covariates, state and year fixed effects, and state-specific linear trends.	RMLs are associated with a 6% decrease in binge drinking among college students. Estimates are larger for college students ages 21 and older.
Anderson et al. (2013), *Journal of Law and Economics* Estimates the effects of legalizing medical marijuana on alcohol-related traffic fatalities, alcohol consumption, and alcohol sales.	Fatality Analysis Reporting System (FARS), 1990-2010 Behavioral Risk Factor Surveillance System (BRFSS), 1993-2010 Beer Institute's *Brewers Almanac*, 1990-2010	FARS analysis: DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends. BRFSS analysis: DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends. *Brewers Almanac* analysis: DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends.	FARS analysis: MMLs are associated with a 13-15% decrease in traffic fatalities involving alcohol. BRFSS analysis: MMLs are associated with a decrease in self-reported past-month alcohol use. Estimates are more pronounced for young adults and for binge drinking (defined as having 5 or more alcoholic beverages on one occasion). *Brewers Almanac* analysis: MMLs are associated with a 5% decrease in beer sales. There is no evidence that MML adoption reduces wine or spirits sales.

Andreyeva and Ukert (2019), *Forum for Health Economics & Policy* Examines the relationship between legalizing medical marijuana and alcohol consumption.	BRFSS, 1993-2013	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	MMLs are associated with decreases in heavy and risky drinking, while dispensary sales are associated with an increase in heavy drinking. Heavy drinking is defined as having consumed 2 or more (1 or more) drinks per day on average for the past month for men (women). Risky drinking is defined as having consumed 60 or more (32 or more) drinks in the past month for men (women). Combined, legalization and dispensary sales have no effect on alcohol consumption.
Baggio et al. (2020), *Canadian Journal of Economics* Estimates the effect of legalizing medical marijuana on retail sales of alcohol.	Nielsen Retail Scanner Data Set, 2006-2015	DD regression at the county-month level. Models include county- and state-level covariates, county and month fixed effects, and state-specific linear trends.	Focusing on contiguous-border county pairs, MMLs are associated with a 12% decrease in retail alcohol sales.
Conyers and Ayres (2020), *Health Economics* Estimates the effect of living near a medical marijuana dispensary on alcohol-related emergency department (ED) visits.	Hospital discharge data from the Arizona Department of Health Services, 2010-2016.	Licenses for medical marijuana dispensaries in Arizona were allocated based on the results of a lottery conducted by the Department of Health Services. DD regression comparing alcohol-related ED visits among residents of zip codes with newly opened dispensaries to alcohol-related ED visits among residents of zip codes without dispensaries.	There is no evidence that living in the same zip code as a newly opened medical marijuana dispensary is associated with alcohol-related ED visits.
Dragone et al. (2019), *Journal of Economic Behavior and Organization* Estimates the effect of legalizing recreational marijuana in Washington state on alcohol consumption near the Washington-Oregon border.	National Survey on Drug Use and Health (NSDUH), 2010-2014	DD and spatial regression discontinuity design at the county-year level near the WA-OR border. Models include county and time fixed effects, and second-order polynomials in the minimum distance of the county centroid from the border.	Legalization of recreational marijuana is associated with a 20% decrease in self-reported binge drinking on the WA side of the border relative to the OR side.

Johnson et al. (2018), ***Substance Abuse*** Examines the association between legalizing medical marijuana and youth alcohol use.	Youth Risk Behavior Surveys (YRBS), 1991-2011	DD regression at the individual-year level. Models include individual-level covariates, state and year fixed effects.	MMLs are associated with an 8% decrease in the odds of past-month alcohol use among high school students.
Kelly and Rasul (2014), ***Journal of Public Economics*** Asks how an experiment depenalizing marijuana in Lambeth, a borough of London, affected hospital admissions involving alcohol.	Inpatient Hospital Episode Statistics (HES), 1997-2009	DD regression at the borough-quarter-year level. Models include borough-level covariates, borough and quarter fixed effects.	There was a substantial reduction in admissions involving alcohol among males ages 15 through 24 after Lambeth depenalized marijuana. Depenalization was not associated with alcohol-related admissions among older male cohorts.
Miller and Seo (forthcoming), ***National Tax Journal*** Estimates the effect of legalizing recreational marijuana in Washington state on retail sales of alcohol.	Nielsen Retail Scanner Data Set, 2013-2016	Estimate a flexible demand system at the county-month level. Models include county and month fixed effects. Hausman, tax, and wholesale instruments are used to instrument for prices. The percentage of population in counties where marijuana retail is banned is used to instrument marijuana availability.	Legalization of recreational marijuana is associated with a 5% decrease in the demand for alcohol.
Sabia et al. (2017), ***Health Economics*** Examines whether legalizing medical marijuana affects alcohol consumption.	BRFSS, 1990-2012	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	MMLs are associated with a 3% decrease in the probability of past-month alcohol consumption and a 5% decrease in the probability of past-month binge drinking among respondents 18 through 24 years of age.

