

The Effect of Recreational Marijuana Laws on Schizophrenia and Psychotic Disorders*

Matt Brown[†]

October 22, 2025

Abstract

Amid the ongoing liberalization of state recreational marijuana laws (RMLs), the National Institutes of Health has expressed concern that expanded marijuana access may elevate the prevalence of schizophrenia and psychotic disorders across the United States. This study presents one of the first causal estimates of the impact of RMLs on the incidence of schizophrenia and other psychotic disorders. Leveraging a generalized difference-in-differences framework to exploit the staggered rollout of RMLs, I first document that the passage of RMLs with recreational dispensaries generates a 20% increase in the rate of prior-month marijuana use in treated states relative to controls. Next, I show that RML adoption with dispensaries leads to a 12% increase in the incidence of schizophrenia and other psychotic disorders at state-sponsored mental health facilities nationwide. These findings suggest that RMLs permitting dispensaries may have unintended adverse effects on the prevalence of schizophrenia.

Keywords: Recreational Marijuana Laws, Schizophrenia, Psychosis, Mental Health

*I thank Michele Baggio, Delia Furtado, Bokyung Kim, Steve Ross, and David Simon for their helpful comments. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

[†]Department of Economics, University of Connecticut. Email: matthew.2.brown@uconn.edu

1 Introduction

Schizophrenia is a debilitating mental health disorder affecting approximately 1% of the US population, generating \$343 billion in excess costs in 2019 due to caregiving, premature mortality, and unemployment (Kadakia et al., 2022). The disorder typically manifests in late adolescence or early adulthood and persists chronically. In addition to experiencing psychotic symptoms such as distorted perceptions and thoughts, individuals with schizophrenia often suffer significant cognitive and functional impairments, particularly in working memory, motivation, and attention span (Ahmed et al., 2021). Co-occurring substance use disorders are frequently observed in psychotic patients as compared to the general population, most commonly with marijuana (Green et al., 2005; Mueser et al., 2000; Ringen et al., 2008; Sevy et al., 2001).

For the past several decades, psychiatric literature has explored the link between schizophrenia and other psychotic disorders with marijuana use. Most of this literature descriptively identifies a positive correlation between marijuana use and the development of psychosis (Caulkins et al., 2015; Gage et al., 2016; Lebowitz et al., 2021; Murray et al., 2016; Ranganathan et al., 2016). There is also some evidence of a dose-response relationship between cannabis use and psychosis risk (Marconi et al., 2016). As Lebowitz (2021) notes, “Decades of longitudinal studies have identified an association between cannabis use and psychosis.”

Building on the evidence-base that includes such findings, researchers continue to develop theory on a complex causal relationship between marijuana and psychosis. Yet, little to no causal evidence exists using a statistical framework to establish a link between marijuana use and the onset or exacerbation of schizophrenia and other psychotic disorders. With ongoing liberalization of marijuana laws at the state level, the National Institutes of Health and several authors have voiced concern about whether easier access to marijuana will generate higher prevalence rates of schizophrenia, citing a need for further investigation (Elser et al., 2023; Ho et al., 2023; Murray et al., 2016).

This paper helps fill this gap by testing the effects of recently passed recreational marijuana laws (RMLs) on rates of schizophrenia and other psychotic disorders at mental health treatment facilities throughout the United States in a causal framework. Specifically, I estimate the effect of RMLs with recreational dispensaries on the prevalence of schizophrenia and other psychotic disorders at state-sponsored mental health treatment facilities using a difference-in-differences event study framework, exploiting the staggered adoption of RMLs across states over time. The analysis uses state-year data on marijuana use from the 2002-2019 National Survey on Drug Use and Health (NSDUH), and state-year data on schizophrenia treatment cases from SAMHSA’s Mental Health Client Dataset (MH-CLD) from 2013-2022. The outcomes of interest are the prevalence rate of prior-month marijuana use, the rate of schizophrenia or other psychotic disorder treatment cases per 1,000 of the state population, and the rate of disordered cannabis use diagnoses per 1,000 state population. All analyses utilize a generalized difference-in-differences method, augmented with newly created event-study estimators that consider dynamic heterogeneous treatment effects in staggered treatment adoption frameworks (Goodman-Bacon, 2021; Sun & Abraham, 2021).

Using this approach, I first document that the final phase of recreational marijuana liberalization, the opening of recreational dispensaries,¹ leads to a 1.42 percentage point increase in the prevalence of prior-month adult marijuana consumption over and above marijuana decriminalization, medical marijuana laws, and RMLs which only permit possession and home cultivation. For the population aged 18+, this constitutes a 20% increase in the prevalence of prior-month marijuana use relative to the pre-treatment mean among adopting states. This is similar to other findings in existing research. For example, Sabia et al. (2021) found that the passage of RMLs increased prior-month adult marijuana use by 1.59 percentage points.²

Next, I present causal evidence that RMLs increase the yearly incidence of both cannabis use disorder (CUD) and co-occurring CUD with schizophrenia at mental health treatment facilities funded by state mental health agencies (SMHAs). My estimates indicate that the rollout of recreational dispensaries leads to an additional 0.102 diagnosed cases of CUD and 0.021 cases of co-occurring CUD with schizophrenia per 1,000 state population. This is an increase of 18.5% and 17.6% relative to the pre-treatment means among RML-adopting states, respectively.

Last, I find that recreational marijuana dispensaries opening lead to significant increases in rates and counts of unique treatment intakes for schizophrenia and other psychotic disorders at the same SMHA-sponsored treatment facilities. Overall, I document a 0.396 increase in schizophrenia cases per 1,000 state population after dispensaries open. This is roughly equal to a 12% increase over the pre-treatment mean of 3.27 cases per 1,000 state residents. The effects are dispersed heterogeneously by age and gender, with young men aged 21-29 experiencing the greatest proportional increases at 20%.

These findings make a critical contribution to the emerging literature by providing some of the first causal evidence on a significant positive relationship between recreational marijuana legalization and the prevalence of schizophrenia and other psychotic disorders. Over the past several decades, psychiatric literature has descriptively identified a positive relationship between marijuana use and schizophrenia, but none have robustly identified a causal relationship. For example Elser et al. (2023), the most similar study, found an insignificant 39% increase in psychosis-related diagnoses in states where recreational dispensaries had opened. Unlike their study, which relies on commercial claims data, this analysis draws on a substantially larger dataset that includes all individuals who access care through state-funded treatment facilities. This is likely to capture more of the population of individuals with schizophrenia, including those who are lower-income, publicly insured, or uninsured, groups often underrepresented in commercial data.

In another study using interrupted time-series methods, Kim et al. (2024) found contrasting evidence, as marijuana legalization was significantly associated with a decrease in emergency department visits involving cannabis and psychosis symptoms in patients with schizophrenia. Consistent with

¹Across the sample period, the average duration between RML passage and the first recreational dispensary opening was approximately 12 months (D. M. Dave et al., 2022).

²The model used by Sabia et al. (2021) does not isolate the effect of dispensaries opening from law passage, which could account for the difference in magnitude.

my findings, Wang et al. (2022) found a 24% increase in rates of psychosis emergency department visits in all counties in Colorado, specifically when dispensaries open. Using high dimensional fixed effects Poisson models, their results provided evidence of an overall positive association.

This paper provides two additional contributions to this body of research. First, all of the above papers rely on point-wise regression estimation, thus are unable to test the parallel trends assumption required for causal identification. In this paper I use event study methodology for all analyses, confirming that results are free from contamination by non-parallel trends. Furthermore, recent studies indicate that traditional TWFE models may be subject to bias when applied to settings with staggered policy adoption (Goodman-Bacon, 2021; Roth et al., 2023). This study applies recent methodological advancements that specifically address these potential sources of bias. The main event study results rely on the estimator developed by Sun and Abraham (2021). Second, by leveraging the MH-CLD 2013-2022 dataset, the analysis incorporates several more years of post-treatment data than most prior work. For example, the most contemporary work that uses U.S. national data to examine this question - Elser et al. (2023) - leverages data through December 2017. By that time only five states had opened recreational dispensaries, with the earliest in 2014. Between January 2018 and December 2022, nine additional states opened recreational marijuana dispensaries. Incorporating these additional treated states and years of data into the analysis facilitates a more comprehensive understanding of RML policy effects.

This paper also contributes to a broader literature on marijuana and health outcomes informing the policy discussion on marijuana legalization. As opportunities to study the impacts of marijuana use have arisen with legalization, researchers are seeking evidence to confirm or deny a wide range of suspected public health effects from increased use of the drug (Anderson & Rees, 2023). Health outcomes of relevance to voters and policymakers have been examined, including levels of adolescent marijuana use and opioid-related deaths. Other key outcomes highlighted in this body of research include traffic fatalities, workplace health, crime rates, and mental health concerns (Anderson & Rees, 2023). The findings in this study inform the public health debate by identifying a causal impact on a serious and costly mental health measure: increases in patients presenting with psychotic symptoms at state-funded mental health treatment facilities after recreational marijuana dispensaries open. This new finding indicates that when marijuana is made accessible to all adults, the rate of individuals with active, distressing psychotic symptoms increases.

This paper is structured as follows: Section 2 offers background on the relationship between marijuana use and schizophrenia, along with a review of the relevant literature and an in-depth exploration of how marijuana use may exacerbate the disorder. Section 3 outlines the data, while Section 4 details the methods. The main findings, along with heterogeneity analysis and robustness checks, are presented in Section 5. Lastly, Section 6 concludes by providing additional context and discussing the implications of my findings.

2 Background and Related Literature

2.1 Marijuana use and psychotic disorders

The public health concerns involved in the debate over marijuana legalization are examined in growing bodies of research on the impact of marijuana use on health conditions including psychotic disorders. Most of the psychiatric literature investigating the relationship between marijuana and schizophrenia has been correlational in nature (Caulkins et al., 2015; Elser et al., 2023; Gage et al., 2016). There are few clinical research trials investigating the effects of marijuana on psychosis, likely due to the federally illegal status of marijuana and associated ethical considerations. Researchers have instead largely relied on difference-in-difference estimation using longitudinal survey data. Generally, these studies have found that cannabis use and psychosis co-occur (Arseneault et al., 2004; Ferdinand et al., 2005; Fergusson et al., 2003; Henquet et al., 2005; Livne et al., 2022; Van Os, 2002; Weiser et al., 2002), or that schizophrenia follows heavy cannabis use (Andréasson et al., 1987). While non-medical cannabis users are up to three times more likely to report psychosis (Livne et al., 2022), this does not imply a causal relationship. For example, it is possible that people experiencing psychosis seek marijuana because of their symptoms (Bowers et al., 2001).

There is more compelling evidence on the causal link between marijuana use and psychosis from the few studies that conduct clinical research trials (Brown et al., 2023). For example, Vadhan et al. (2017) administered marijuana to 12 subjects in a laboratory, 6 of whom were clinical high-risk (CHR) for psychosis, to examine the acute psychological and physiological effects of the drug. They found that CHR marijuana smokers displayed temporary increases in acute psychotic behavior during marijuana intoxication, while control marijuana smokers did not. D’Souza et al. (2005) conducted a similar trial, administering marijuana intravenously in a laboratory setting to 13 stable schizophrenia patients being treated with antipsychotics. They found that, relative to healthy controls, THC transiently increased “positive, negative, and general schizophrenia symptoms” for the schizophrenic participants. These findings support the claim that psychotic patients experience marijuana differently than healthy subjects, but provide insufficient evidence to support a causal link (D’Souza et al., 2005).

Three recent observational studies have examined the link between recreational marijuana laws and schizophrenia (Elser et al., 2023; Vignault et al., 2021; Wang et al., 2022). Vignault et al. examined recreational law changes in Canada, comparing emergency psychiatric diagnostic codes before and after legalization during October 2016 to March 2019. Although they found statistically significant increases in rates of cannabis use disorder (CUD) among emergency psychiatric patients, they observed no statistically significant changes in rates of schizophrenia diagnoses (Vignault et al., 2021).

