



SCHOOL OF
ECONOMICS AND
MANAGEMENT

Being High, Feeling Low?
Effects of Recreational Marijuana Legalization Policies on
Mental Health

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Abstract

In the last years, several states in the United States have enacted medical and recreational marijuana legalization laws (MMLs and RMLs). These policies aim to regulate the handling of marijuana consumption at the state level. This led to an ongoing debate on the effects of such laws on public health. However, the literature on this topic is very limited regarding the effects of recreational marijuana legalization on mental health. In this paper, we present new insights on this matter by additionally disentangling the policy heterogeneity and considering the opening of recreational marijuana dispensaries (RMDs) in the United States. Exploiting the staggered implementation of the legalization laws across states and over time, we follow a two-way fixed effects regression model. Using monthly individual-level data from the Behavioral Risk Factor Surveillance System (BRFSS) for 1993 - 2020 we find that recreational marijuana legalization only significantly affects mental health through operational marijuana dispensaries. The introduction of RMDs increases the probability of having at least one bad mental health day in the last 30 days by 2.3 p.p., which corresponds to a 7.23 % increase relative to the sample mean. Following an event study approach we show that this effect does not begin immediately but only two years after the dispensaries became operational. In contrast, the sole enactment of recreational marijuana legalization laws does not significantly affect mental health.

Keywords: recreational marijuana laws, dispensaries, mental health, BRFSS

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1. Introduction

In the last decades, several countries introduced marijuana legalization laws e.g., Canada, Mexico, and parts of the United States (Baggio et al., 2020). The reasoning behind this legalization is different across the countries. In Canada, the Cannabis Act was created in 2018 to protect the youth, to decrease criminal activities in context of marijuana and to protect the public health by regulating cannabis sales (Government of Canada, 2018). In the U.S., medical and recreational marijuana legalization laws were enacted e.g., due to therapeutic benefits or potential decreases in criminal justice disparities. Furthermore, other countries, such as Germany, are considering to legalize marijuana as well (SPD, 2021). Hereby, especially the legalization of recreational marijuana is subject to heated discussions. The focus of these ongoing debates is preliminary whether the benefits of recreational marijuana legalization laws outweigh the costs for the society. However, the evidence on possible public health risks is inconclusive (Meinhofer et al., 2021).

We contribute to this ongoing debate by shedding a light on the impact of recreational marijuana legalization policies on mental health in the United States. Hereby, we draw monthly individual-level data from the Behavioral Risk Factor Surveillance System (BRFSS) on mental health for the period 1993 - 2020. Furthermore, we gain information on the corresponding law effectiveness dates from ProCon and previous studies (Procon.org, 2022a,b; Meinhofer et al., 2021). Given the staggered nature of the law enactments across states and over time, we exploit a two-way fixed effects regression model with state and month-to-year fixed effects. Instead of focusing on the sole recreational marijuana legalization laws, we additionally consider the implementation of operational dispensaries. To this date, we are the first paper to disentangle this policy heterogeneity when analyzing the effects of recreational marijuana legalization on mental health.

Our results suggest that pure recreational marijuana legalization laws (RMLs) do not significantly affect mental health. Only the opening of recreational marijuana dispensaries (RMDs) significantly decreases the mental well-being. More specifically, the availability of recreational marijuana through dispensaries increases the probability

of having at least one bad mental health day in the last 30 days by 2.3 p.p., which corresponds to a 7.23 % increase relative to the sample mean. By following an event study approach we show that this effect does not begin immediately but only two years after the dispensaries became operational. This analysis also reveals that our key identifying assumption i.e., the existence of parallel pre-trends, does not seem to be violated. Furthermore, we find that the effect of RMDs on mental health is not driven by complementary consumption of alcohol but likely by increased marijuana prevalence.

This paper is organized as follows. Section 2 provides the institutional background of marijuana legalization policies in the United States. Section 3 reviews the literature on the effects of such policies on health-related outcomes, especially on mental health. Section 4 presents the conceptual framework. Section 5 describes the data used in our empirical analyses as well as details on our sample selection and the definition of our main variables. Section 6 outlines the empirical strategy. Section 7 presents the main results including the event study analysis and the discussion of possible treatment channels behind our findings. Section 8 contains the results of our heterogeneity analysis and Section 9 the robustness check. Finally, Section 10 concludes.

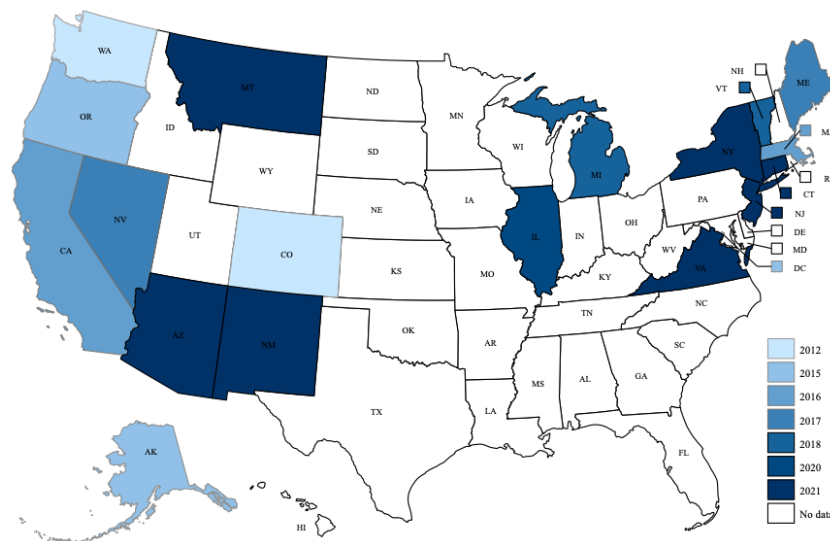
2. Institutional Background

Schedule I of the "Drugs of Abuse" resource guide of the Drug Enforcement Administration (DEA) lists marijuana as a substance with a high potential of abuse and no current accepted medical use in the United States on a federal level (DEA, 2020). Nevertheless, the existing clinical evidence testifies marijuana's medical value in alleviating symptoms and treating diseases (Wen et al., 2015). Therefore, over the last two decades states in the United States began using their authority to implement their own laws to legalize marijuana for medical purposes (The White House, 2022; Procon.org, 2022a).

The first state to enact such medical marijuana legalization laws (MMLs) was California in 1996 while the latest MML adopter, South Dakota, passed the law in 2021. Although there are differences in decriminalization, medical use conditions and

consumption regulations, up until now 36 states and the District of Columbia passed laws allowing the use of marijuana for medical treatments (Meinhofer et al., 2021; Procon.org, 2022a). Additional heterogeneity between the enacted marijuana laws lies in the accessibility of marijuana for patients. In the beginning, early adopters of MMLs provided supply of marijuana mostly indirectly by allowing patients to grow a certain number of plants at home. In contrast, late adopters introduced licensed and legally protected medical marijuana dispensaries (MMDs) soon after enacting the law¹ (Meinhofer et al., 2021; Pacula et al., 2015; Powell et al., 2018).