Veligati et al. (2020), ***International Journal of Drug Policy*** Examines the association between legalizing medical marijuana and per capita alcohol consumption. In addition, examines the association between legalizing recreational marijuana and alcohol consumption.	National Institute on Alcohol Abuse and Alcoholism's Alcohol Epidemiologic Data System (AEDS), 1990-2016	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects.	There is no evidence that MMLs or RMLs increase per capita alcohol sales.
Wen et al. (2015), ***Journal of Health Economics*** Estimates the effect of legalizing medical marijuana on alcohol consumption.	NSDUH, 2004-2012	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	MMLs are associated with a 10% increase in binge drinking among respondents ages 21 and older. There is no evidence that MMLs affect alcohol consumption among 12- through 20-year-olds.

Table 4. Marijuana Legalization and the Use of Opioids

Study	Data Sources	Empirical strategy and identification	Results
Bachhuber et al. (2014), ***JAMA Internal Medicine*** Examines the association between legalizing medical marijuana and opioid-related mortality.	National Vital Statistics System (NVSS) multiple cause-of-death mortality files, 1999-2010	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends.	Without state-specific time trends, MMLs are associated with a 25% reduction in opioid-related mortality. With state-specific linear trends, MMLs are associated with an 18% reduction in opioid-related mortality.
Bradford and Bradford (2016), ***Health Affairs*** Examines the association between legalizing medical marijuana and prescribing under Medicare Part D.	Medicare Part D Prescription Drug Event Standard Analytic File, 2010-2013	DD regression at the physician-year level. Models include physician- and state-level covariates, state and year fixed effects.	MMLs are associated with a reduction in the prescribing of pain medications under Medicare Part D.
Bradford and Bradford (2017), ***Health Affairs*** Examines the association between legalizing medical marijuana and prescribing to Medicaid enrollees.	State Drug Utilization Data (SDUD), 2007-2014	DD regression at the state-quarter level. Models include state-level covariates, state and year fixed effects.	MMLs are associated with a reduction in the prescribing of pain medications to Medicaid enrollees.
Bradford and Bradford (2018), ***Journal of Law and Economics*** Examines the association between legalizing medical marijuana and prescribing under Medicare Part D.	Medical Expenditure Panel Survey (MEPS), 2007-2011	DD regression at the physician-year level. Models include physician and year fixed effects.	MMLs are associated with a reduction in the prescribing of pain medications under Medicare Part D.
Bradford et al. (2018), ***JAMA Internal Medicine*** Examines the association between legalizing medical marijuana and the prescribing of opioids under Medicare Part D.	Medicare Part D Prescription Drug Event Standard Analytic File, 2010-2015.	DD regression at the state-year level. Models include state-level covariates, state fixed effects and a linear time trend.	MMLs are associated with an 8.5% reduction in the prescribing of opioids under Medicare Part D.