Wang et al. (2022) explored the impact of recreational legalization in Colorado through a difference-in-difference design, analyzing county-level administrative data from the Colorado Hospital Association from 2013 to 2018. They observed the rate of emergency department [ED] visits for

psychosis and schizophrenia, comparing counties with no prior cannabis dispensary to counties with low or high dispensary exposure. They found a large, statistically significant increase in rates of psychosis visits to the ED as recreational dispensaries per 10,000 residents increased.

Elser et al. (2023) used state-year commercial claims data from the 2003 to 2017 Optum Clininformatics Data Mart to explore the association between recreational marijuana legalization and psychosis-related diagnoses. They aggregated the data to a state-month panel to track monthly rates of psychosis-related health claims across states. While their analysis included state and time fixed effects, it did not engage a quasi-experimental framework to estimate causal effects. They found no statistically significant change in psychosis-related diagnoses following legalization overall. However, they reported a 39% increase in states where recreational dispensaries had opened - a result that narrowly missed conventional significance thresholds. Notably, their use of commercial claims data may limit the study's scope, whereas the MH-CLD dataset used in this study is more likely to capture all patients so long as they are admitted to any state institution at some point during the year. This includes people with less financial means who have public or no insurance at all, and only access treatment at state-funded facilities. This population may be more likely to use marijuana on the extensive margin, more likely to use on the intensive margin, or more vulnerable to experiencing psychotic episodes.

2.2 Variations in marijuana’s effects on psychotic illness

The nature of the relationship between marijuana and psychosis appears to have variations in which groups of at-risk individuals respond differently to the drug’s effects. This is important to take into account with regard to research design, particularly when aiming to clearly delineate the public health impacts of marijuana use. Many studies examine diagnoses of psychotic disorders in relation to cannabis use, but it may be more relevant to consider incidences of psychotic episodes or increased severity of symptoms.

While patterns in the existing literature generally support an association between marijuana use and psychotic experiences, in many cases these are temporary. For decades there has been debate over differentiating “cannabis psychosis” or cannabis-induced psychotic disorder as a distinct and transient condition dependent on marijuana use. It is possible that a subset of marijuana users experience an episode of psychotic symptoms without developing a chronic mental illness, while a separate group of users have an increased risk of incident schizophrenia or other psychotic disorders (Bowers et al., 2001; Gage et al., 2016). There are a number of studies that have demonstrated correlation between marijuana use or marijuana dependence and increased psychotic symptoms, such as in individuals who have a preexisting diagnosis of a psychotic disorder (Bowers et al., 2001; Gage et al., 2016). In a review of the literature, Degenhardt et al. (2003) described a dual relationship between marijuana use and psychosis. Marijuana use can have a detrimental impact on the severity of psychotic illness over the life course. At the same time, regular marijuana use is consistently found to be more common in people with schizophrenia as compared to the general population

(Degenhardt et al., 2003).

2.3 Challenges to research design

Although there are longstanding bodies of observational research documenting associations between marijuana and psychotic symptoms or schizophrenia, several methodological challenges make it difficult to confirm causality (Bowers et al., 2001; Caulkins et al., 2015; Gage et al., 2016). Historically, the evidence base for this association has relied on observational research such as patient case studies of psychotic symptoms following marijuana use, community-based survey data reporting rates of psychosis among marijuana users, studies of cannabis use initiation in temporal relation to the onset of schizophrenia, and epidemiological findings on risk of schizophrenia incidence in marijuana users (Bowers et al., 2001). Much of this literature has been critiqued for insufficient specificity such as a lack of standardized measures of both marijuana dosage and psychotic symptoms and diagnoses, timing of onset, and other aspects of schizophrenia, which is a complex disorder in nature (Bowers et al., 2001; Gage et al., 2016). More recently, researchers have utilized methods such as the experimental clinical trials described in the prior section, supporting the association between marijuana use and psychotic symptoms in certain groups of people both with and without schizophrenia diagnoses.

Despite the large body of support, we have yet to clearly establish either causality or the specific mechanisms of this relationship. The design of this study takes advantage of the natural experimental conditions observed with the staggered adoption of RMLs at the state level over recent years. Although RML adoption is not randomly assigned, the effects of the laws are most relevant for policymakers to consider. Additionally, public data gathered year-by-year throughout this period is able to capture a far greater number of participants than clinical trials.

2.4 Early marijuana use as a risk factor

A number of researchers have identified initiation of marijuana use at a young age as a potential risk factor for schizophrenia and other psychotic disorder diagnoses (Bowers et al., 2001; Chadwick et al., 2013; Gage et al., 2016; Ho et al., 2023). Some warn that public health consequences may be greatest for early use of marijuana, and that preventative efforts should be made, especially for youth who have risk factors for mental illness early in life (Arseneault et al., 2002). Some studies have found that individuals who experience their first psychotic episode at an earlier age are typically marijuana users, suggesting that marijuana use may trigger an earlier onset of the disorder. But again, causality has been difficult to determine (Bowers et al., 2001; Degenhardt et al., 2003). Notably, an earlier use effect may be confounded by effects of accumulative use over time, and there is evidence that controlling for accumulative use reduces the strength of association between age of first marijuana use and development of psychotic outcomes (Gage et al., 2016; Moore et al., 2007). Researchers also continue to examine the interactions between THC and developing brains during adolescence. At younger ages, cannabinoid receptors function in less stable ways than in adulthood, and may be

susceptible to THC use shifting the brain's developmental trajectory toward a disease-vulnerable state (Chadwick et al., 2013). Thus, researchers warn that there is sufficient evidence for public health warnings against use of marijuana at an early age due to the increased risk of psychosis.

2.5 Risk factors in an additive model

After systematic reviews of the existing evidence, some researchers have concluded that if there is a causal impact of marijuana use on psychosis, it is likely contingent on multiple factors such as dosage, timing of use in development, and pre-existing propensity for the disorder based on genetic disposition or other risk factors (Caulkins et al., 2015; Gage et al., 2016; Marconi et al., 2016). Furthermore, schizophrenia and other psychotic disorders are heterogeneous illnesses which may have variations that are more sensitive to THC use or respond to it in different ways (Bowers et al., 2001). Therefore, the effect may trigger the onset at an earlier age or potentially cause the disorder to arise in some users whose predisposition may otherwise have remained dormant. This aligns with estimations that the increased risk of developing psychosis after marijuana use has a small impact on the overall population. For example, in 2009 Hickman et al. estimated that if marijuana use is causal, approximately 1 in 1500 young men and 1 in 4000 young women are at risk of developing psychosis due to heavy marijuana use, with rates decreasing in older age groups. Thus, thousands of people would need to be prevented from using marijuana heavily in order to prevent each causal incidence of disease. Regardless, even if some cases are only accelerated by marijuana and would have had later onset, each instance of psychotic disorder poses substantial costs in person-years of debilitating illness (Caulkins et al., 2015).

The main mechanism through which marijuana use may impact psychotic disorders appears to be marijuana use among individuals with predisposed risk of developing such conditions. Current theorists explain that schizophrenia and other psychotic disorders are multifactorial complex diseases, so no one risk factor can be a deterministic cause alone, and some risk factors may be neither necessary nor sufficient (D'Souza et al., 2009; Gage et al., 2016). However, researchers are working to identify characteristics of people at higher risk of developing psychosis after marijuana use, potentially facilitating targeted interventions. These include those who start using marijuana early in life during adolescence, who are shown not only to have higher risk of psychosis, but also earlier onset of the disorder, and worse severity of symptoms over the life course (Dragt et al., 2012; Vita & Barlati, 2018). People at risk also include those who have experienced trauma in childhood or adulthood. Multiple studies have found that dual exposure to marijuana use and trauma increases the risk of psychosis to a greater degree than either risk factor alone (Harley et al., 2010; Houston et al., 2007; Vita & Barlati, 2018).

For example, Arranz et al. (2018) found evidence that marijuana has both a cumulative and dose-dependent effect, interacting with trauma in childhood as well as recent stress. Notably, these researchers classified marijuana use by frequency, with use more than once per week or daily designated "severe" use. The severe level of marijuana use was associated with recent onset of

psychosis, while low to moderate marijuana use was not. Compared to a group of healthy controls, those with recent onset psychosis were also more likely to have experienced childhood trauma, particularly physical abuse or neglect, as well as high rates of recent life stressors. Using a logit model, they found a cumulative effect of these three risk factors on the development of psychosis, with trauma being the strongest contributor, and marijuana use and recent stressful events further increasing the variance.

Current epidemiological theory supports the concept that co-exposure to two or more risk factors shows an additive risk for complex multifactorial diseases, and applies this model specifically to psychotic disorders (Chadwick et al., 2013; Zammit et al., 2010). Additional risk factors for psychotic disorders may include genetic susceptibility. Studies in this area have made initial findings of specific genetic variations increasing risk of psychotic disorders, although the literature does not yet have clear and robust conclusions (Di Forti et al., 2012; Gage et al., 2016). The potency of marijuana used is also being studied as a risk factor, as higher THC to CBD ratios may be associated with increased risk of psychosis, and higher dosing is more likely as high potency strains of marijuana have become more commonly available in recent years (Arranz et al., 2018; Di Forti et al., 2015).

Some risk factors are related to the recurrence of psychotic symptoms in individuals whose illness may otherwise have been in remission, although the field has not yet differentiated these factors fully. Stressful life events such as a recent trauma, bereavement, financial problems, and conflict are associated with relapse of psychotic symptoms and/or hospitalizations, as found in a systematic review of psychological medical studies on relapse rates among individuals with psychotic disorders (Martland et al., 2020).

A current understanding of marijuana use in relation to psychosis is that it is a risk factor, and is most likely to impact a small portion of the general population who also have additional risks for developing schizophrenia and other psychotic disorders. Marijuana use is not a necessary or sufficient causal factor alone, but confirming that it does have a role in causality for some cases or symptomatic episodes of psychotic disorders would help clarify the public health risks of legalizing recreational marijuana.

3 Data

3.1 National survey of drug use and health (NSDUH)

I first estimate changes in marijuana use for adults aged 18-65 with data from the 2002-2019 National Survey of Drug Use and Health (NSDUH). Although access to individual geocoded data is restricted, state-year means are publicly available. Data on marijuana use is collected in each survey wave and reported in overlapping 2-year periods.

The overlapping time dimension challenges the construction of state-level marijuana policy indicators that accurately reflect reality. To overcome this, I follow Choi et al. (2019) in designing marijuana policy indicators which precisely capture the fraction of the two-year period during which

the policy was in effect (Choi et al., 2019, p. 312). The values range from 0 for no adoption, to 1 for full adoption during the overlapping 2-year period. For example, if a state adopted the policy two-thirds of the way through the two-year period, the value would be 0.66.

The data for marijuana prevalence rates are generated from a survey question asking each respondent to self-report how many days in the last month they used marijuana or hashish. Respondents reporting at least one day of marijuana use in the past month are considered marijuana users. Between 2002 and 2019, approximately 7.5 percent of all adult respondents reported using any marijuana in the past month. Prevalence rates are higher for certain age groups: approximately 19 percent of 18-25 year old respondents reported using marijuana, compared to 5.5 percent of respondents aged 26 and older. For all adults, prevalence rates steadily increased over the sample period, from 6 percent in 2002 to 11 percent in 2019.

3.2 Mental Health Client-Level Data (MH-CLD)

The main analyses use MH-CLD, which collects data on mental health diagnoses, treatment services, and outcomes for individuals using state mental health agencies (SMHAs). Data are collected annually at the state level. There is one record for each unique person served at any point during the year, which may include continuing care or multiple treatment episodes. SMHAs must submit information on all enrolled clients who were served by the SMHA within a 12-month reporting period to be eligible for grant funding. Clients who received any mental health services by the SMHA are reported, including inpatient hospitalization and community-based services and treatments such as screening, assessment, crisis services, and telemedicine. Data are available from 2013 to 2022, with approximately 6 million client intake observations per year.