Figure 1: Effective Dates of Recreational Marijuana Legalization Laws by State

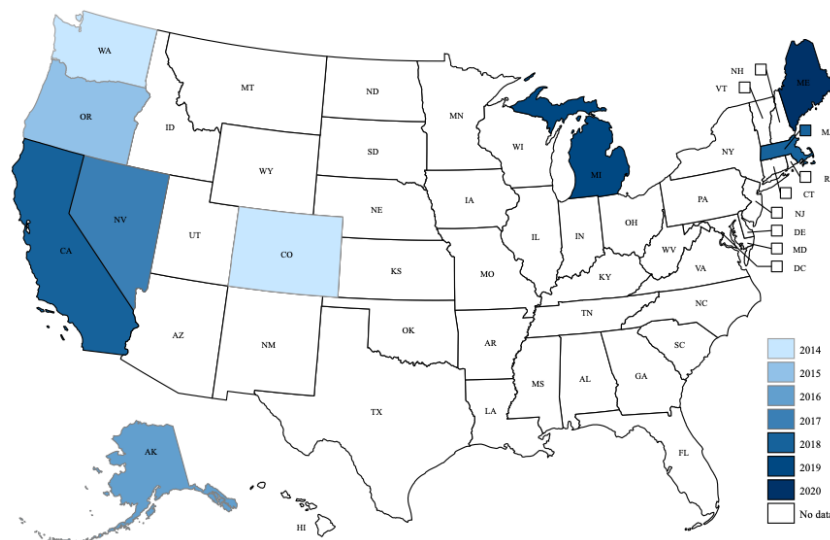


Until 2022, 19 of these 37 MML adopters enacted recreational legalization laws beginning with Washington and Colorado in 2012 as presented in Figure 1. Consequently, all RML states had previously enacted medical marijuana laws. In contrast to MML laws, RMLs do not involve a doctor’s recommendation for marijuana consumption as every person over 21 years is allowed to possess a limited amount of this drug (Sabia et al., 2021). The enactment of recreational marijuana legalization laws also took place across the United States at different points in time. Similar to medical marijuana legalization laws, they also differ considerably in their policy dimensions (Meinhofer et al., 2021). More specifically, RMLs differ in terms of marijuana accessibility and allowed

¹Hereby, early adopters are those states which introduced MMLs before 2010 (e.g., Colorado and Washington). Those states have less stringent regulations for marijuana dispensaries compared to late adopters (e.g., Massachusetts and New York) (Powell et al., 2018).

quantities one can legally possess. However, most RML states usually followed the enactment quickly with introducing recreational marijuana dispensaries as shown in Figure 2. Hereby, the already existing network of medical marijuana dispensaries was reused and complemented by new dispensaries² (Hollingsworth et al., 2020). In the absence of such dispensaries, recreational marijuana is only available through own cultivation (Procon.org, 2022b).

Figure 2: Effective Dates of Recreational Marijuana Dispensaries by State



3. Literature Review

In the last decade, a growing body of literature in economics on the impacts of marijuana legalization policies on public-health consequences has emerged. Given the staggered enactment of the legalization laws in the United States, almost all studies exploit a difference-in-difference design as an empirical approach. The majority of these studies focuses on the effects of medical rather than recreational marijuana legalization presumably due to relative recentness of RMLs (Meinhofer et al., 2021; Sabia et al., 2021). Hereby, the main outcome of interest is usually substance use, such as marijuana, alcohol, cigarettes or opioid consumption. However, only little attention

²In the appendix, Table A.1 provides a comprehensive overview of the effective dates of the marijuana legalization policies.

is paid on the effects of marijuana legalization, especially recreational marijuana legalization policies, on mental health (Anderson and Rees, 2021).

In terms of substance use, the broad consensus is that MMLs seem to increase marijuana but decrease alcohol, tobacco and opioids consumption among adults, suggesting substitutability (Anderson et al., 2013; Bachhuber et al., 2014; Baggio et al., 2020; Bradford et al., 2018; Bradford and Bradford, 2016; Choi et al., 2019; Chu, 2014; Harper et al., 2012; Hasin et al., 2017; Martins et al., 2016; Pacula et al., 2015; Powell et al., 2018; Sabia et al., 2017; Shi, 2017; Wen et al., 2015; Wen and Hockenberry, 2018). For teenagers, there is only little evidence for an effect of MMLs on other substance use (Choo et al., 2014; Harper et al., 2012; Keyes et al., 2016; Martins et al., 2016; Pacula et al., 2015). Recreational marijuana legalization is associated with an increase of marijuana consumption among adults, with less conclusive evidence for teenagers (Anderson et al., 2020, 2019; Kerr et al., 2018; Sabia et al., 2021; Wang et al., 2018). Furthermore, the overall effects on the use of opioids are negative (Shi, 2017; Wen and Hockenberry, 2018), suggesting substitutional spillover effects. For alcohol and tobacco, most studies find either negative effects (Kerr et al., 2018; Meinhofer et al., 2021; Sabia et al., 2021), or no effects at all (Alley et al., 2020; Anderson et al., 2020; Anderson and Rees, 2021; Kerr et al., 2018; Veligati et al., 2020).

The previous literature on the effects of marijuana legalization policies on mental health is rather thin, inconclusive, and only limited to MMLs. To measure mental health, those studies either utilize self-reported survey data or use suicide rates as a proxy. In general, medical marijuana legalization seems to improve self-reported mental health. Using data from the Behavioral Risk Factor Surveillance System Database (BRFSS), Andreyeva and Ukert (2019) and Kalbfuß et al. (2018) show that MMLs are associated with a 3 % or 5 % reduction of days in poor mental health, respectively. Likewise, Sabia et al. (2017) find a negative relationship between MMLs and the probability of having any poor mental health days in the last 30 days. Interestingly, there is no evidence that medical marijuana legalization affects suicide rates (Anderson et al., 2014; Grucza et al., 2015).

So far, almost none of the existing studies has investigated the effects of *recreational* marijuana legalization on mental health, which opens a gap for further research. One

exception is an unpublished working paper from Singer et al. (2020) and the recent working paper from Sabia et al. (2021). Using suicide rates as a proxy, both papers do not find significant effects of RMLs on mental health (Sabia et al., 2021; Singer et al., 2020).

We contribute to the existing literature on marijuana legalization policies in three ways. First, given the more developed literature on the effects of medical marijuana legalization on public-health, our study attaches to the very limited literature on *recreational* marijuana legalization policies. More specifically, we exploit the research gap and shed light on the effects of RMLs on mental health. As the trend in legalizing recreational marijuana is accelerating, providing empirical evidence on this matter becomes increasingly important for policy makers. Second, in an extension to our analyses, we follow Pacula et al. (2015) and Powell et al. (2018) and consider an additional policy dimension of marijuana legalization laws. Hereby, we focus on the effects of operational marijuana dispensaries for recreational purposes while additionally controlling for medical marijuana dispensaries. The rationale behind this step is that operational marijuana dispensaries are associated with a facilitated access to and consumption of marijuana. Ignoring this treatment heterogeneity will potentially lead to inadequate effects of marijuana legalization laws on mental health (Pacula et al., 2015; Powell et al., 2018). To the best of our knowledge, we are the first paper which analyses the effects of RMD on mental health. Third, we explore direct and indirect channels through which (recreational) marijuana legalization laws might affect mental health. Hereby, we investigate the hypotheses of complementary substance (ab-)use and marijuana consumption which can potentially be triggered through the legalization.