Carrieri et al. (2020), ***Journal of Health Economics*** Asks whether a 2016 Italian law permitting the cultivation of marijuana with low levels of THC affected prescription opioid sales.	Data on prescription opioid sales for the period 2016-2018 are from *Federfarma*, the Italian association of pharmacy owners.	DD regression at the province-month level. Models include province-level covariates, province, month and year fixed effects, and province-specific linear time trends.	Without province-specific linear trends, the legalization of "light cannabis" is associated with a 1% reduction in prescription opioid sales. With province-specific linear trends, the legalization of "light cannabis" is associated with a 2% reduction in prescription opioid sales.
Chan et al. (2020), ***Economic Inquiry*** Estimates the effects of legalizing medical and recreational marijuana on opioid-related mortality.	NVSS multiple cause-of-death mortality files, 1999-2017.	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear trends.	Legalization of recreational marijuana is associated with a (statistically insignificant) 4% reduction in opioid-related mortality. Recreational sales are associated with a 16-21% reduction in opioid-related mortality.
Chu (2015), ***Journal of Law and Economics*** Estimates the effects of legalizing medical marijuana on admissions for heroin treatment.	Treatment Episode Data Set (TEDS), 1992-2011.	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear trends.	MMLs are associated with a 20% reduction in admissions to substance abuse treatment for heroin.
Conyers and Ayres (2020), ***Health Economics*** Estimates the effect of living near a medical marijuana dispensary on opioid-related emergency department (ED) visits.	Hospital discharge data from the Arizona Department of Health Services, 2010-2016.	Licenses for medical marijuana dispensaries in Arizona were allocated based on the results of a lottery conducted by the Department of Health Services. DD regression comparing opioid-related ED visits among residents of zip codes with newly opened dispensaries to opioid-related ED visits among residents of zip codes without dispensaries.	Living in the same zip code as a newly opened medical marijuana dispensary is associated with an increase in opioid-related ED visits of 0.8% per quarter.
McMichael et al. (2020), ***Journal of Health Economics*** Estimates the effects of legalizing medical and recreational marijuana on the prescribing of opioids by healthcare providers.	Symphony Health's IDV® (Integrated Dataverse) dataset, 2011-2018.	DD regression at the provider-state-year level. Models include state-level covariates, state and year fixed effects, and healthcare provider fixed effects.	Legalizing medical marijuana is associated with a 4% reduction in opioid prescribing. Legalizing recreational marijuana is associated with a 12% reduction in opioid prescribing.

Powell et al. (2018), *Journal of Health Economics* Estimates the effects of legalizing medical marijuana on opioid-related mortality using data after the release of the Ogden memo in October of 2009.	NVSS multiple cause-of-death mortality files, 1999-2013	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects.	1999–2010: MMLs are associated with a 20% reduction in opioid-related mortality. 1999–2013: MMLs are associated with a (statistically insignificant) 10% reduction in opioid-related mortality.
Shover et al. (2019), *Proceedings of the National Academy of Sciences* Replicates and extends Bachhuber et al. (2014) by examining the effects of legalizing medical and recreational marijuana on opioid-related mortality using data from 1999-2017.	NVSS multiple cause-of-death mortality files, 1999-2017	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends.	1999-2010: Without state-specific time trends, MMLs are associated with a 21.1% reduction in opioid-related mortality. With state-specific linear trends, the association between MMLs and opioid-related mortality is not statistically significant at the 5% level. 1999-2017: Without state-specific time trends, MMLs are associated with a 22.7% increase in opioid-related mortality; RMLs are associated with a (statistically insignificant) 14.7 percent reduction in opioid-related mortality. With state-specific linear trends, the association between MMLs and opioid-related mortality is not statistically significant at the 5% level.

Smith (2020), ***Economic Inquiry*** Examines the effects of medical marijuana dispensaries on mortality involving a prescription opioid and admissions to substance abuse treatment for opioids.	NVSS multiple cause-of-death mortality files, 1999-2014 TEDS, 1992-2014	DD regression at the county-year level. Models include county- and state-level covariates, county and year fixed effects, and state-specific linear time trends.	NVSS analysis: Without state-specific linear trends, the opening of a medical marijuana dispensary is associated with an 11% reduction in mortality involving a prescription opioid. With state-specific linear trends, the opening of a medical marijuana dispensary is associated with a 7% reduction in mortality involving a prescription opioid. TEDS analysis: Without state-specific linear trends, the opening of a medical marijuana dispensary is associated with a (statistically insignificant) 5% reduction in admissions to substance abuse treatment for opioids. With state-specific linear trends, the opening of a medical marijuana dispensary is associated with a (statistically insignificant) 8% reduction admissions to substance abuse treatment for opioids.
Wen et al. (2015), ***Journal of Health Economics*** Estimates the effects of legalizing medical marijuana on the use of prescription painkillers and heroin by adolescents and adults.	NSDUH, 2004-2012	DD regression on repeated cross sections of individuals. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	There is no evidence that MMLs affect the use of prescription painkillers or heroin.
Wen and Hockenberry (2018), ***JAMA Internal Medicine*** Examines the association between legalizing medical marijuana and the prescribing of opioids to Medicaid enrollees.	SDUD, 2011-2016	DD regression using at the state-quarter level. Models include state-level covariates, state and quarter fixed effects.	MMLs are associated with a 6% reduction in opioid prescribing to Medicaid enrollees.