For each client record, I observe whether the primary, secondary, or tertiary diagnosis is in the category of schizophrenia and other psychotic disorders. I derive the primary outcome variable *Schizophrenia Rate*, the state-year rate of SMHA cases of clients with a diagnosis of schizophrenia and other psychotic disorders per 1000 of the state population, from a count of this measure. If any of the client's diagnoses are schizophrenia or another psychotic disorder, they are included in the count. Carefully following Sabia et al. (2024) I then generate the rate by dividing the state-year case counts by the state-year population, using precise population data from the Surveillance, Epidemiology, and End Results Program (SEER) (Sabia et al., 2024, p. 6).³

For the disordered cannabis use analysis, the data also indicate whether or not each observation is diagnosed with cannabis use disorder (CUD) at the time of treatment. From this measure, I compute the state-year count of CUD diagnoses and then generate a *CUD Rate* per 1,000 of the state population using SEER data. I do the same for co-occurring schizophrenia and CUD diagnoses. Across the sample period there were approximately 0.53 cases of CUD per 1,000 state population, and 0.13 cases of co-occurring CUD and schizophrenia per 1000 state population.

³In an alternative set of specifications, I also estimate Poisson regressions on state-year count data using the state population as the exposure variable, as explained in section 4.

Table 1: Descriptive Statistics for Outcome Variables

	All States		Treated States		Control States	
	Mean (1)	SD (2)	Mean (3)	SD (4)	Mean (5)	SD (6)
Panel A: MH-CLD (2013-2022)						
<i>Schizophrenia & other psychotic disorders</i>						
Rate (per 1000 population)	2.83	(1.23)	3.13	(1.39)	2.64	(1.08)
Men	1.77	(0.73)	1.98	(0.85)	1.63	(0.61)
Women	1.07	(0.51)	1.15	(0.57)	1.01	(0.47)
Case count	35,666	(39,467)	58,215	(52,327)	20,840	(15,463)
Men	22,823	(25,815)	37,618	(34,338)	13,094	(9,788)
Women	12,843	(13,700)	20,597	(18,052)	7,746	(5,718)
<i>Disordered Cannabis Use</i>						
Rate (per 1000 population)	0.53	(0.43)	0.41	(0.35)	0.61	(0.46)
State-year Observations	360		100		260	
Underlying Individual Observations	29,227,689		12,886,660		16,341,029	
Number of States	36		10		26	
Panel B: NSDUH (2002-2019)						
<i>Used marijuana in the last 30 days</i>						
Rate, Ages 18+	7.5%	(2.6%)	9.8%	(3.1%)	6.8%	(1.9%)
Ages 18-25	18.7%	(4.2%)	22.2%	(4.6%)	17.9%	(3.6%)
Ages 25+	5.6%	(2.4%)	7.6%	(3.1%)	5.0%	(1.8%)
State-year Observations	867		136		731	
Number of States	51		8		43	

Notes: This table presents the average characteristics across all states (columns 1–2), treated states (columns 3–4), and control states (columns 5–6) utilized in the baseline analysis. It reports both mean values and standard deviations, with observations weighted according to state population using SEER data. The initial two columns encompass all states, while columns 3–4 focus on the treated states that enacted a Recreational Marijuana Law (RML) and opened recreational dispensaries. The final two columns pertain to control states that did not open recreational dispensaries prior to the conclusion of the sample period.

Prior to analysis, the data are collapsed into a state-year panel of means for all adults aged 18+. Table 1 provides descriptive statistics for the sample. To test for heterogeneous effects, I also collapse the data into a set of mutually exclusive state-year panels by age group and gender. The analysis is only performed on one panel in any given regression, with all errors clustered by state. Each panel is precisely matched on age and gender to the SEER population data to generate the main outcome variable *Schizophrenia Rate*.

There are two key limitations of the MH-CLD. First, the data are not representative of the total national demand for mental health treatment nor do they describe the mental health of the nation. They are administrative data counting only patients who seek treatment through SMHAs; private facility admissions are not counted. This limitation does not preclude causal analysis, but it diminishes the external validity of this study.

The second major limitation is that every state does not report its client data every year, and the reason for the gaps is unclear. This presents a threat to identification, because the reason states fail to consistently report data may be a confounder in the model. It is also possible that states with reporting year gaps are not comparable to states without such gaps, raising an endogeneity concern: the inconsistency may be due to issues with that state's mental health system (Ortega, 2023b). I address this limitation in my primary analyses by selecting a balanced panel of states that report data in all 10 years of the sample period. This includes 36 states, 10 of which are treated at varying points in time. Approximately 13% of the sample is fully treated with active recreational marijuana dispensaries.

3.3 Recreational Marijuana Law Dates

I use the effective dates catalogued by Anderson and Rees (2023), updated with my own research into legislative changes. The relevant dates are listed in appendix table A1.

4 Methods

I exploit variation across state and time in the enactment of recreational marijuana laws to identify their effect on rates of schizophrenia and other psychotic disorder intakes for treatment at state-sponsored mental health treatment facilities. Following recent work by Sabia et al. (2024), estimation proceeds in two phases. First, I estimate two-way fixed effects (TWFE) difference-in-differences panel models to identify the overall impact of changes in marijuana laws on the outcomes of interest. Second, recent developments in econometrics literature suggest that TWFE estimates within a staggered adoption framework may be biased (Goodman-Bacon, 2021), potentially affecting traditional event study models used to test pre-treatment trends (Callaway & Sant'Anna, 2021; Sun & Abraham, 2021). To address this, and to test for non-parallel pre-trends, I estimate event study models for all outcomes using Sun & Abraham's interaction weighted estimator designed to expunge bias due to timing heterogeneity in state policy adoption. I also provide results from traditional

TWFE event study analyses in the appendix for comparison.

4.1 Empirical model

Following the work of Mathur and Ruhm (2023) and Wen et al. (2015), I estimate the following two-way fixed effects (TWFE) difference-in-differences panel regression model:

$$Y_{st} = \beta_0 + \beta_1 RMD_{st} + \beta_2 RML_{st} + \beta_3 MML_{st} + X'_{st}\beta_4 + \alpha_s + \gamma_t + \vartheta_s t + \epsilon_{st} \quad (1)$$

where Y_{st} represents one of several outcomes in state s during year t . Among these are the prevalence of prior-month marijuana use, the rate of cannabis use disorder (CUD) diagnoses per 1,000 state population, and the rate of schizophrenia or other psychotic disorder diagnoses per 1,000. Following Wang et al. (2022), I also analyze the raw counts of schizophrenia or other psychotic disorder diagnoses. When the outcome is a dichotomous variable or rate, I estimate eq. (1) with a linear probability model. When the outcome is a count, I estimate eq. (1) with a Poisson model, including the total state population (aged 18+) as the exposure variable. All standard errors are clustered at the state level (Bertrand et al., 2004).

The regressor of interest, RMD_{st} , measures the share of states s which have at least one operational recreational marijuana dispensary during year t . RML_{st} and MML_{st} measure the share of states which have enacted recreational and medical marijuana laws by time t . The recovered LATE, β_1 , is therefore the marginal effect of RMLs with operational recreational dispensaries over and above the effect induced by RMLs which only legalize possession and permit home cultivation, and by MMLs.

This method of modeling marijuana legalization policies separately has been explored in recent literature by Mathur and Ruhm on marijuana legalization and opioid deaths (Mathur & Ruhm, 2023). They argue that the set of marijuana liberalization policies are hierarchical: all states that opened retail dispensaries had already legalized recreational marijuana, and all states that legalized had already implemented medical marijuana laws. This feature of the data suggests that the parameter estimates for RMD_{st} , RML_{st} , and MML_{st} represent incremental effects over the preceding forms of legalization. In Equation (1), the parameter of interest β_1 identifies the effect from recreational marijuana dispensaries opening, the final phase of liberalization.

The vector X_{st} contains a set of time-varying, state-level controls derived from the ACS, FRED, the CDC, and the MH-CLD. They are intended to model the evolution of states' population characteristics over time, and include demographics controls (age, gender, race, ethnicity, education level); macroeconomic controls (the real state GDP per capita, the unemployment rate); social welfare policies (the real binding state minimum wage, whether or not the state expanded Medicaid); and substance use controls (whether the state has a mandatory prescription monitoring drug program, the real state beer tax, the real state cigarette tax).

α_s is a vector of time-invariant state effects and γ_t is a vector of state-invariant time effects. $\vartheta_s t$ is a state-specific linear time trend. Following several recent studies on recreational marijuana law,⁴ I use trends in the baseline model. They are included to account for long-run differences in the prevalence of schizophrenia and other psychotic disorders that may evolve gradually over time due to factors such as demographic shifts, state-level healthcare policies, or reporting standards. These trends allow the model to flexibly absorb pre-existing trajectories in mental health outcomes, reducing the risk of spurious attribution of changes to RML adoption.

Identification of treatment effects is permitted by states' differential enactment of RMLs and subsequent variation in recreational dispensaries opening over time. In total, 10 treated states contribute to the identification of β_1 in a strongly balanced panel across states and years. The model can only generate an unbiased estimate of β_1 if the parallel trends assumption holds. This assumption could be violated if pre-treatment trends in schizophrenia or psychotic disorder intakes differ between treatment and control states, or if RMLs are adopted in response to trends in schizophrenia and psychosis cases.

I use several strategies to mitigate concerns with non-parallel pre-treatment trends. First, I examine the sensitivity of my results to using a simplified set of covariates compared to the fully specified model. Second, I test the pre-treatment trends between treatment and control states for all outcomes in an event study framework using Sun & Abraham's interaction weighted estimator to correct for potential timing heterogeneity bias. This analysis uses never treated states as the control group, avoiding problematic comparisons between early and late RML adopters. Third, I explore the sensitivity of the key findings of this paper to the exclusion of the state-specific linear time trend.

4.2 Event study methodology

It is crucial to confirm that the estimates from eq. (1) are not contaminated by differential trends in the pre-treatment period. Further, it could take time for the effects of recreational marijuana laws to unfold given the potential for a plethora of mechanisms. To explore these possibilities, I generate a set of exclusive RMD indicator variables for all years between five or more years prior to the first recreational dispensary opening, and up to four years after. I then estimate the following equation:

$$Y_{st} = \delta_0 + \sum_{t=0}^4 \phi_t RMD_{st} + \sum_{t=2}^4 \phi_{-t} RMD_{s(-t)} + \phi_{(-5-)} RMD_{s(-5-)} + \dots \\ \dots + \delta_1 RML_{st} + \delta_2 MML_{st} + X_{st} \delta_3 + \alpha_s + \gamma_t + \vartheta_s t + \epsilon_{st} \quad (2)$$

where one year prior to the first recreational marijuana dispensary opening is omitted as the base period. Each RMD coefficient from eq. (2) is estimated relative to this period. This selected

⁴Baggio et al. (2020, p. 6), Wen et al. (2015, p. 70), and Ortega (2023a, p. 2174) use state-specific linear time trends in their primary model specifications.

relative time range enlists the use of all available data-years with suitable variation for event study analysis across the two datasets.⁵

Considering the staggered timing of RML adoption by state throughout the sample period, I estimate eq. (2) using Sun & Abraham's interaction weighted estimator. This should expunge any bias present due to differences in recreational dispensary adoption timing. I also estimate equation eq. (2) using the canonical TWFE event study methodology, and share the results in the appendix. They are similar across the main outcomes.

5 Results

This section contains four parts. First, I share evidence that the prevalence rate of adult marijuana use increases after the passage of RMLs with active recreational dispensaries. Second, I demonstrate that these RMLs lead to increases in unique diagnoses of disordered cannabis use. Third, I show that RMLs with active recreational dispensaries lead to increases in unique cases of schizophrenia and psychotic disorders at state-sponsored mental health treatment facilities. Fourth, I explore heterogeneity in treatment effects by age and sex. All standard errors are corrected for clustering at the state level (Bertrand et al., 2004).