4. Conceptual Framework

The economic model for marijuana but also the current evidence on the effects of marijuana laws predict an increased marijuana use after the legalization (Guttmanova et al., 2017). Therefore, it is necessary to investigate possible channels through which marijuana consumption can affect mental health.

Earlier studies have focused on MMLs to capture the effects of marijuana consumption on mental health (Andreyeva and Ukert, 2019; Kalbfuß et al., 2018; Sabia et al., 2017). Hereby, MMLs might have a positive impact on mental health as they facilitate the access to marijuana for patients with chronic pain diseases. Therefore, given its alleviating pain effects (pain-relief component), marijuana may increase the mental well-being. Furthermore, MMLs can increase utilization of healthcare services. Going to the doctor more often can increase mental health by improving information and awareness through counseling (Sabia et al., 2017). Hence, the effect of MML on mental health can be decomposed into a pure marijuana consumption component and a pain-relief component.

In contrast, recreational marijuana laws presumably address mostly non-high pain consumers. Hence, investigating RML effects might not only give insights about the effects of recreational marijuana legalization laws but might also hint towards the pure effect of marijuana consumption. Consequently, in our paper we focus on two possible channels through which recreational marijuana might affect mental health.

The first channel explores the direct effect of RML on mental health through marijuana consumption. Clinical research shows that regular marijuana consumption is associated with negative effects on mental health, such as an increase in generalized anxiety disorders, depressions, and suicide attempts (Guttmanova et al., 2017; Memedovich et al., 2018). Thus, recreational marijuana legalization might have a negative effect on mental health.

The second channel suggests positive spillovers of RMLs on substance (ab-)use, such as alcohol and opioid consumption. Hence, RML implementation can negatively affect mental health through possible complementary effects on those drugs. In contrast, if considered as a substitute, the availability of recreational marijuana could positively affect the mental well-being due to a decrease in demand for alcohol and opioids (Anderson et al., 2014; Sabia et al., 2021).

5. Data

The following subsections provide information about the BRFSS data used in our empirical analyses as well as details on our sample selection. We further present detailed summary statistics for our outcome variables and individual- as well as state-level characteristics employed as controls in our two-way fixed effects specifications.

5.1. Behavioral Risk Factor Surveillance System (BRFSS)

We obtain our data on mental health from the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a cross-sectional telephone survey which is annually conducted by the Center for Disease Control and Prevention (CDC) on non-institutionalized adult population (18+ years) since 1984. The survey collects health-related self-reported data along with demographic characteristics on 50 U.S. federal states and the District of Columbia (CDC, 2021a). Given the nature of BRFSS, we gain repeated cross-sectional data for our analyses.

Importantly, all surveys were conducted via landline telephones until 2010. In 2011, CDC also enabled cellular telephone surveys which resulted in a different sampling method and weighting protocols (CDC, 2021a). Consequently, BRFSS incorporates different sampling weights before and after 2011. We follow Simon et al. (2017) and account for this fact by recalculating sampling weights of an individual as the fraction of its assigned BRFSS sampling weight over the sum of all individuals' weights in the respective year. Consequently, we make use of these adjusted weights throughout the whole analysis.

Using the BRFSS data has three advantages. First, the data are available for a long period of time which allows us to study the entire period of recreational marijuana policy expansions across affected states. Moreover, BRFSS' sample size is with roughly 400,000 interviews per year large enough to get meaningful precision in our estimates. Second, BRFSS contains many measures of health which are likely to be influenced by marijuana consumption (Andreyeva and Ukert, 2019; CDC, 2021a). This facilitates the exploration of the possible channels which might explain the effects of recreational

marijuana legalization on mental health as discussed in Section 4. Lastly, BRFSS allows us to use monthly data to estimate the month-on-month instead of the year-on-year policy effect. This reduces the potential measurement error and enables us to identify a more detailed time pattern of impacts (Wen et al., 2015).

5.2. Sample Selection and Definition of Main Variables

We obtain our final sample by merging monthly individual-level data from BRFSS with the monthly data on marijuana legalization laws which are presented in Table A.1. We collect information on the corresponding law effectiveness dates from ProCon and previous studies (Meinhofer et al., 2021; Powell et al., 2018; Procon.org, 2022b). Note that given our data restrictions (BRFSS provides data only until 2020), we exclude all states in which marijuana legalization policies became effective in year 2021 from our analyses. The final data set comprises 50 U.S. states plus the District of Columbia and roughly eight million observations for the period 1993 – 2020.

Our main outcome variable measures respondents' mental health. Hereby, we use survey responses to the following question:

"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?".

As over 50 % of the respondents answered this question with *zero days*, this variable of interest contains a disproportional large share of zeroes. We account for this fact by constructing two different outcome variables. First, we create a dummy which is equal to 1 if an individual reported any bad mental health days in the past 30 days, and 0 otherwise. Second, we use the logarithm of bad mental health days in our analyses³.

We further consider a rich set of individual- and state-level time-varying controls to address possible confounders to our empirical strategy. In terms of individual-level controls, we use BRFSS data on demographic variables, such as gender, race, age measured in 5-year bins, marital status, number of children and adults in a household. Motivated by previous literature on marijuana legalization laws, we also include

³More specifically, we use $\log(1 + \text{number of bad mental health days})$ as the logarithm of zero bad mental health days is not defined.

income and education indicators and a control for health insurance coverage. In order to maintain the sample size, we impute all missing values for the control variables. Additionally, we include a dummy for each variable with missing observations taking the value 1 indicating imputation, and 0 otherwise. This approach is standard in the empirical microeconomic literature (see, for example, Hanushek et al. (2013) or Bietenbeck (2014)).

At the state level, we use monthly data from the U.S. Bureau of Labor Statistics (2021), the Brewers Almanac 2020 (Beer Institute, 2022), and the Center for Disease Control and Prevention (CDC, 2021b) for seasonally adjusted unemployment rate, beer taxes and tobacco taxes, respectively. We follow Buchmueller and Carey (2018) and Powell et al. (2018) and also include a dummy variable indicating whether a state has a “must access” state-level prescription drug monitoring program (PDMP). The rationale behind including beer and tobacco taxes as well as PDMP is that they might indicate whether states handle risky health behaviors, such as drinking and smoking, differently than others. In that case, such states might very likely also deviate in how they handle marijuana legalization, e.g. by setting higher prices for marijuana, potentially leading to a lower take-up rate. Moreover, as PDMP limits access to opioids, it is likely to intervene with mental health.