Table 5. Marijuana Legalization and the Use of Tobacco

Study	Data Sources	Empirical strategy and identification	Results
Alley et al. (2020), ***Addictive Behaviors*** Examines the association between legalizing recreational marijuana and tobacco use among college students. The mode of tobacco use includes cigarettes, pipes, cigars, e-cigarettes, and smokeless tobacco.	NCHA-II, 2008-2018	DD regression at the individual-year level. Models include individual- and institution-level covariates, state and year fixed effects, and state-specific linear trends.	There is no evidence of an association between RMLs and tobacco use among college students.
Anderson et al. (2020), ***National Tax Journal*** Estimates the effects of medical and recreational marijuana legalization on teen cigarette use.	YRBS, 1991-2017	DD regression at the individual-year level. Models include individual- and state-level covariates, and state and year fixed effects.	MMLs are associated with a 6% reduction in any teen cigarette use in the past month and a 12% reduction in frequent teen cigarette, defined as having smoked cigarettes during at least 20 of the past 30 days. There is little evidence to suggest that RMLs are associated with teen cigarette use.
Andreyeva and Ukert (2019), ***Forum for Health Economics & Policy*** Examines the relationship between medical marijuana legalization and cigarette use.	BRFSS, 1993-2013	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	There is no evidence of an association between MMLs and cigarette smoking.

Choi et al. (2019), ***American Journal of Health Economics*** Estimates the effect of legalizing medical marijuana on cigarette use.	NSDUH, 2002-2015 BRFSS, 1990-2015 Current Population Survey Tobacco Use Supplements (CPS-TUS), 1992-2015	NSDUH analysis: DD regression at the state-year level. Models include state-level covariates, and state and year fixed effects. BRFSS analysis: DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear and higher order trends. CPS-TUS analysis: DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear and higher order trends.	Across all three data sets, the authors find evidence that MMLs are associated with a 1 to 1.5 percentage-point reduction in any cigarette smoking. There is also evidence that MMLs are associated with a reduction in the number of cigarettes consumed per day among current smokers, suggesting effects at the intensive margin.
Miller and Seo (forthcoming), ***National Tax Journal*** Examines the effect of legalizing recreational marijuana in Washington state on retail sales of tobacco.	Nielsen Retail Scanner Data Set, 2013-2016	Estimate a flexible demand system at the county-month level. Models include county and month fixed effects. Hausman, tax, and wholesale instruments are used to instrument for prices. The percentage of population in counties where marijuana retail is banned is used to instrument marijuana availability.	Legalization of recreational marijuana is associated with a 12% decrease in tobacco demand.
Veligati et al. (2020), ***International Journal of Drug Policy*** Estimates the effects of legalizing medical and recreational marijuana on per capita cigarette sales.	National Institute on Alcohol Abuse and Alcoholism's AEDS, 1990-2016	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects.	There is no evidence that MMLs or RMLs increased per capita cigarette sales.