5.1 RMLs and marijuana use

I first present estimates for the effect of RMLs with active recreational dispensaries on the prevalence of marijuana use. Table 2 below contains TWFE estimates from eq. (1), showing that RMLs with recreational dispensaries increase marijuana use. Estimates are highly stable across model specifications, ranging from a sparse set of controls (column 1) to the fully saturated model (column 3). Panel A of Table 2 reports estimates for “any marijuana use” in the past month for all adults aged 18+. The preferred specification (column 3) includes the full set of controls, and shows that RMLs with open dispensaries increase the probability of marijuana use in the past 30 days by 1.4 percentage points. This implies an approximate 20% increase in the probability of an adult consuming marijuana relative to the pre-treatment mean in RML-adopting states.

The size of this effect is smaller than many estimates from recent literature, that largely use policy instruments which do not differentiate between RML passage and the opening of dispensaries. For example, using law passage as the policy instrument, D. Dave et al. (2023), Hollingsworth et al. (2020), and Sabia et al. (2024) all find an approximate 50% increase in prior-month marijuana use among adults relative to the pre-treatment mean in RML adopting states in the 2002-2019 NSDUH data. This is roughly equal to 4 percentage points. Of these studies, Hollingsworth et al. (2020) and Sabia et al. (2024) decompose their RML estimate into the effects of law passage versus when dispensaries open. For prior-month marijuana use among adults aged 18+, the former attribute 53%

⁵In the 2002-2019 NSDUH, only a single state contributes data for relative treatment years 5 and beyond.

of the effect to law passage and 47% to dispensaries opening. This is similar to the effect identified in Table 2, falling within the 5% confidence intervals of my preferred estimate.

I examine heterogeneity by age in Panel B, which presents separate analyses for younger adults (ages 18–25) and older adults (ages 26 and above). I find no significant difference in marijuana use for respondents aged 18–25 after recreational dispensaries open. However, I find that for all adults aged 26 and above, RMLs with active dispensaries lead to a 1.45-percentage point increase in the prevalence of prior-month marijuana use. Together, these results suggest that the significant increases in adult marijuana use from recreational dispensaries opening could be driven by users above the minimum legal age to purchase of 21 years old.

Figure 1 shows the event study for “any marijuana use” in the prior month among adults using Sun & Abraham’s interaction weighted estimator. Never-adopting states are used as the control group, bypassing any problematic early versus late comparisons. There is no significant evidence that marijuana use for adults aged 18+ was trending differently between treated and control states prior to dispensaries opening. All pre-period coefficients are statistically indistinguishable from zero at the 5% significance level. This supports the pre-treatment parallel trends assumption of the first stage difference-in-difference model. In the post-treatment period, the prevalence of adult marijuana use increases in treated states during the year that dispensaries open, then increases again more sharply in the following year to approximately 1.5 percentage points over the pre-dispensary mean. The effect levels off there, but persists for at least four years after dispensaries open. This is consistent with the marginal expansion of marijuana access following the introduction of recreational dispensaries.

Table 2: TWFE estimates for effect of RML with recreational dispensaries on prevalence of prior-month marijuana use (NSDUH, 2002-2019)

	(1) Demographics Only ¹	(2) Add Social Welfare Controls ²	(3) Add Substance Use Controls ³
Panel A: All 18+			
<i>RML with dispensaries</i>	0.0128* (0.0067)	0.0131* (0.0070)	0.0142** (0.0064)
Pre-treatment Mean	0.0713	0.0713	0.0713
State-year Observations	867	867	867
Panel B: Age Heterogeneity			
Ages 18-25			
<i>RML with dispensaries</i>	.0159 (.0178)	.0162 (.0189)	.0188 (.0181)
Pre-treatment Mean	0.1837	0.1837	0.1837
State-year Observations	867	867	867
Ages 26+			
<i>RML with dispensaries</i>	.0134** (.0057)	.0136** (.0059)	.0145*** (.0055)
Pre-treatment Mean	0.0523	0.0523	0.0523
State-year Observations	867	867	867
Demographic Controls	Yes	Yes	Yes
Social Welfare Policies	No	Yes	Yes
Substance Use Controls	No	No	Yes

* $p < 0.10$, ** $p < .05$, *** $p < .01$.

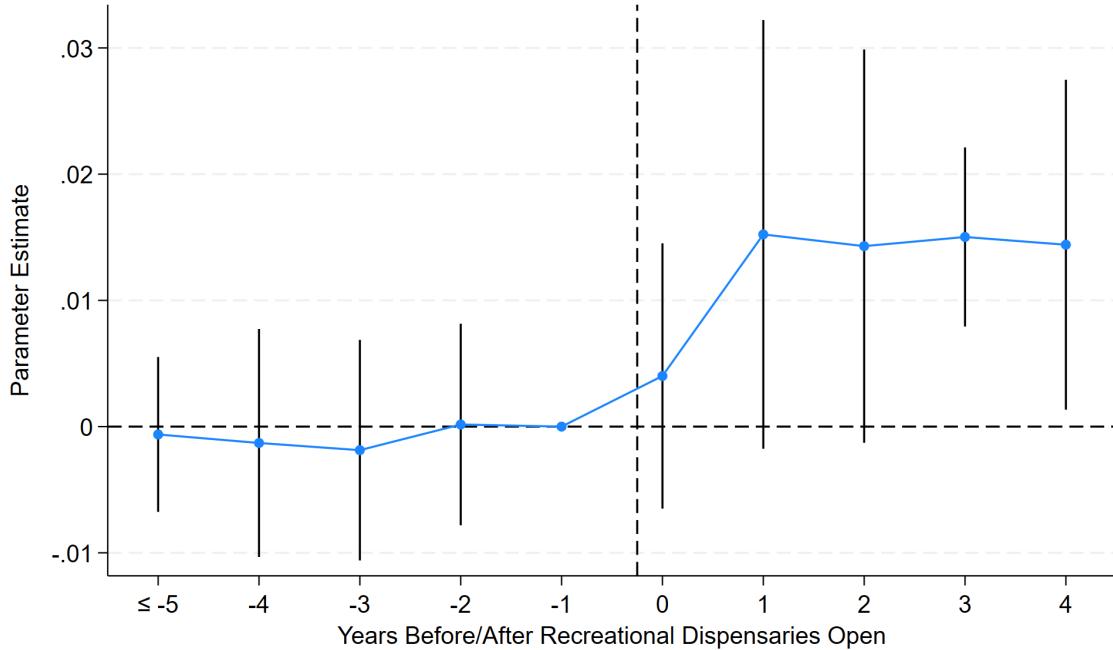
Notes: Each column represents a separate regression. Results are derived from linear probability models estimated through OLS using data from the 2002-2019 NSDUH. All regressions include state and year fixed effects, and state-specific linear time trends. Standard errors, clustered at the state level, are in parentheses.

¹ Demographic controls encompass age, gender, race, ethnicity, and education level.

² Social welfare controls add a state-level indicator for Medicaid expansion under the Affordable Care Act, the real binding state minimum wage, the real state GDP per capita, and the state unemployment rate.

³ Substance use controls add mandatory prescription-monitoring drug laws, the real beer tax per gallon, and the real cigarette tax per pack.

Figure 1: Sun & Abraham Event Study, Effect of RML with recreational dispensaries on prevalence of prior-month marijuana use (NSDUH, 2002-2019)



Notes: The graph contains coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator to account for timing-induced bias. The regression controls for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level. Data are from the 2002-2019 NSDUH and include all observations aged 18+.

5.2 RMLs and disordered cannabis use

Next, I discuss repeated cross-sectional evidence from the MH-CLD. In Table 3 below, I present the estimated effects of RML passage with recreational dispensaries on the incidence of cannabis-related diagnoses observed at all state-sponsored mental health treatment facilities. Overall, I find significant increases in disordered cannabis use, and co-occurring schizophrenia and disordered cannabis use in states that opened recreational marijuana dispensaries versus those that did not. The estimates remain highly consistent across alternative covariate specifications.

Panel A of Table 3 shows impacts of dispensaries opening on disordered cannabis use (CUD) among all adults aged 18+ in the 2013-2022 MH-CLD administrative dataset. For this group, I find that recreational dispensaries opening leads to an additional 0.102 CUD treatment admissions per 1,000 state population. Although small in magnitude, this represents an increase of 18.5% in the rate of CUD diagnoses relative to the pre-treatment mean in RML-adopting states. In Panel B I extend this analysis to look at co-occurring schizophrenia with disordered cannabis use. I document an increase of 0.021 cases per 1,000 state population after dispensaries open, equivalent to approximately 17.5% of the pre-treatment mean.

Figure 2 presents event study estimates to formally assess the validity of the differential trends assumption necessary for causal identification of these findings. Estimation is performed using Sun & Abraham's interaction weighted estimator. There is no significant evidence of non-parallel pre-trends at any point in the pre-period for both outcomes. The figure then shows a continuous and persistent increase in CUD diagnoses and co-occurring schizophrenia with CUD over the four years following dispensaries opening. Considered altogether, these results are consistent with a hypothesis that increases in disordered cannabis use after recreational dispensaries open may be one channel through which RMLs lead to additional cases of schizophrenia and other psychotic disorders requiring mental health services.

Table 3: TWFE Estimates for effects of RML with recreational dispensaries on disordered cannabis use (MH-CLD, 2013-2022)

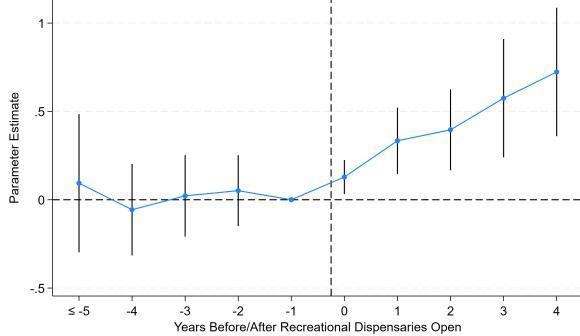
	(1) Demographics Only	(2) Add Social Welfare Policies	(3) Add Substance Use Controls
Panel A: Disordered Cannabis Use			
<i>RML with dispensaries</i>	0.100* (0.051)	0.101** (0.050)	0.102** (0.048)
Pre-treatment Mean	0.550	0.550	0.550
State-year Observations	360	360	360
Panel B: Co-occurring Schizophrenia & Disordered Cannabis Use			
<i>RML with dispensaries</i>	0.018** (0.008)	0.018** (0.008)	0.021** (0.008)
Pre-treatment Mean	0.119	0.119	0.119
State-year Observations	360	360	360
Demographic Controls	Yes	Yes	Yes
Social Welfare Policies	No	Yes	Yes
Substance Use Controls	No	No	Yes

* $p < 0.10$, ** $p < .05$, *** $p < .01$.

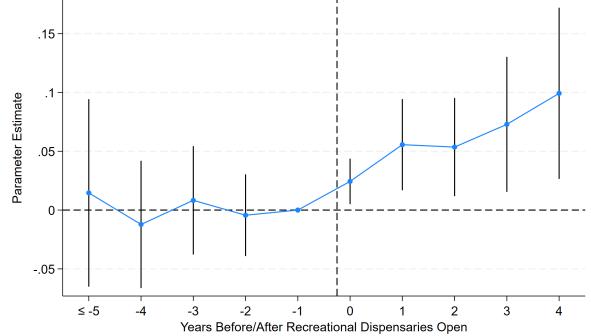
Notes: Each column represents a separate regression. Results are derived from linear probability models estimated through OLS using data from the 2013-2022 MH-CLD. All observations aged 18+ are included in the sample. All regressions include state and year fixed effects, and state-specific linear time trends. Standard errors, clustered at the state level, are in parentheses.