Table 1 presents our descriptive statistics including the sample means and standard deviations for mental health as well as individual- and state-level controls. According to the summary, 32 % of the individuals in our sample had at least one bad mental health day in the last 30 days. Hereby, 59 % of all respondents are between 30 and 64 years, while 11 % are under 29 years and approximately 30 % are 65 or above. In terms of gender and race, 59 % are female and 84 % are white. Roughly half of the sample is married and 61 % hold a highschool degree or higher. In terms of household size, we observe 1.3 children and 1.8 adults in a household on average. Furthermore, 73 % of all respondents have an annual household income level of less than \$ 75,000 and about 90 % have a health insurance coverage. At the state level, the average unemployment rate is 5.6 %, the average specific excise beer tax is \$ 0.27 per gallon and the average cigarette state tax is \$ 1.3 per pack. Finally, 8 % of all states have a “must access” state-level prescription drug monitoring program.

Table 1: Summary Statistics

	Mean	SD
Dependent Variables		
Mental health (1 = at least one bad mental health day in the last 30 days)	0.32	0.466
Logarithm of the number of bad mental health days	0.655	1.1
Individual-Level Characteristics		
Age		
18 - 24	0.057	0.231
25 - 29	0.054	0.226
30 - 34	0.065	0.247
35 - 39	0.073	0.261
40 - 44	0.078	0.268
45 - 49	0.084	0.278
50 - 54	0.094	0.292
55 - 59	0.098	0.297
60 - 64	0.098	0.297
65 - 69	0.092	0.289
70 - 74	0.077	0.267
75 - 79	0.059	0.235
80+	0.071	0.257
Gender (1 = female)	0.590	0.492
Race (1 = white)	0.841	0.365
Marital status (1 = married)	0.542	0.498
Number of children in household	1.270	2.370
Number of adults in household	1.823	0.693
Annual household income level		
Less than \$ 10,000	0.054	0.227
Less than \$ 15,000	0.058	0.234
Less than \$ 20,000	0.078	0.268
Less than \$ 25,000	0.097	0.296
Less than \$ 35,000	0.125	0.331
Less than \$ 50,000	0.157	0.364
Less than \$ 75,000	0.163	0.70
\$ 75,000 or more	0.266	0.441
Education (1 = highschool graduate or higher)	0.614	0.487
Health insurance coverage (1 = yes)	0.896	0.305
State-Level Characteristics		
% Unemployment rate	5.613	2.20
\$ Specific excise beer tax (per gallon)	0.267	0.204
\$ Cigarette state tax (per pack)	1.273	1.001
PDMP "must access" (1 = yes)	0.082	0.274

Notes: The table presents means and standard deviations (SD) for the dependent variables as well as for the individual- and state-level characteristics. All calculations are based on non-imputed data. Logarithm of the number of bad mental health days is specified as $\log(1 + \text{number of bad mental health days})$.

6. Empirical Strategy

A naive OLS regression of mental health on recreational marijuana policies would likely yield biased results due to persistent time-varying and time-invariant state characteristics. As presented in Figure 1, we can exploit the staggered implementation of those policies across federal states and over time to overcome this bias by following the generalized difference-in-difference approach. More specifically, we estimate the effects of recreational marijuana legalization laws on mental health by applying a two-way fixed effects regression model. If the treatment effects are constant across groups i.e., states, and over time, this model can estimate the average treatment effect on the treated (ATT), assuming the common trend assumption to be fulfilled (De Chaisemartin and d’Haultfoeuille, 2020; Meinhofer et al., 2021).

In our analysis, we control for time-invariant state characteristics using state fixed effects. Additionally, time fixed effects capture time-varying but state-invariant factors, such as common shocks to marijuana use or common trends across the states. Therefore, our specification is:

$$y_{ist} = \beta_0 + \beta_1 RML_{st} + \gamma_1 X'_{ist} + \gamma_2 Z'_{st} + \delta_s + \omega_t + \delta_s \cdot t + \epsilon_{ist}, \quad (1)$$

where i represents the individual, s represents the state and t represents the time which is a month-to-year combination. y_{ist} denotes an individual’s mental health outcome. RML_{st} is the policy indicator equal to 1 if the state s passed the RML law in time t , and 0 otherwise. Thus, we compare health outcomes of individuals in states which adopted RMLs to individuals in states which did not adopt RMLs. In our analyses, β_1 represents our parameter of interest. X'_{ist} and Z'_{st} are the vectors of individual- and state-level controls, respectively, as depicted in Table 1. At the state level, we also explicitly control for the enactment of medical marijuana legalization laws as every RML state adopted medical marijuana legalization laws previously. δ_s captures the state fixed effects and ω_t the month-to-year fixed effects. Additionally, we follow the literature on marijuana legalization policies and include a state-specific linear time trend $\delta_s \cdot t$. The rationale behind this step is that unobserved time varying

factors at the state level which might develop constantly e.g., cultural and social norms or public sentiments, could likely be correlated with the enactment of recreational marijuana policies and mental health (Choi et al., 2019; Wen et al., 2015). Finally, ϵ_{ist} represents the error term. We estimate Equation (1) by using a linear probability model and address potential correlations in the error terms within states by clustering the standard errors at the state level.

Besides this basic model, we follow Pacula et al. (2015) and Powell et al. (2018) and exploit the policy heterogeneity of marijuana legalization laws discussed in Section 2. More specifically, we introduce the effectiveness of operational recreational marijuana dispensaries to our regression. Empirical evidence shows that operational marijuana dispensaries are strongly associated with a facilitated access to and consumption of marijuana. Therefore, only considering a simple indicator of RML adoption in the analysis might lead to inadequate estimates of recreational marijuana legalization laws on mental health (Pacula et al., 2015; Powell et al., 2018). Consequently, we augment Equation (1) and include an additional indicator for whether recreational marijuana dispensaries became operational:

$$y_{ist} = \beta_0 + \beta_1 RML_{st} + \beta_2 RMD_{st} + \gamma_1 X'_{ist} + \gamma_2 Z'_{st} + \delta_s + \omega_t + \delta_s \cdot t + \epsilon_{ist}. \quad (2)$$

Similar to Equation (1), RMD_{st} equals 1 if the state s passed the RMD law in time t , and 0 otherwise. Note that besides controlling for medical marijuana legalization laws, here we also control for whether MMDs became operational at the state level.

Our framework is based on the key identifying assumption of parallel trends. This means that in the absence of the treatment i.e., recreational marijuana legalization policies, trends in mental health would be the same in treatment and control states. We will investigate this fact in more detail in Section 7.1 by using an event study approach. We estimate the following equation and use years instead of months of policy implementation dates to reduce noise:

$$y_{ist} = \beta_0 + \sum_{j=-5}^5 \theta_j \times 1\{\tau_{ist} = j\} + \gamma_1 X'_{ist} + \gamma_2 Z'_{st} + \delta_s + \omega_t + \delta_s \cdot t + \epsilon_{ist}, \quad (3)$$

where τ_{ist} denotes the event year. $\tau_{ist} = 0$ indicates that a recreational marijuana legalization policy was introduced in state s . Hence, $\tau_{ist} = 1$ is one year after the legalization, $\tau_{ist} = 2$ are two years after the legalization, and so on. For $\tau_{ist} \leq -1$, states where untreated i.e, no recreational marijuana policies were introduced⁴. Note that $j = -5$ and $j = 5$ corresponds to more than five years before and after the policy implementation, respectively. The coefficients θ_j were measured relative to one year before the policy introduction ($\theta_j = -1$)⁵. Similar to Equation (1) and Equation (2), our event study approach includes individual- and state-level covariates, state and time fixed effects as well as a state-specific linear time trend.