Table 6. Marijuana Legalization and the Use of Other Substances

Study	Data Sources	Empirical strategy and identification	Results
Bradford and Bradford (2016), ***Health Affairs*** Examines the association between legalizing medical marijuana and prescribing under Medicare Part D.	Medicare Part D Prescription Drug Event Standard Analytic File, 2010-2013	DD regression at the physician-year level. Models include physician- and state-level covariates, state and year fixed effects.	MMLs are associated with reductions in the prescribing of medications for anxiety, depression, nausea, pain, psychosis, seizures, and sleep disorders under Medicare Part D. There is no evidence that MMLs reduce the prescribing of medications for glaucoma and spasticity.
Bradford and Bradford (2017), ***Health Affairs*** Examines the association between legalizing medical marijuana and prescribing to Medicaid enrollees.	SDUD, 2007-2014	DD regression at the state-quarter level. Models include state-level covariates, state and year fixed effects.	MMLs are associated with reductions in the prescribing of medications for depression, nausea, pain, psychosis, and seizures under Medicaid. There is no evidence that MMLs reduce the prescribing of medications for glaucoma and spasticity.
Bradford and Bradford (2018), ***Journal of Law and Economics*** Examines the association between legalizing medical marijuana and prescribing under Medicare Part D.	MEPS, 2007-2011	DD regression at the physician-year level. Models include physician and year fixed effects.	MMLs are associated with reductions in the prescribing of medications for anxiety, depression, nausea, pain, psychosis, seizures and sleep disorders under Medicare Part D. There is no evidence that MMLs reduce the prescribing of medications for glaucoma and spasticity.
Carrieri et al. (2020), ***Journal of Health Economics*** Asks whether a 2016 Italian law permitting the cultivation of marijuana with low levels of THC affected prescription sales.	Data on prescription sales for the period 2016-2018 are from *Federfarma*, the Italian association of pharmacy owners.	DD regression at the province-month level. Models include province-level covariates, province, month and year fixed effects, and province-specific linear trends.	Without province-specific linear trends, the legalization of "light cannabis" is associated with a 1.6% reduction in prescription sales (including sales of sedatives, anti-epileptics, anti-psychotics, and anti-depressives). With province-specific linear trends, legalization is associated with a 1.7% reduction in prescription sales.

Chu (2015), ***Journal of Law and Economics*** Estimates the effect of legalizing medical marijuana on admissions to substance abuse treatment for cocaine.	TEDS, 1992-2011.	DD regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear trends.	No evidence that MMLs are related to admissions to substance abuse treatment for cocaine.
Conyers and Ayres (2020), ***Health Economics*** Estimates the effect of living near a medical marijuana dispensary on cocaine-related emergency department (ED) visits.	Hospital discharge data from the Arizona Department of Health Services, 2010-2016.	Licenses for medical marijuana dispensaries in Arizona were allocated based on the results of a lottery conducted by the Department of Health Services. DD regression comparing cocaine-related ED visits among residents of zip codes with newly opened dispensaries to cocaine-related ED visits among residents of zip codes without dispensaries.	There is no evidence that living in the same zip code as a newly opened medical marijuana dispensary is associated with cocaine-related ED visits.
Doremus et al. (2020), ***Complementary Therapies in Medicine*** Asks whether the opening of recreational marijuana dispensaries affected the growth in sales of over-the-counter sleep aids.	Nielsen Retail Scanner Data Set, 2012-2014	Panel regression at the store-month level. Growth in market share of over-the-counter sleep aids regressed on store- and county-level controls, store indicators, and indicator for recreational dispensary in county.	Recreational dispensary openings are associated with a 0.33 percentage point decrease in the market share growth of over-the-counter sleep aids.
Hollingsworth et al. (2020), Working Paper Estimates the effects of legalizing medical and recreational marijuana on cocaine use.	NSDUH, 2001-2017	DD regression at the state-year level. Models include state-level covariates, state fixed effects, and region-by-year fixed effects.	There is no evidence that MML adoption is associated with cocaine use. There is also evidence that RMLs increase cocaine use, but these estimates are sensitive to model specification.

Kelly and Rasul (2014), *Journal of Public Economics* Asks how an experiment depenalizing marijuana in Lambeth, a borough of London, affected hospital admissions involving hard drugs (including cocaine, crack, crystal-meth, heroin, LSD, MDMA and methadone).	Inpatient HES, 1997-2009	DD regression at the borough-quarter level. Models include borough-level covariates, quarter and borough fixed effects.	Admission rates involving hard drugs increased by 40-100 percent after Lambeth depenalized marijuana.
Wen et al. (2015), *Journal of Health Economics* Examines whether legalizing medical marijuana affects adolescent and adult cocaine use.	NSDUH, 2004-2012	DD regression on repeated cross sections of individuals. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	There is no evidence that MMLs affect the use of cocaine.