Figure 2: Sun & Abraham Event Study, Effects of RML with recreational dispensaries on disordered cannabis use (MH-CLD, 2013-2022)

Panel (a): Any Disordered Cannabis Use



Panel (b): Co-occurring Schizophrenia & CUD



Notes: The graphs contains coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator to account for timing-induced bias. The regressions control for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level. The dependent variables are the annual rates of unique cases per 1,000 state population for each disorder. Data are from the 2013-2022 MH-CLD and include all observations aged 18+.

5.3 RMLs and schizophrenia or other psychotic disorders

I find evidence that RMLs with operational recreational dispensaries increase unique intake rates and counts for mental health services at SMHAs by individuals diagnosed with schizophrenia or another psychotic disorder. I present the results from Equation (1) in Table 4 below. Panel A, column 3 contains the main estimate for the change in rates of schizophrenia and psychotic disorder intakes per 1000 of the state population. Generally, among adults aged 18 and older, I find that the passage of RMLs with operational recreational dispensaries leads to a 0.396 increase per 1,000 state population in the rate of schizophrenia and psychotic disorder treatment admissions at SMHAs. This effect represents an increase of approximately 12% over the pre-treatment mean among adopting states.

I next turn to Table 4, Panel B to examine the Poisson regression estimation results for the change in schizophrenia and psychotic disorder case counts after recreational dispensaries open. Column 3 contains the main estimate from the preferred specification. Overall, I find an effect size of 0.135 for all adults aged 18+. This suggests that, *ceteris paribus*, the expected count of schizophrenia and psychotic disorder cases per year increases by 13.5% above the mean after recreational dispensaries open. Given the pre-treatment state-year mean of 30,353 cases, this represents an average expected increase of approximately 4,000 cases per state.

Next, I move to eq. (2) to test pre-treatment parallel trends and explore effects in future years within an event study framework. Estimation for rates is performed using Sun & Abraham's

interaction weighted estimator, while estimation for case counts uses Poisson regression. The results are depicted in Figure 3. Reassuringly, I find no significant evidence in either model that schizophrenia and other psychotic disorder rates were trending differently in states that opened recreational marijuana dispensaries versus those that did not in the years preceding legalization. Although there is some insignificant evidence of pre-treatment trends in the earliest years, point estimates for differences between treated and control states stabilize near zero by the third prior relative year in both models. This offers compelling support for the parallel trends assumption required for causal inference. Then, once dispensaries open there is a significant jump in the predicted intake rate for schizophrenia and other psychotic disorders. The effect persists, albeit with some noise⁶, for at least 4 years. In a supplemental analysis using a multi-dimensional panel, I find a similar pattern of effects with substantially smaller standard errors, as shown in Appendix Figure B4.

These findings indicate that RMLs with recreational dispensaries lead to significant increases in unique patients presenting with schizophrenia symptoms at state-funded mental health facilities. However, due to limitations of the MH-CLD, they do not distinguish whether these are cases of first-episode psychosis or recurrence. Therefore these results do not necessarily demonstrate a broader rise in the overall lifetime prevalence of schizophrenia and other psychotic disorders, but they do indicate an increase in the prevalence of active cases requiring treatment.

⁶Because the underlying MH-CLD data include over 29 million observations across state, year, age group, and gender, I also follow the approach of Miller and Wherry (2018) in estimating the same model on a more granular, multi-dimensional panel. This structure increases the number of observations, leveraging additional group variation while preserving the original identification strategy. The resulting estimates, shown in Appendix Figure B4, exhibit a similar pattern of effects with substantially smaller standard errors.

Table 4: TWFE Estimates for effects of RML with recreational dispensaries on schizophrenia and other psychotic disorders (MH-CLD, 2013-2022)

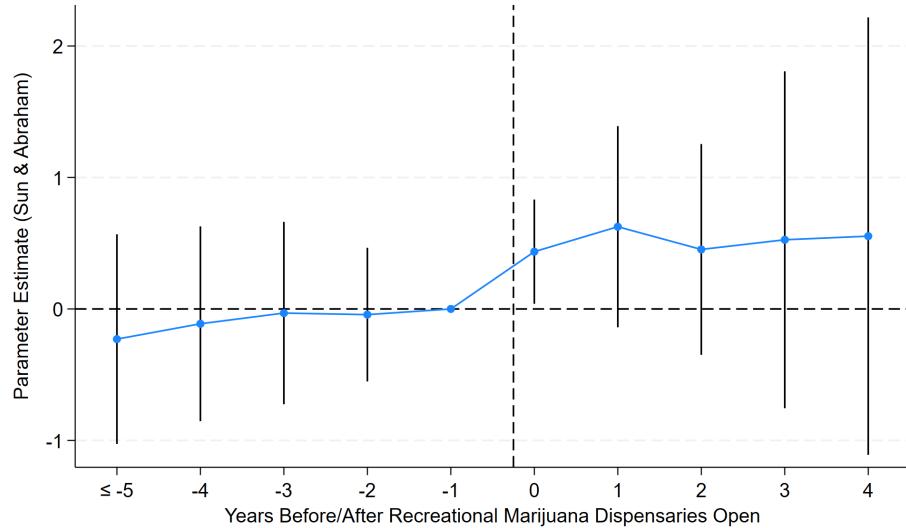
	(1) Demographics Only	(2) Add Social Welfare Policies	(3) Add Substance Use Controls
Panel A: Schizophrenia rate (per 1,000 state population) (LPM)			
<i>RML with dispensaries</i>	0.346** (0.171)	0.373*** (0.109)	0.396*** (0.098)
Pre-treatment Mean	3.274	3.274	3.274
State-year Observations	360	360	360
Panel B: Schizophrenia case counts (Poisson Model)			
<i>RML with dispensaries</i>	0.095** (0.049)	0.121*** (0.033)	0.135*** (0.029)
Pre-treatment Mean	30,353	30,353	30,353
State-year Observations	360	360	360
Demographic Controls	Yes	Yes	Yes
Social Welfare Policies	No	Yes	Yes
Substance Use Controls	No	No	Yes

* $p < 0.10$, ** $p < .05$, *** $p < .01$.

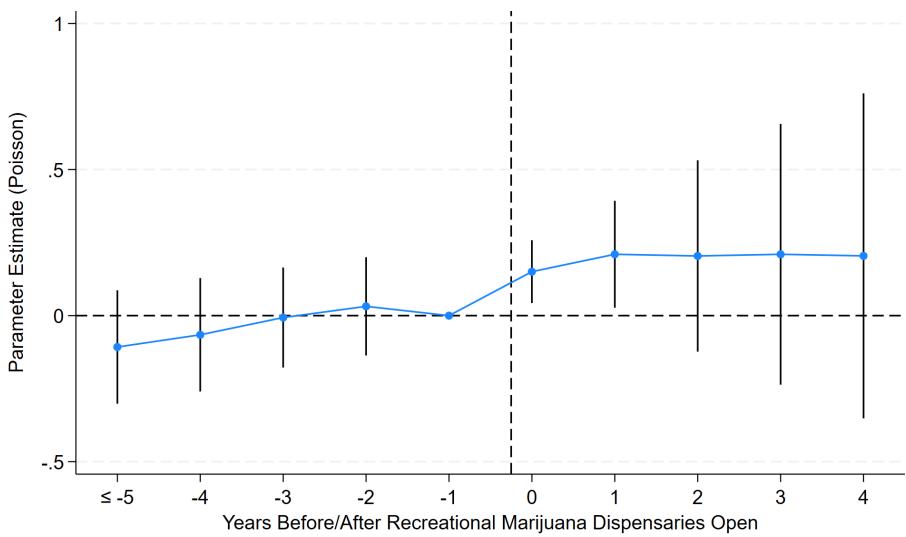
Notes: Each column represents a separate regression. Results are derived from linear probability models estimated through OLS using data from the 2013-2022 MH-CLD. All observations aged 18+ are included in the sample. All regressions include state and year fixed effects, and state-specific linear time trends. Standard errors, clustered at the state level, are in parentheses.

Figure 3: Event Studies, Effects of RML with recreational dispensaries on schizophrenia and other psychotic disorders (MH-CLD, 2013-2022)

Panel (a): Schizophrenia Rate (per 1000)



Panel (b): Schizophrenia Case Counts



Notes: The graphs contain coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using (a) Sun and Abraham's (2021) dynamic treatment effect estimator to account for timing-induced bias; and (b) Poisson estimation. Both regressions control for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level. The dependent variables are (a) the annual rate of unique schizophrenia cases per 1,000 state population; and (b) the annual count of unique schizophrenia cases. Data are from the 2013-2022 MH-CLD and include all observations aged 18+.

5.4 Heterogeneous effects

The effects of RMLs on schizophrenia and psychotic disorders are not distributed evenly across age and gender. In Table 5 below, I stratify the sample by age category and gender to explore differences in effects across these dimensions through separate regressions. I begin with age in Panel A. Notably, in column 1 the model finds a nearly null effect of recreational marijuana dispensaries opening on schizophrenia or other psychotic disorders for ages 18-20, those below the minimum legal age of purchase. This is consistent with the “first stage” effects of dispensaries opening on marijuana use found in this study, which show no significant increase among younger adults aged 18-25.

All other age categories, with the exception of 60+, see significant increases in schizophrenia and psychotic disorders. The effects are relatively strongest for the 21-29 age group, for whom the opening of recreational dispensaries leads to an increase of 0.516 diagnoses per 1,000 of the state population. This constitutes an increase of approximately 20% over the pre-treatment mean in adopting states. The next most impacted age group is 50-59 with an increase of 0.638 cases per 1,000 of the state population, constituting a 15% increase.

These findings fit into the epidemiological model of schizophrenia and other psychotic disorders as heterogeneous illnesses in which about 75 percent of affected individuals experience relapses for at least a portion of their lifespan (Vita & Barlati, 2018). The course of relapses in psychotic illnesses are predicted or modified by factors including substance use; specifically, numerous studies have shown a correlation between cannabis use and increased psychotic symptoms (Bowers et al., 2001; Degenhardt et al., 2003; Gage et al., 2016; Martland et al., 2020; Vita & Barlati, 2018). There is also a body of evidence showing that during old age, about half of individuals with schizophrenia and other psychotic disorders significantly improve with long-term remission (Degenhardt et al., 2003; Vita & Barlati, 2018). This may help explain the findings here that show increased rates of psychotic treatment cases across the entire adulthood range, with men and women in their 50s experiencing significant effects at the next highest rate after young men. At a time in their lives when psychotic symptoms may otherwise be declining, initiation or increase of marijuana use may exacerbate their mental illness.

In Panels B and C, I further stratify the sample by gender to investigate heterogeneity by gender across age groups. I find that, in general, effect sizes for men are larger than those for women. Young men in the 21-29 age category suffer the greatest increase in magnitude with an additional 0.711 psychotic disorder cases per 1,000 of the state population after dispensaries open. This is a 19% increase over the pre-treatment mean, greater than any other group.

The current model of predictive factors in the literature aligns with the pattern of heterogeneity by age and gender found in this study. Male sex is shown to be a predictive factor for psychotic relapses across multiple studies (Bowtell et al., 2018). Younger age onset of marijuana use is a risk factor for psychosis (Chadwick et al., 2013; Gage et al., 2016; Ho et al., 2023), so in combination, young men who use marijuana may be at a higher risk. This is supported by the findings here for men age 21-29, who were the most disaffected demographic group.