7. Results

In the following section we will first present our results regarding the effects of marijuana legalization policies on mental health, with focus on RML and RMD. In the second subsection, we will further investigate which of the channels described in Section 4 are supported by our results.

7.1. Main Results

Table 2 presents the effects of recreational marijuana policies on mental health. All regressions include state and month-to-year fixed effects, individual- and state-level controls as well as a state-specific linear time trend. As already mentioned in Section 6, we explicitly control for the enactment of medical marijuana laws and dispensaries. For reference, the coefficients for MML and MMD are also presented in Table 2. While the first two columns consider a dummy for mental health as a dependent variable, columns 3 and 4 consider logarithm of bad mental health days in the last 30 days.

Column 1 presents the basic model without accounting for policy heterogeneity introduced by operational marijuana dispensaries (see Equation (1)). In this case, the legalization of recreational marijuana decreases the probability of having at least one

⁴In an event study approach, $\tau_{ist} \leq -1$ are called leads and $\tau_{ist} \geq 1$ are called lags.

⁵Studies which investigate the effects of marijuana legalization policies on public health outcomes usually use the same baseline period i.e., one year before the legalization (Baggio et al., 2020).

bad mental health day in the last 30 days by 0.3 p.p. This corresponds to a 0.94 % decrease relative to sample mean. However, this estimate is not statistically significant.

Column 2 estimates Equation (2) and includes the effects of operational marijuana dispensaries. Hereby, the coefficient for RML remains negative and insignificant. However, the results for RMD suggest that recreational marijuana dispensaries have a negative effect on mental health. Opening operational RMDs is associated with an 2.3 p.p increase in the probability of having at least one bad mental health day, which corresponds to a 7.23 % increase relative to the sample mean. This results is statistically significant at the 10 % level.

Table 2: Effects of Recreational Marijuana Legalization Policies on Mental Health

	Dummy		Log	
	(1)	(2)	(3)	(4)
RML	-0.003 (0.011)	-0.015 (0.014)	-0.01 (0.023)	-0.031 (0.03)
RMD		0.023* (0.012)		0.04* (0.023)
MML	-0.014** (0.006)	-0.01** (0.005)	-0.029** (0.012)	-0.022** (0.010)
MMD		-0.006 (0.006)		-0.01 (0.012)
Pre-RML mean	0.318	0.318	0.653	0.653
R^2	0.084	0.084	0.096	0.096
No. of Observations	8,650,247	8,650,247	8,650,247	8,650,247

Notes: Results from weighted two-way fixed effects regressions with a dummy as a measure for mental health (columns 1-2) and logarithm of bad mental health days (columns 3-4) as dependent variables. *RML* = Recreational Marijuana Legalization, *RMD* = Recreational Marijuana Dispensary, *MML* = Medical Marijuana Legalization, *MMD* = Medical Marijuana Dispensary. Robust standard errors clustered at the state level are in parentheses. All regressions include state and time fixed effects, individual- and state-level controls as specified in Table 1, as well as a state-specific linear time trend. Constants are included. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, columns 3 and 4 of Table 2 also estimate Equation (1) and (2), respectively, but use a logarithmic transformation of bad mental health days as a dependent variable. Our findings suggest that similar to columns 1 and 2, recreational marijuana legalization positively affects mental health albeit not showing statistical significance.

In line with column 2, the coefficient for RMD in column 4 is positive and statistically significant at the 10 % level. More specifically, the introduction of recreational marijuana dispensaries is associated with an 4 % increase in bad mental health days. Consequently, considering an alternative specification of the outcome variable does not change our findings. Therefore, we facilitate our further analyses and henceforth use the dummy variable as our main measure of mental health.

Figure 3 shows the results for the event study and reveals that our findings for RML do not seem to be driven by pre-existing trends. Before the recreational marijuana legalization, the trends for mental health in treated and control states are flat i.e., the effects of leads ($\tau_{ist} \leq -1$) are virtually zero and not statistically significant. Although not significant, the effect of RML on mental health is the strongest in the second year after the legalization but dissipates afterwards. For recreational marijuana dispensaries, we also do not find any significant effects before the policy implementation which indicates that the parallel trend assumption does not seem to be violated (see Figure 4). However, the pre-treatment coefficients follow a monotonic upward trend which continues after the opening of recreational marijuana dispensaries. Therefore, we cannot fully exclude pre-existing trend differences in mental health between treated and controlled states.

Furthermore, Figure 4 shows that RMDs do not immediately lead to a significant reduction in the mental well-being but two years after their openings. Hence, we observe differences in short- and long-term effects. This can be explained by staggered openings of recreational marijuana dispensaries and non-immediate information spread about the availability of and thus, accessibility to recreational marijuana (Baggio et al., 2020).

Overall, our findings emphasize the importance of distinguishing between RML and RMD when investigating (recreational) marijuana legalization policies. Therefore, we include the additional dimension of operational marijuana dispensaries in our further analysis and treat Equation (2) as our main specification.

It is noteworthy that our findings further support the existing literature on the effects of MMLs on (self-reported) mental health. The enactment of medical marijuana laws leads to a significant decrease in the probability of having at least one bad mental

Figure 3: Event Study Analysis: Effects of Recreational Marijuana Legalization Laws on Mental Health