Table 7. Marijuana Legalization and Suicides

Study	Data Sources	Empirical strategy and identification	Results
Anderson et al. (2014), ***American Journal of Public Health*** Estimates the effect of legalizing medical marijuana on suicide rates.	NVSS multiple cause-of-death mortality files, 1990-2007	Difference-in-difference (DD) regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends.	Controlling for state-specific linear trends, MML adoption is associated with a 5-6% reduction in the male suicide rate. The association between MML adoption and the female suicide rate is of comparable magnitude but not statistically significant. MML adoption is associated with an 11% reduction in suicides among male 20- through 29-year-olds, and a 9% reduction in suicides among male 30- through 39-year-olds.
Bartos et al. (2020), ***Archives of Suicide Research*** Asks whether the legalization of medical marijuana in California affected total, firearm-related, and non-firearm-related suicides.	NVSS multiple cause-of-death mortality files, 1970-2004	Uses a synthetic control approach to compare suicides in California with those in its synthetic control. Matching on pre-treatment suicide counts.	After medical marijuana was legalized in 1996, suicides fell by 398.9 per year (or approximately 11%) in California as compared to its synthetic control. This estimated effect is largely driven by firearm-related suicides.
Grucza et al. (2015), ***Drug and Alcohol Dependence.*** Estimates the association between legalizing medical marijuana and the odds of suicide.	NVSS multiple cause-of-death mortality files, 1990-2010	DD regression using individual-level data. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	Controlling for state-specific linear trends, there is no evidence that MML adoption is related to suicides. MML adoption is associated with a (statistically insignificant) 4% reduction in the odds of suicide among male 20- through 29-year-olds (p-value = 0.39), and a (statistically insignificant) 6% reduction in the odds of suicide among male 30- through 39-year-olds (p-value = 0.14).

Table 8. Marijuana Legalization and Traffic Fatalities

Study	Data Sources	Empirical strategy and identification	Results
Anderson et al. (2013), ***Journal of Law and Economics*** Estimates the effect of legalizing medical marijuana on traffic fatalities.	Fatality Analysis Reporting System (FARS), 1990-2010	Difference-in-differences (DD) regression at the state-year level. Models include state-level covariates, state and year fixed effects, and state-specific linear time trends.	Without state-specific time trends, MMLs are associated with a 10% reduction in traffic fatalities. With state-specific linear trends, MMLs are associated with a (statistically insignificant) 9% reduction in traffic fatalities. Estimated effects are larger in magnitude for traffic fatalities involving alcohol, traffic fatalities on weekends, and traffic fatalities at night.
Aydelotte et al. (2017), ***American Journal of Public Health*** Examines the association between legalizing recreational marijuana and traffic fatalities in Colorado and Washington.	FARS, 2009-2015.	DD regression at the state-year level. Models include state-level covariates, pre- and post-treatment dummies.	RML adoption is not associated with changes in traffic fatalities. The authors define the post-treatment period as beginning in 2013, before recreational sales in Colorado and Washington began.
Cook et al. (2020), ***American Journal of Public Health*** Examines the association between legalizing medical marijuana and fatal crashes. In addition, examines the association between decriminalizing marijuana and fatal crashes.	FARS, 2010-2017	DD regression at the city-half year (i.e., 6 month) level. Models include city- and state-level covariates, city and half-year fixed effects.	MMLs are associated with a 9% reduction in fatal crashes. Decriminalization of marijuana is associated with a 13% increase in fatal crashes involving 15- through 24-year-old male drivers.

Hansen et al. (2020), ***Economic Inquiry*** Asks whether the start of recreational marijuana sales in Colorado and Washington affected traffic fatalities.	FARS, 2000-2016	Used a synthetic control approach to produce separate estimates for Colorado and Washington. Matching variables include the marijuana testing rate, the alcohol testing rate, the fraction of vehicle miles traveled (VMT) on urban roads, average VMT, and the unemployment rate.	Little evidence that RMLs impacted total traffic fatalities or traffic fatalities involving alcohol.
Santaella-Tenorio et al. (2020), ***JAMA Internal Medicine*** Asks whether the start of recreational marijuana sales in Colorado and Washington affected traffic fatalities.	FARS, 2005-2017	Used a synthetic control approach to produce separate estimates for Colorado and Washington. Matching variables not listed.	In Colorado, legalization of recreational sales increased traffic fatalities. Traffic fatalities in Washington also increased after recreational sales began but this increase is comparable to the increase in the synthetic control group.