Table 5: TWFE Estimates for heterogeneous effects of RML with recreational dispensaries on schizophrenia and other psychotic disorders (MH-CLD, 2013-2022)

	Age Category					
	(1) 18-20	(2) 21-29	(3) 30-39	(4) 40-49	(5) 50-59	(6) 60+
Schizophrenia Rate						
Panel A: All Genders						
<i>RML with dispensaries</i>	0.062 (0.069)	0.516*** (0.115)	0.456*** (0.120)	0.472*** (0.141)	0.638*** (0.192)	0.139 (0.160)
Pre-treatment Mean	1.21	2.61	3.60	3.76	4.20	2.37
Panel B: Males						
<i>RML with dispensaries</i>	0.082 (0.076)	0.711*** (0.147)	0.573*** (0.149)	0.569*** (0.154)	0.709*** (0.235)	0.212 (0.179)
Pre-treatment Mean	1.66	3.71	4.90	4.65	4.85	2.51
Panel C: Females						
<i>RML with dispensaries</i>	0.092 (0.069)	0.284*** (0.090)	0.333*** (0.089)	0.420*** (0.124)	0.619*** (0.151)	0.100 (0.156)
Pre-treatment Mean	0.76	1.52	2.29	2.87	3.55	2.24
State-year Observations	360	360	360	360	360	360

* p < .10, ** p < .05, *** p < .01.

Notes: results derived using an OLS two-way fixed effects regression on state-year panel data from the 2013-2022 MH-CLD. The model controls for all covariates, state and time fixed effects, state-specific linear time trends, and is weighted by state population. Standard errors are clustered at the state level. Coefficients represent the change in unique schizophrenia and other psychotic disorder cases per 1,000 state population after dispensaries became operational.

5.5 Robustness checks

I conduct three supplementary analyses to evaluate the robustness of my findings. First, I assess the sensitivity of the main analysis to the exclusion of state-specific linear time trends. In Figure 4 below, I estimate eq. (2) for the effect of recreational dispensaries opening on schizophrenia and other psychotic disorders without linear time trends in an event-study framework using Sun & Abraham's interaction weighted estimator. Reassuringly, the event-study estimates remain largely unchanged when state-specific linear time trends are excluded from the model.

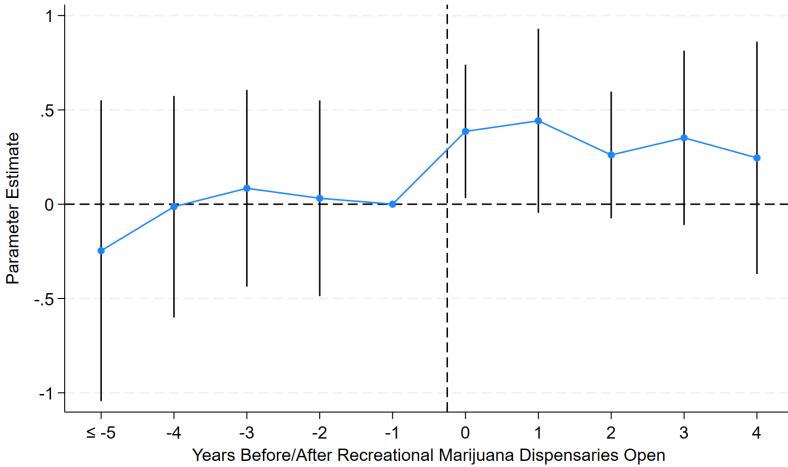
As in the baseline specification, there is no significant evidence of pre-trends, with point estimates centered around zero for four years prior to dispensary openings. Once dispensaries open, there is an immediate and significant jump in treatment cases for schizophrenia and other psychotic disorders in the following year. These results closely align with those derived from the model with trends included (Figure 3, Panel a). While estimates begin to diverge around the second year post-treatment, the differences are not statistically significant. The consistency of these results provides evidence that trends are not driving causal identification.

Second, I evaluate the possibility that my findings may be influenced by spurious factors by conducting a placebo treatment test on Equation (1). I perform 500 Monte Carlo simulations, replacing the primary regressor RMD_{st} with a randomly generated placebo policy indicator while retaining all covariates. During each simulation, random treatment status and treatment timing indicators are drawn from uniform distributions such that approximately 20% of the sample is placebo-treated in expectation, roughly matching the 2013-2022 MH-CLD data. I collect the coefficient estimate for the placebo treatment indicator each repetition, then assemble all of them into the histogram portrayed by Figure 5.

The results support the main findings presented in Table 4. The distribution of placebo coefficients closely resembles a normal distribution with mean 0, evidence of a null difference-in-difference effect on psychotic disorder rates between treated and control states when there was no actual treatment. This supports the parallel trends assumption. Next, the main estimate from Equation (1), for the effect of retail marijuana dispensaries opening on rates of treatment cases for schizophrenia and other psychotic disorders, is overlaid in the plot. This estimate falls within the upper 2.5% tail of placebo coefficients, suggesting that the estimation results in Table 4 are not spurious.

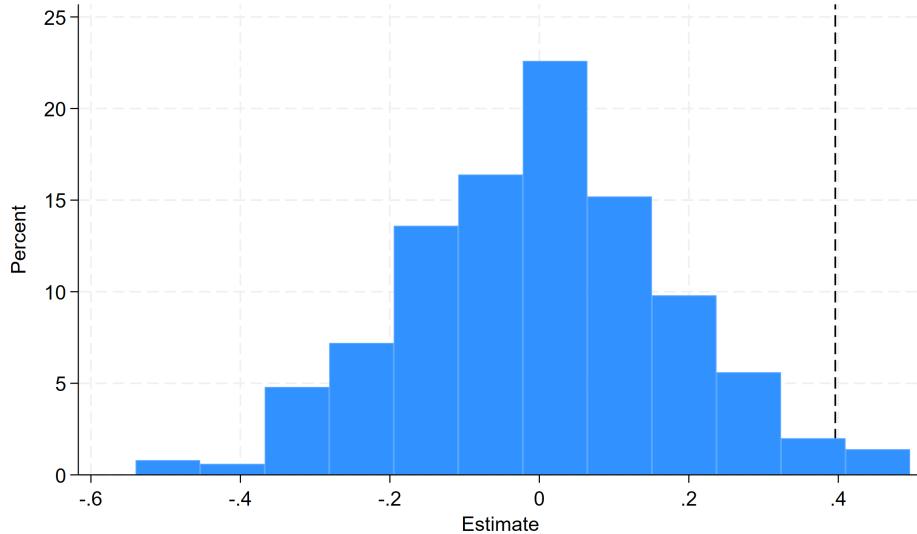
Last, my identification strategy is predicated on the assumption that the passage of RML's and subsequent opening of recreational dispensaries is uncorrelated with any state-specific characteristics or underlying trends that may affect rates of schizophrenia diagnoses. It is possible that state-level funding for SMHA services is correlated with RML adoption, which could potentially confound the results. To assess this, I replace the outcome variable in eq. (2) with the state-year level of funding and perform an event study analysis. The results, depicted in appendix fig. B6, assuage these concerns: there are no significant differences in trends in funding levels between treatment and control states at any point in time.

Figure 4: Sun & Abraham Event Study, Effect of RML with recreational dispensaries on schizophrenia and psychotic disorders (Robustness to Exclusion of State-Specific Linear Time Trends)



Notes: The graph contains coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator. The regression controls for all covariates, state and time fixed effects. Standard errors are clustered at the state level. The dependent variable is the annual rate of unique schizophrenia or other psychotic disorder cases per 1,000 state population. Data are from the 2013-2022 MH-CLD and include all observations aged 18+.

Figure 5: Placebo Test, Effect of RML with recreational dispensaries on schizophrenia and other psychotic disorders (MH-CLD, 2013-2022)



Notes: The graph plots the density of parameter estimates from 500 Monte Carlo simulations of equation (1), replacing the main regressor (RMD_{st}) with a randomly generated placebo policy date drawn from a uniform distribution during each iteration. The dashed line represents the main estimate from Panel A of Table 4. Only 1.4% of estimates fall to the right. Data are from the 2013-2022 MH-CLD and include all observations aged 18+.

6 Discussion

This study presents some of the first estimates of a causal relationship between state marijuana laws and treatment admissions for schizophrenia or other psychotic disorder symptoms. First, leveraging NSDUH data, I show that opening recreational dispensaries induces an increase in marijuana use over and above the increases driven by legalization without dispensaries and medical marijuana laws. To be specific, I find that opening dispensaries leads to a 20% increase in the prevalence of marijuana consumption over the pre-treatment mean among adopting states. The results appear to be driven by users above the minimum legal purchase age of 21. Turning to schizophrenia and other psychotic disorders, data from the MH-CLD show that recreational dispensaries opening lead to increases of 18.5% in the rate of cannabis use disorder, and 17.5% in the rate of co-occurring CUD with schizophrenia. This is consistent with the ex-ante hypothesis that increases in CUD after dispensaries open may drive increases in schizophrenia.

Next, in the main analysis I document that opening recreational dispensaries significantly increases intake rates for schizophrenia and other psychotic disorders at state-funded mental health facilities throughout the United States. I find an overall effect of 0.396 unique additional cases per 1,000 state population, a 12% increase over the pre-treatment mean among adopting states. The magnitude of the estimate is reasonable considering available institutional knowledge⁷. Event study analyses, which account for differential policy effects over time, provide robust support for a causal interpretation of these findings.

These results provide evidence that increases in marijuana use across the general population lead to increased rates of treatment engagement for people with psychotic disorders, which indicate increases in psychotic symptoms or acute episodes initiated or exacerbated by marijuana use. Consequently, these are impacts of laws that legalize recreational marijuana use. Further research should examine what proportion of those affected experience first-time onset of psychosis. This study confirms that RMLs bring on more psychotic symptoms or episodes in those with a diagnosis, but does not differentiate if these were new cases and whether first-episode psychosis specifically increases with marijuana use. This does not necessarily demonstrate that more individuals are affected by schizophrenia and other psychotic disorders overall. It is also important to further establish whether RMLs lead to earlier onset of the illness in people who were likely to experience psychosis, costing valuable time in their lives when they may have remained psychosis-free.

Public health advocates and policymakers should consider increased treatment admissions for schizophrenia and other psychotic disorders as an unintended cost of RMLs, paid most heavily by vulnerable people who have preexisting risk factors or chronic psychotic disorders. Although this number is a small percentage of the overall population, the costs of psychotic symptoms are severe and affect their families, caretakers and society as well.

⁷Recent literature has estimated the lifetime population prevalence rate of schizophrenia at 4.8 cases per 1,000 people (Simeone et al., 2015).

A Appendix Tables

Table A1: State Marijuana Policy Timeline

State	MML Effective Date	RML Effective Date	Recreational Sales Allowed
Alaska	03/04/1999	02/24/2015	10/29/2016
Arkansas	11/09/2016	-	-
Arizona	04/14/2011	11/30/2020	01/22/2021
California	11/06/1996	11/09/2016	01/01/2018
Colorado	06/01/2001	12/10/2012	01/01/2014
Connecticut	08/20/2014	07/01/2021	-
Delaware	06/26/2015	-	-
District of Columbia	07/30/2013	02/26/2015	02/26/2015
Florida	07/26/2016	-	-
Hawaii	12/28/2000	-	-
Illinois	11/09/2015	01/01/2020	01/01/2020
Louisiana	08/06/2019	-	-
Maine	12/22/1999	01/31/2017	10/09/2020
Maryland	12/02/2017	-	-
Massachusetts	01/01/2013	12/15/2016	11/20/2018
Michigan	12/04/2008	12/06/2018	12/01/2019
Minnesota	07/01/2015	-	-
Mississippi	02/02/2022	-	-
Missouri	10/17/2020	12/08/2022	-
Montana	11/02/2004	01/01/2021	01/01/2022
Nevada	10/01/2001	01/01/2017	07/01/2017
New Hampshire	05/01/2016	-	-
New Jersey	12/06/2012	02/22/2021	04/21/2022
New Mexico	07/01/2007	06/29/2021	04/01/2022
New York	01/08/2016	03/31/2021	12/29/2022
North Dakota	03/01/2019	-	-
Ohio	01/16/201	-	-
Oklahoma	07/26/2018	-	-
Oregon	12/03/1998	07/01/2015	10/01/2015
Pennsylvania	01/17/2018	-	-
Rhode Island	01/03/2006	5/25/2022	12/01/2022
South Dakota	07/01/2021	-	-
Utah	03/02/2020	-	-
Vermont	07/01/2004	07/01/2018	10/01/2022
Virginia	10/17/2020	07/01/2021	-
Washington	11/03/1998	12/06/2012	07/08/2014
West Virginia	08/22/2017	-	-

Notes: all original policy dates are drawn directly from (Anderson & Rees, 2023). Updated dates, in bold print, are drawn from the author's research into legislative changes.