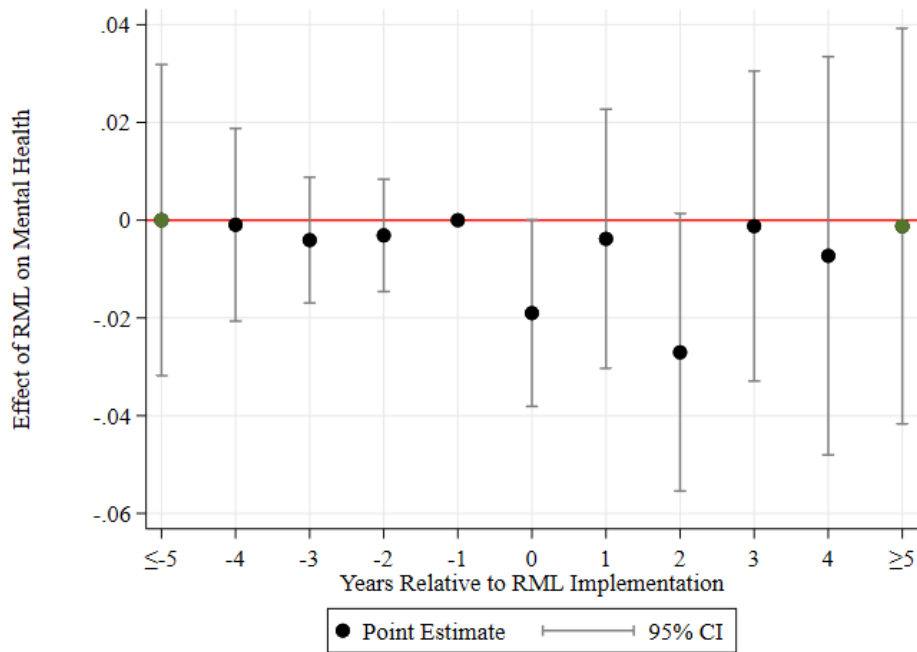
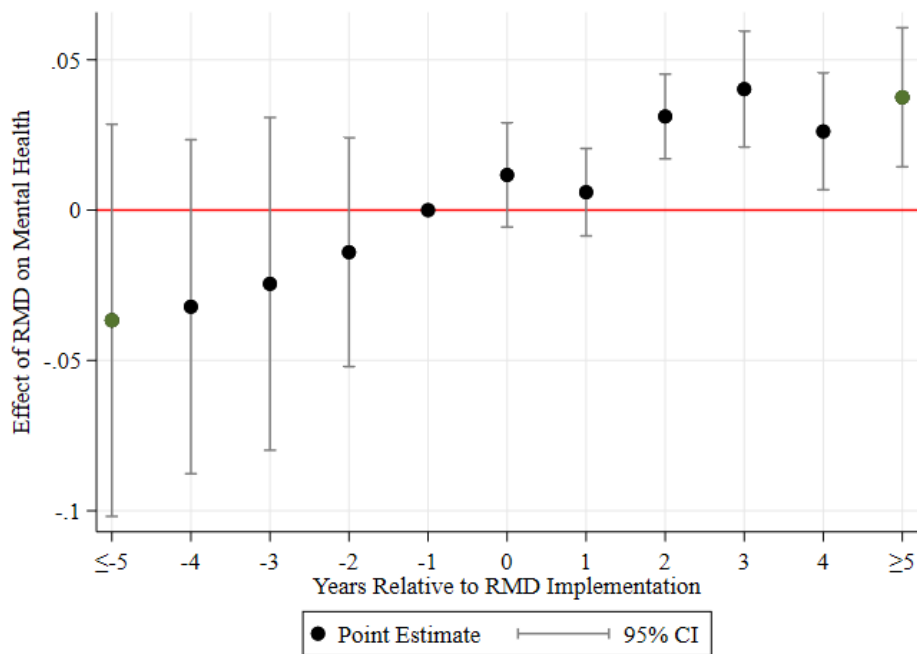


Figure 4: Event Study Analysis: Effects of Recreational Marijuana Dispensaries on Mental Health



Notes: Figure 3 and Figure 4 consider the dummy variable as a measure of mental health.

health day in the last 30 days by 1-1.4 p.p. (see Andreyeva and Ukert (2019), Kalbfuß et al. (2018) and Sabia et al. (2017)). In contrast, opening of operational medical marijuana dispensaries do not seem to affect mental health.

The importance of the dispensaries seems to differ between the treatment types. While it is necessary to include controls for the existence of dispensaries to capture the effect of recreational marijuana, this does not seem to matter for medical marijuana. The reason behind this is likely to be the difference in marijuana availability provided by those laws. Early adopters of MMLs allowed the home growing of plants under the supervision of physicians combined with a decriminalization of marijuana for medical purposes (Bridgeman and Abazia, 2017). Therefore, the enactment of MMLs already led to a sufficient availability of medical marijuana to meet the demand even without dispensaries. In contrast, recreational marijuana mostly needs to be bought in dispensaries and not all RML states make marijuana easily accessible to the consumers. For example, there still exist several RML states which did not open dispensaries. Furthermore, we also would not expect effects of recreational marijuana to be present before the opening of dispensaries. The reasoning behind this is that we do not expect consumption to reach a reasonable level without dispensaries as recreational consumers are likely to have less intrinsic motivation to produce their own products, compared to medical marijuana consumers. Therefore, it might be that it is the introduction of dispensaries with ready-to-consume products which increases the demand for recreational marijuana to the extent that effects are measurable.

7.2. Exploring Possible Treatment Channels

Our results in Table 2 suggest that the significant effects of medical and recreational marijuana legalization have different signs. While the approval of medical marijuana is associated with a decrease in the probability of having at least one bad mental health day, the availability of recreational marijuana seems to be harmful for the mental well-being. In the following, we will discuss these results using the channels presented in Section 4.

The first channel suggests that recreational marijuana legalization laws might have

a negative spillover effect on mental health through increased marijuana consumption. The positive coefficients for RMD in columns 2 and 4 of Table 2 are in line with this hypothesis. However, MML seems to have a positive spillover effect on mental health. To explain the difference between recreational and medical marijuana estimates, we recall that the MML coefficient can be decomposed into a pure marijuana consumption component and a pain-relief component. The target population of MML could experience negative spillover effects on mental health through the actual marijuana consumption which are outweighed by strong positive spillovers through the alleviating pain effects of marijuana. As this medical component is arguably not present in recreational marijuana, we claim that RMD could likely capture the sign of the pure marijuana consumption effect⁶.

The second channel explores negative or positive spillover effects of recreational marijuana availability on mental health through possible complementary or substitution effects on alcohol or opioid use. We investigate this hypothesis in more detail by focusing our analysis on the effects of recreational marijuana legalization on alcohol consumption⁷. Hereby, we follow Equation (2) but use the probability of whether a person had any alcohol beverages in the last 30 days as a dependent variable⁸. Table A.2 in the appendix shows that recreational marijuana legalization laws but also the presence of operative recreational marijuana dispensaries are associated with an increase in the alcohol consumption. However, both coefficients are relatively small and not statistically significant. Hence, we do not expect alcohol consumption to be a possible driver of the negative spillover effects of RMD on mental health.

In conclusion, it is likely that the negative effect of recreational marijuana availability on mental health is due to the facilitated access to and consumption of marijuana. However, given our data we cannot fully exclude other possible drivers, such as opioid

⁶Unfortunately, BRFSS does not include any survey questions with respect to marijuana consumption in its questionnaire. Therefore, we cannot fully confirm this hypothesis.

⁷Note that BRFSS does not provide any information on opioid use in its data. Therefore, we can only investigate possible spillover effects of RML and RMD on alcohol consumption.

⁸More specifically, we use survey responses to the following question: *"During the past 30 days, how many days per week or per month did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage or liquor?"*. We create a dummy variable equal to 1 if a respondent had any alcoholic beverages in the last 30 days, and 0 otherwise.

use, or whether marijuana consumption increased after recreational marijuana legalization. Nevertheless, invoking the existing evidence presented in Section 3, we argue that recreational marijuana availability actually increases the marijuana prevalence (Anderson et al., 2020; Guttmanova et al., 2017; Sabia et al., 2021).

8. Heterogeneity Analysis

In our previous analyses we presented the effects of recreational marijuana policies on mental health in the general population. However, our findings do not necessarily apply to all subpopulations with different sociodemographic characteristics. Hence, in this section we investigate heterogeneous treatment effects across several subgroups by estimating Equation (2) separately by age and gender. As discussed in Section 7.1, we continue to use the dummy variable as our main measure of mental health to facilitate our interpretation.