Table 9. Marijuana Legalization and Workplace Health

Study	Data Sources	Empirical strategy and identification	Results
Anderson et al. (2018), ***International Journal of Drug Policy*** Estimates the effect of legalizing medical marijuana on workplace fatalities.	Census of Fatal Occupational Injuries from the Bureau of Labor Statistics, 1992-2015	Difference-in-difference (DD) regression at the state-year level. Models include state-level covariates, state and year fixed effects.	MML adoption is associated with a 19.5% reduction in the expected number of workplace fatalities among workers aged 25-44. MMLs that list pain as a qualifying condition or allow collective cultivation are associated with larger reductions in fatalities among workers aged 25-44 than those that do not.
Ghimire and Maclean (2020), ***Health Economics*** Examines the association between MMLs and workers' compensation (WC) claims.	Annual Social and Economic Supplement to the Current Population Survey (CPS), 1990-2013.	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects.	MMLs are associated with a 6-7% decrease in the likelihood of claiming WC and a 0.8% decrease in the level of WC income.
Maclean et al. (2021), ***Health Economics*** Estimates the effect of RMLs on new applications and allowances for Social Security Disability Insurance (SSDI) and Supplemental Security Income (SSI)	Social Security Administration State Agency Monthly Workload Data, 2001-2019.	DD regression at the state-quarter level. Models include state-level covariates, state and quarter fixed effects.	RMLs adoption associated with a 3.6% increase in SSDI applications and a 6.5% increase in SSI applications. The authors find no evidence of an association between RMLs and allowances.
Nicholas and Maclean (2019), ***Journal of Policy Analysis and Management*** Estimates the effect of legalizing medical marijuana on self-reported pain, overall	Health and Retirement Study, 1992-2012.	DD regression at the individual-year level. Models include individual- and state-level covariates, state and year fixed effects, and state-specific linear time trends.	MMLs are associated with a reduction in self-reported pain and an improvement in self-assessed health among older adults. MMLs are also associated with increases in work hours among older adults already working. Estimated effects are largest among those with a health condition that would qualify for legal medical marijuana use.

health and labor supply of adults ages 51 and older.			
Ullman (2017), ***Health Economics*** Asks whether the legalization of medical marijuana affected workplace absences due to sickness.	March CPS, 1992-2012	DD regression at the individual-year level. Models include individual-level covariates, state and year fixed effects, and state-specific linear time trends.	The legalization of medical marijuana is associated with an 8% reduction in the likelihood of missing work due to health issues. Estimated effects are larger for individuals in MML states with lax supply-side restrictions, full-time workers, and middle-aged males.

Table 10. Marijuana Legalization and Crime

Study	Data Sources	Empirical strategy and identification	Results
Adda et al. (2014), ***Journal of Political Economy*** Asks how an experiment depenalizing marijuana in Lambeth, a borough of London, affected crime.	Administrative records from the London Metropolitan Police Service, April 1998-January 2006.	Difference-in-differences (DD) regression at the borough-month-year level. Models include borough-level covariates, borough and month fixed effects.	Depenalization is associated with a 29% increase in marijuana-related offenses (e.g., trafficking and intent to supply). There is also evidence that depenalization shifted police effort towards crime related to hard drugs (e.g., heroin and crack) and non-drug crime. Reallocation of effort led to a 9% decrease in non-drug offenses (e.g., robbery and burglary).
Brinkman and Mok-Lamme (2019), ***Regional Science and Urban Economics.*** Estimates the effect of recreational marijuana dispensary openings on neighborhood crime rates in Denver, Colorado.	Administrative records from the City and County of Denver, 2013-2016.	Instrumental variables regression at the census tract-month level. The distance of census tract centroid to nearest municipal border and distance to a major roadway are used to instrument for the change in the number of dispensaries. Models include census tract-level covariates and month fixed effects.	The opening of a dispensary is associated with a 19% reduction in total crime. This estimated effect is driven primarily by nonviolent offenses.
Burkhardt and Goemans (2019), ***Annals of Regional Science*** Estimates the effect of recreational marijuana dispensary openings on neighborhood crime rates in Denver, Colorado.	Administrative records from the Denver police department, 2010-2016.	DD regression at the half-mile-radius-month level, where the half-mile radius is drawn around a specific dispensary location. Models include radius-level covariates, dispensary and police-district-by-month fixed effects.	The opening of dispensaries is associated with a decrease in violent crime offenses within a half-mile radius in neighborhoods with above median income. Dispensary openings are also associated with 13% fewer hard drug- and alcohol-related crimes, suggesting that legal marijuana sales are substitutes for hard drug and alcohol sales. Finally, dispensary openings are associated with a 15% increase in vehicle break-ins within a one-mile radius.