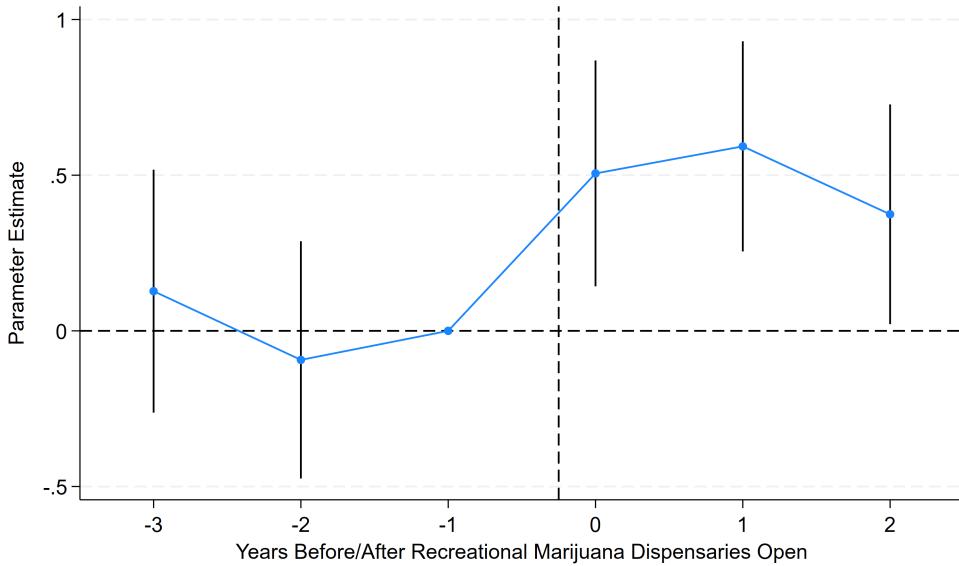
Table A2: States Contributing to Treatment Effect Estimation for MH-CLD Outcomes

Relative Year	States Included in Estimation
≤ -5	CA, IL, MA, MT, NV, NJ, NM
-4	CA, IL, MA, MT, NV, NJ, NM
-3	CA, IL, MA, MT, NV, NJ, NM, OR
-2	CA, IL, MA, MT, NV, NJ, NM, OR, WA
-1	CA, CO, IL, MA, MT, NV, NJ, NM, OR, WA
0	CA, CO, IL, MA, MT, NV, NJ, NM, OR, WA
1	CA, CO, IL, MA, NV, OR, WA
2	CA, CO, IL, MA, NV, OR, WA
3	CA, CO, MA, NV, OR, WA
4	CA, CO, NV, OR, WA

Notes: This table lists the states contributing to CATT estimation for MH-CLD outcomes in each relative year of the event study, based on the weighting structure of the Sun and Abraham (2021) estimator. A state appears in a given relative year if it provides non-zero identifying variation for that event-time coefficient. This breakdown complements the descriptive statistics in Table 1.

B Appendix Figures

Figure B1: Event Time Balanced Panel: Effect of RML with recreational dispensaries on schizophrenia and other psychotic disorders (MH-CLD, 2013-2022)



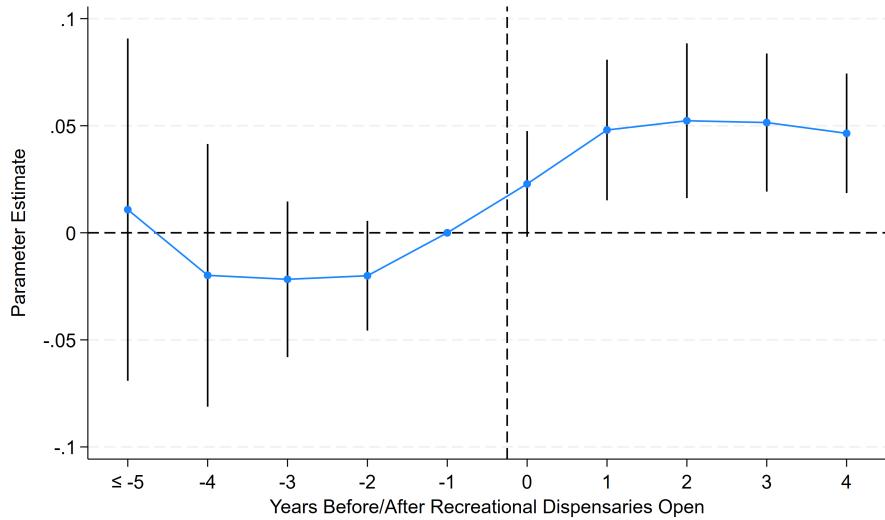
States Contributing to CATT Estimation

Relative Year	States Included in Estimation ¹
-3	CA, IL, MA, NV, OR
-2	CA, IL, MA, NV, OR
-1	CA, IL, MA, NV, OR
0	CA, IL, MA, NV, OR
1	CA, IL, MA, NV, OR
2	CA, IL, MA, NV, OR

Notes: The graph contains coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator. This analysis is balanced in event time per the included table. The dependent variable is the annual rate of unique schizophrenia or other psychotic disorder cases per 1,000 state population. The regression controls for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level.

¹ To address concerns about event-time compositional change, I construct a restricted panel that is balanced in event time from -3 to $+2$ relative to the year of recreational dispensary implementation. The sample includes the subset of states that contribute identifying variation to all six of these relative years: CA, IL, MA, NV, and OR. This combination of states and event time reflects the optimal tradeoff between the number of treated states and the total number of balanced pre- and post-treatment periods observed. Including any additional treated state would require shortening the range of event-time balance, as later or edge-adopting states lack sufficient data across all post-treatment periods. The control group is held constant and matches that used in the primary analysis. This restriction allows for a cleaner interpretation of dynamic treatment effects and mitigates concerns about compositional bias across event time.

Figure B2: Matched Panel: Effect of RML with recreational dispensaries on prevalence of prior-month marijuana use (NSDUH, 2013-2019)



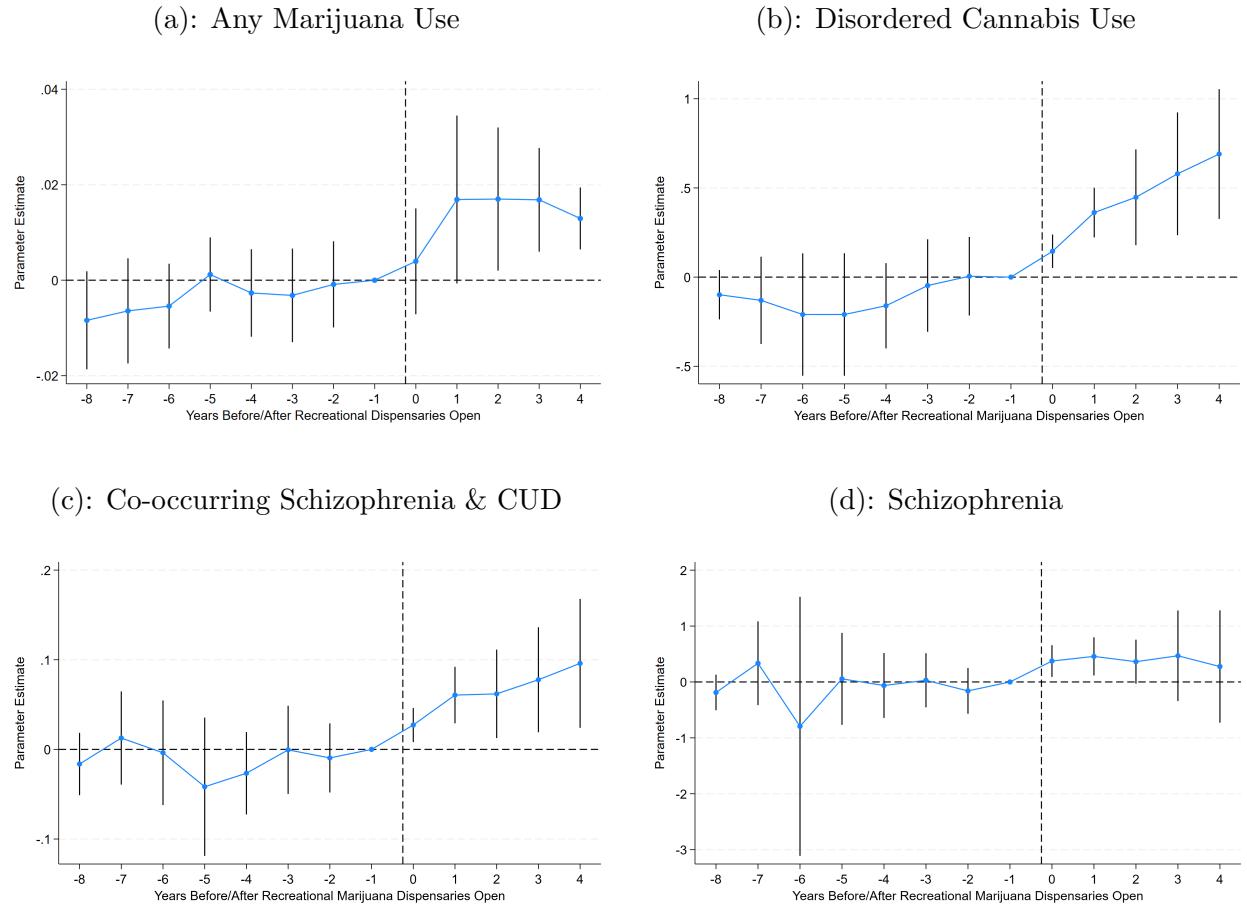
Notes: The graph contains coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator to account for timing-induced bias. This analysis is restricted to the same 36 states and overlapping 2013–2019 time period available in both the NSDUH and MH-CLD datasets, ensuring a strongly balanced panel and consistent comparison across the datasets. The regression controls for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level.