Table 3 shows that recreational marijuana legalization does not have a statistically significant effect on any of the subgroups. However, recreational marijuana dispensaries seem to affect several subpopulations differently. In terms of gender, only females seem to experience significant disadvantages of recreational marijuana availability. Column 1 suggests that RMDs are associated with an 2.7 p.p. increase in the probability of having at least one bad mental health day for females (about 10 % relative to the sample mean). This estimate for males is also positive but not statistically significant.

Columns 3-5 in Table 3 present the estimates of (recreational) marijuana laws by age. For the definition of age subsamples we follow the literature on medical marijuana policies which suggests that MMLs tend to have a larger effect on individuals under 30 and the elderly population. Moreover, while the older group is likely to use marijuana for medical purposes, people under 30 will mainly consume it for recreational purposes⁹ (Choi et al., 2019). Hence, we consider the following three age

⁹The interpretation that young adults abuse MML to consume recreational marijuana stems from a literature that solely focuses on MML. However, as we are able to dissect the effects to capture both medical and recreational policies, we argue that there is likely to be another explanation for the strong effects of MML on this age group. Higher awareness among young adults for mental health issues and

clusters: young adults (18-29 years), adults (30-64 years) and elderly people (65+ years). Recreational marijuana dispensaries have a significant negative effect on mental health

Table 3: Heterogeneous Effects of Recreational Marijuana Legalization Policies on Mental Health by Gender and Age Groups

	Gender		Age		
	Female	Male	Young Adults (18-29)	Adults (30-64)	Elderly (65+)
	(1)	(2)	(3)	(4)	(5)
RML	-0.016 (0.012)	-0.014 (0.017)	-0.004 (0.018)	-0.018 (0.013)	-0.024 (0.017)
RMD	0.027** (0.011)	0.02 (0.014)	0.029* (0.018)	0.022** (0.009)	0.018 (0.015)
MML	-0.010** (0.005)	-0.010** (0.005)	-0.022*** (0.007)	-0.005 (0.005)	-0.010** (0.004)
MMD	-0.005 (0.006)	-0.007 (0.007)	0.0002 (0.008)	-0.008 (0.006)	-0.003 (0.007)
Pre-RML mean	0.260	0.358	0.451	0.354	0.199
R^2	0.073	0.077	0.046	0.071	0.038
No. of Observations	3,544,273	5,104,617	945,985	5,060,982	2,553,760

Notes: Results from weighted two-way fixed effects regressions with a dummy as a measure for mental health as the dependent variable. *RML* = Recreational Marijuana Legalization, *RMD* = Recreational Marijuana Dispensary, *MML* = Medical Marijuana Legalization, *MMD* = Medical Marijuana Dispensary. Robust standard errors clustered at the state level are in parentheses. All regressions include state and time fixed effects, individual- and state-level controls as specified in Table 1, as well as a state-specific linear time trend. Constants are included. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

for people under 64 years: the availability of recreational marijuana increases the probability of having at least one bad mental health day by 2.9 p.p. and 2.2 p.p. for young adults and adults, respectively. These findings are in line with our result for the general population that RMDs are necessary for the effect of recreational marijuana to unfold. However, for elderly population over 65 years only MMLs seem to significantly affect mental health. While medical marijuana legalization has a positive spillover effect on the mental well-being, the RMD coefficient is not statistically significant. The reason for that could be that elderly people tend to use marijuana usually for medical

the pure medical use of marijuana could also increase the take-up rate of medical marijuana and thus, the effects among this age group.

purposes e.g., to alleviate pain. Hence, the introduction of recreational marijuana dispensaries would most likely not affect this subgroup.

9. Robustness Check

As our empirical strategy makes use of multiple treated states to identify the effects of recreational marijuana legalization on mental health, one might be concerned that our results are driven by the experiences of a few treated states (Sabia et al., 2021). To address this possible drawback, we implement a leave-one-out analysis and re-run our main specification according to Equation (2). Hereby, we omit each treated RML state in turn from our sample which results in 12 separate regressions¹⁰. The results of these regressions are presented in Table A.3 in the appendix. The coefficients for RML are all negative and statistically insignificant. Similarly, after excluding each treated state from the analysis, the estimates for RMD remain stable. Therefore, we conclude that our results are not driven by a few treated states.

10. Conclusion

Our results contribute to the very limited literature on the effects of recreational marijuana legalization policies on mental health. To the best of our knowledge, this paper provides the most comprehensive overview of such impacts. Using monthly individual-level data from the Behavioral Risk Factor Surveillance System (BRFSS), we exploit the staggered implementation of the laws across states and over time by following a two-way fixed effects regression model. Our findings suggest that recreational marijuana legalization only significantly affects mental health through operational marijuana dispensaries. The introduction of RMDs increases the probability of having at least one bad mental health day in the last 30 days by 2.3 p.p., which corresponds to a 7.23 % increase relative to the sample mean. In contrast, the sole enactment of recreational marijuana legalization laws does not significantly affect mental health.

¹⁰Similar to Section 8, we continue to use the dummy variable as our main measure of mental health.

Hence, our paper underlines the importance of RMDs when investigating recreational marijuana legalization policies.

By following an event study approach we show that our key identifying assumption i.e., the existence of parallel pre-trends, does not seem to be violated. Furthermore, this analysis reveals that the effect of recreational marijuana dispensaries on mental health does not begin immediately but two years after their opening. Finally, our discussion in Section 7.2 suggests that RMDs are likely to affect mental health through increased marijuana consumption although we cannot fully exclude possible other drivers, such as opioid (ab-)use.

From a policy perspective, our results emphasize the multidimensional impact of recreational marijuana legalization policies on public health. Due to negative effects on mental health, policymakers need to weigh the social costs and benefits of such laws. Should governmental taxation gains or increased producer and consumer surplus be valued higher than possible adverse effects, such as decreased mental well-being? However, our analysis shows that the legalization only becomes harmful to individuals' mental health after the opening of dispensaries. This creates an opportunity for policy makers to limit possible adverse effects of legalizing recreational marijuana. By restricting such policies to the sole legalization without introducing RMDs, consumers do not have a facilitated access to ready-to-use products. In combination with drug education programs this might be the right step towards reduced prevalence, a higher awareness of possible consequences of marijuana use and thus, reduced health care costs for the society.

We acknowledge three limitations of our paper. First, using self-reported data, our investigations might suffer from potential biases of misreporting. Respondents might not admit that they had a bad mental health day because they are afraid of being stigmatized or are lacking awareness about the mental well-being. Second, recreational marijuana legalization policies became effective only recently compared to medical marijuana legalization policies and only in few states. Thus, there is a limited geographical and temporal variation in the RML and RMD implementations which might be a caveat for our analyses. Especially for RMD, our estimations are based on the variation from only few states which are additionally early adopters i.e., they

introduced MMLs before 2010. In general, those states have less stringent regulations for marijuana dispensaries compared to late adopters (Meinhofer et al., 2021; Powell et al., 2018). Thus, our results may not be generally extended to future RMDs and should be considered with caution. Finally, without data on marijuana or other drug use, we could only hypothesize that the negative effect of recreational marijuana availability on mental health is due to the facilitated access to and consumption of marijuana. Even though the literature suggests increased prevalence after the legalization of recreational marijuana, given the limitations of our data we cannot fully exclude possible other drivers, such as opioid (ab-)use.