Chang and Jacobson (2017), ***Journal of Urban Economics*** Analyzes the short-run effect of closing hundreds of medical marijuana dispensaries in Los Angeles, California on local crime rates.	Incident-level crime data provided by the Los Angeles Police Department and the Los Angeles Sheriff's Department to the Los Angeles Times "Mapping L.A." project.	DD regression at the dispensary-day level, where the number of crimes near a dispensary is regressed on an indicator for whether the dispensary closed after a temporary shutdown of medical marijuana dispensaries in Los Angeles on June 7, 2010. Models include dispensary and day fixed effects.	Dispensary closures lead to increases in property crimes (particularly theft from vehicles) near the dispensary. There are similar increases in property crimes after restaurant closures, suggesting a general retail effect could be driving the marijuana dispensary estimates.
Chu and Townsend (2019), ***Journal of Economic Behavior and Organization*** Estimates the effect legalizing medical marijuana on crime.	Uniform Crime Reports (UCR), 1988-2013.	DD regression at the city-year level. Models include city-level covariates, city and year fixed effects, and city-specific time trends. The authors also estimate synthetic control models.	There is little evidence that MMLs affected property or violent crimes in the full sample. Within California, legalization of medical marijuana is associated with a 20% reduction in both violent and property crime.
Dragone et al. (2019), ***Journal of Economic Behavior and Organization*** Estimates the effect of legalizing recreational marijuana in Washington state on crime near the Washington-Oregon border.	UCR, 2010-2014	DD and spatial regression discontinuity design at the county-year level near the WA-OR border. Models include county and time fixed effects, and second-order polynomials in the minimum distance of the county centroid from the border.	Legalization of recreational marijuana is associated with a 15-30% reduction in rapes and a 10-20% reduction in thefts in counties on the WA side of the border relative to the OR side.
Gavrilova et al. (2019), ***Economic Journal*** Asks whether legalizing medical marijuana affected violent crime in U.S. states on the Mexican border.	UCR, 1994-2012 Supplementary Homicide Reports (SHR), 1994-2012	Difference-in-difference-in-differences (DDD) regression at the county-year level comparing the effect of legalizing medical marijuana in U.S. states on the Mexican border with its effect in non-border states. Models include county-level covariates, county and year fixed effects, border-by-year fixed effects, and state-specific linear time trends. The authors also estimate models that interact MML adoption with the distance of the county centroid to the U.S.-Mexico border.	UCR analysis: MML adoption by states on the Mexican border is associated with a 12.5% reduction in the violent crime rate, and this result is driven primarily by robberies, homicides, and aggravated assaults. SHR analysis: MMLs are associated with a 41% decrease in drug-law-related homicides, consistent with the hypothesis that MMLs reduce violent crimes committed by drug trafficking organizations.

Huber III et al. (2016), ***B.E. Journal of Economic Analysis and Policy*** Estimates the effect of legalizing medical marijuana and marijuana decriminalization on nondrug crime.	UCR, 1970-2012	DD regression at the state-year level. Models include state-level covariates, and state and year fixed effects. The authors also experiment with controlling for region-by-year fixed effects and higher-order state-specific time trends.	MML adoption is associated with a 4-12% reduction in robberies, larcenies, and burglaries. There is tentative evidence that decriminalization may lead to increases in burglaries and robberies.
Morris et al. (2014), ***PLOS ONE*** Estimates the association between medical marijuana laws and crime.	UCR, 1990-2006	DD regression at the state-year level. Models include state-level covariates, and state and year fixed effects.	MMLs are associated with a 2-3% reduction in homicides and a 2-3% reduction in assaults.