Our limitations and the very thin evidence on recreational marijuana legalization policies on mental health open a gap for future research. As the legalization of recreational marijuana is accelerating, it would be interesting to gain further knowledge about its effects on mental health and possible drivers behind those impacts. Hereby, further studies could contribute valuable insights to the public debate and support policymakers in comparing social costs and benefits of such policies.

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Appendix A.

Table A.1: Effective Dates of Medical and Recreational Marijuana Legalization Policies

	MML	MMD	RML	RMD
Alabama	17 May 2021*	-	-	-
Alaska	04 Mar 1999	29 Oct 2016	24 Feb 2015	29 Oct 2016
Arizona	29 Nov 2010	06 Dec 2016	30 Jan 2021*	-
Arkansas	09 Nov 2016	11 May 2019	-	-
California	06 Nov 1996	01 Nov 1996	09 Nov 2016	01 Jan 2018
Colorado	28 Dec 2000	01 Jul 2005	10 Dec 2012	01 Jan 2014
Connecticut	01 Oct 2012	22 Sep 2014	01 Jul 2021*	-
Delaware	01 Jul 2010	26 Jun 2015	-	-
District of Columbia	27 Jul 2010	29 Jul 2013	26 Feb 2015	-
Florida	03 Jan 2017	19 Dec 2018	-	-
Georgia	-	-	-	-
Hawaii	14 Jun 2000	08 Aug 2017	-	-
Idaho	-	-	-	-
Illinois	01 Apr 2014	09 Nov 2015	01 Jan 2020	-
Indiana	-	-	-	-
Iowa	-	-	-	-
Kansas	-	-	-	-
Louisiana	19 May 2016	06 Aug 2019	-	-
Maine	23 Dec 1999	01 Apr 2011	30 Jan 2017	09 Oct 2020
Maryland	01 Jun 2014	01 Dec 2017	-	-
Massachusetts	01 Jan 2013	24 Jun 2015	15 Dec 2016	20 Nov 2018
Michigan	04 Dec 2008	01 Dec 2009	06 Dec 2018	01 Dec 2019
Minnesota	30 May 2014	01 Jul 2015	-	-
Mississippi	-	-	-	-
Missouri	06 Dec 2018	-	-	-
Montana	02 Nov 2004	01 Apr 2009	01 Jan 2021*	-
Nebraska	-	-	-	-
Nevada	01 Oct 2001	31 Jul 2015	01 Jan 2017	01 Jul 2017
New Hampshire	23 Jul 2013	30 Apr 2016	-	-
New Jersey	01 Jun 2010	06 Dec 2009	01 Jan 2021*	-
New Mexico	01 Jul 2007	01 Jun 2009	29 Jun 2021*	-
New York	05 Jul 2014	01 Jan 2016	31 Mar 2021*	-
North Carolina	-	-	-	-
North Dakota	08 Dec 2016	01 Mar 2019	-	-
Ohio	08 Sep 2016	10 Jan 2019	-	-
Oklahoma	26 Jul 2018	26 Oct 2018	-	-
Oregon	03 Dec 1998	01 Jul 2009	01 Jul 2015	01 Oct 2015
Pennsylvania	17 Mai 2016	17 Jan 2018	-	-
Rhode Island	03 Jan 2006	19 Apr 2013	-	-
South Carolina	-	-	-	-
South Dakota	18 Nov 2021*	-	-	-
Tennessee	-	-	-	-
Texas	-	-	-	-
Utah	03 Dec 2018	-	-	-
Vermont	01 Jul 2004	01 Jun 2013	01 Jul 2018	-
Virginia	01 Jul 2020	01 Aug 2020	01 Jul 2021*	-
Washington	03 Dec 1998	01 Oct 2009	06 Dec 2012	08 Jul 2014
West Virginia	01 Jul 2019	-	-	-
Wisconsin	-	-	-	-
Wyoming	-	-	-	-

Notes: *MML* refers to the date when medical marijuana legalization laws became effective. *MMD* denotes the dates when medical marijuana dispensaries became operational. *RML* refers to the date when recreational marijuana legalization laws became effective. *RMD* denotes the dates when medical marijuana dispensaries became operational. In states which are marked with a *, marijuana policies became effective after 2020. As already mentioned in Section 5.2, we exclude those from our analyses.

Table A.2: Effects of Recreational Marijuana Legalization Policies on Alcohol Consumption

	(1)
RML	0.004 (0.013)
RMD	0.002 (0.01)
Pre-RML mean	0.502
R^2	0.131
No. of Observations	8,250,315

Notes: Results from a weighted two-way fixed effects regression. We measure alcohol consumption as an indicator variable which takes value 1 if the respondent has drunk alcoholic beverages at least on one day in the last 30 days, and 0 otherwise. *RML* = Recreational Marijuana Legalization, *RMD* = Recreational Marijuana Dispensary. Robust standard errors clustered at the state level are in parentheses. All regressions include state and time fixed effects, individual- and state-level controls as specified in Table 1, a state-specific linear time trend as well as controls for medical marijuana legalization laws. Constants are included. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.3: Leave-One-Out Analysis

	w/o Alaska (1)	w/o California (2)	w/o Colorado (3)
RML	-0.016 (0.015)	-0.01 (0.023)	-0.017 (0.016)
RMD	0.024* (0.012)	0.032 (0.02)	0.022* (0.013)
Pre-RML mean	0.318	0.317	0.318
R^2	0.084	0.085	0.084
No. of Observations	8,576,975	8,424,272	8,446,152
	w/o District of Columbia (4)	w/o Illinois (5)	w/o Maine (6)
RML	-0.015 (0.015)	-0.003 (0.01)	-0.014 (0.015)
RMD	0.026* (0.012)	0.011* (0.006)	0.022* (0.012)
Pre-RML mean	0.318	0.318	0.318
R^2	0.084	0.085	0.084
No. of Observations	8,571,485	8,529,592	8,489,145
	w/o Massachusetts (7)	w/o Michigan (8)	w/o Nevada (9)
RML	-0.023 (0.015)	-0.021 (0.016)	-0.015 (0.015)
RMD	0.029** (0.013)	0.025* (0.019)	0.023* (0.012)
Pre-RML mean	0.318	0.318	0.318
R^2	0.084	0.084	0.084
No. of Observations	8,386,390	8,465,943	8,565,163
	w/o Oregon (10)	w/o Vermont (11)	w/o Washington (12)
RML	-0.017 (0.015)	-0.016 (0.015)	-0.018 (0.016)
RMD	0.022* (0.012)	0.024* (0.012)	0.024* (0.014)
Pre-RML mean	0.318	0.318	0.317
R^2	0.084	0.084	0.084
No. of Observations	8,523,115	8,508,939	8,312,944

Notes: Results from weighted two-way fixed effects regressions with a dummy as a measure for mental health as the dependent variable. *RML* = Recreational Marijuana Legalization, *RMD* = Recreational Marijuana Dispensary. Robust standard errors clustered at the state level are in parentheses. All regressions include state and time fixed effects, individual- and state-level controls as specified in Table 1, a state-specific linear time trend as well as controls for medical marijuana legalization laws. Constants are included. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.