Descriptive Statistics for Matched NSDUH Analysis

	All States		Treated States		Control States	
	Mean	SD	Mean	SD	Mean	SD
	(1)	(2)	(3)	(4)	(5)	(6)
NSDUH (2013-2019)						
<i>Used marijuana in the last 30 days</i>						
Rate, Ages 18+	9.1%	(3.0%)	12.4%	(2.9%)	7.8%	(1.9%)
Ages 18-25	20.5%	(4.8%)	25.2%	(4.1%)	18.7%	(3.7%)
Ages 25+	7.2%	(2.9%)	10.2%	(2.9%)	6.0%	(1.8%)
State-year Observations	252		42		210	
Number of States	36		6		30	

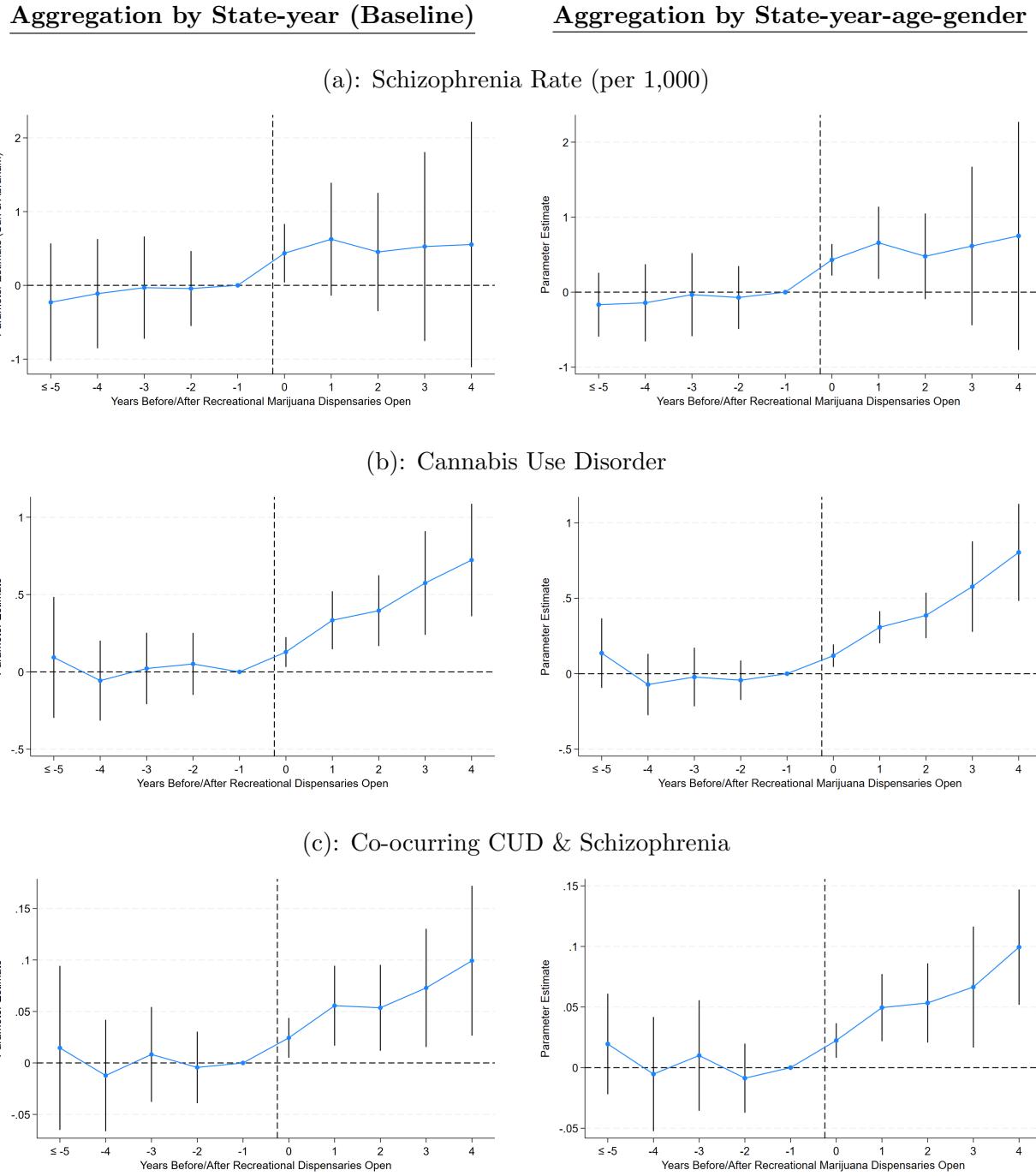
Notes: This table presents the average characteristics across all states (columns 1–2), treated states (columns 3–4), and control states (columns 5–6) utilized in this matched NSDUH analysis. It reports both mean values and standard deviations, with observations weighted according to state population using SEER data.

Figure B3: Expanded Event Studies, Effect of RML with recreational dispensaries on all outcomes



Notes: The graphs contain coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator to account for timing-induced bias. The regressions control for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level. Data are from the 2002-2019 NSDUH and 2013-2022 MH-CLD. The analyses are equivalent to main figures 1, 2, and 3 with the sole exception of the expanded pre-period. The dependent variables are (a) the prevalence rate of adult marijuana use; and (b, c, d) annual rates of unique cases per 1,000 state population for each disorder.

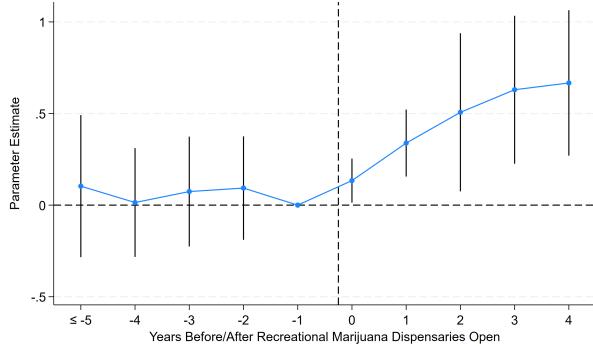
Figure B4: Event Studies: Effect of RML with recreational dispensaries on MH-CLD outcomes (Alternative Estimation)



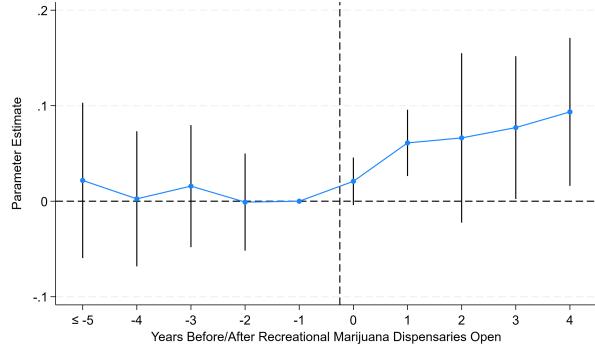
Notes: The graphs contain coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator to account for timing-induced bias. Dependent variables are the annual rates of unique cases per 1,000 state population for each disorder. The regressions control for all covariates, state and time fixed effects, and state-specific linear time trends. The analyses on the left use the original state-year panel. Those on the right follow Miller and Wherry (2018, p.18) in incorporating more granular heterogeneity by aggregating the original data to the state-year-age-gender level. The models are otherwise identical, except for the inclusion of age and gender fixed effects.

Figure B5: Sensitivity to Covid-19: Effect of RML with recreational dispensaries on MH-CLD outcomes (excludes 2020)

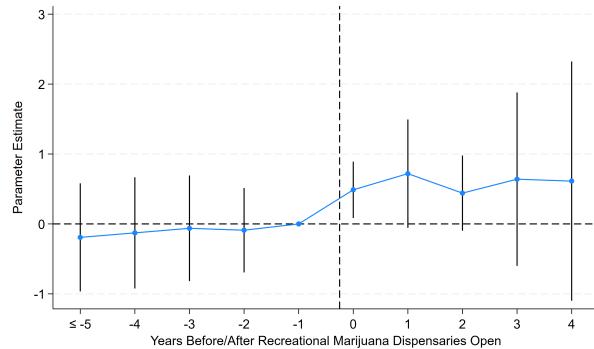
(a): Disordered Cannabis Use



(b): Co-occurring Schizophrenia & CUD

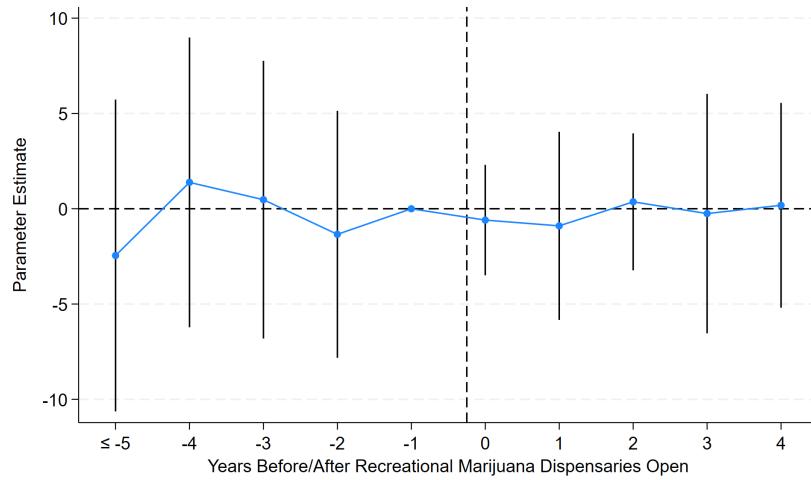


(c): Schizophrenia



Notes: The graphs contain coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator to account for timing-induced bias. The regressions control for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level. Data are from the 2013-2019 and 2021-2022 MH-CLD. Data from the year 2020 are excluded from this analysis. Dependent variables are the annual rates of unique cases per 1,000 state population for each disorder.

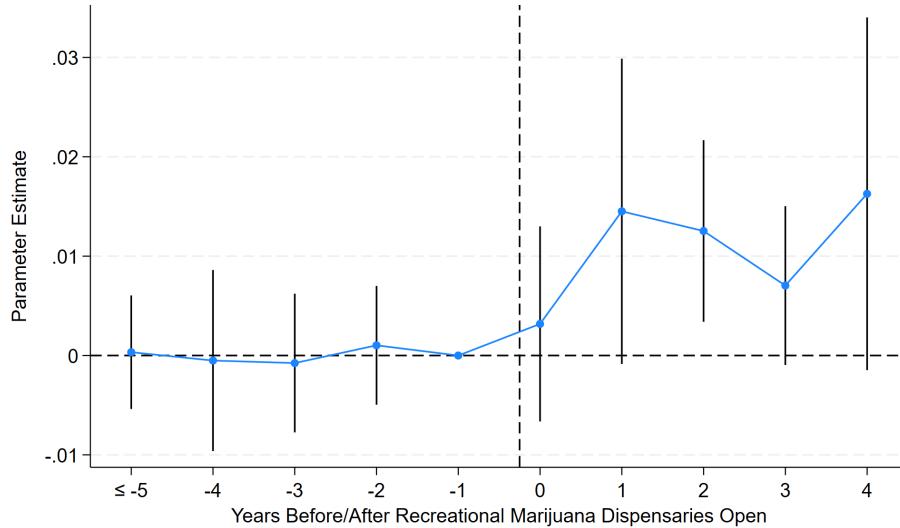
Figure B6: Sun & Abraham Event Study, Effect of RML with recreational dispensaries on annual change in state grant funding received (identification check)



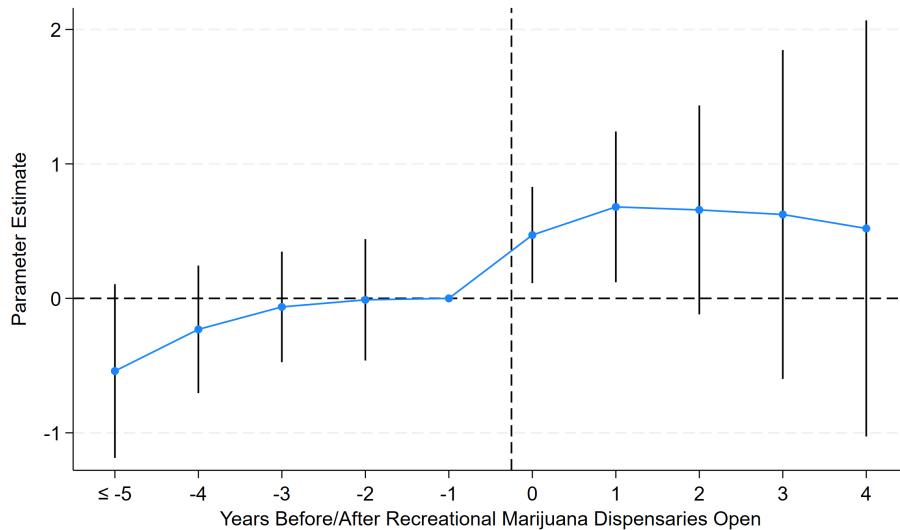
Notes: The graph contains coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using Sun and Abraham's (2021) dynamic treatment effect estimator. The regression controls for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level. The analysis uses publicly available data from SAMHSA for the period 2013-2022.

Figure B7: OLS TWFE Event Study, Effects of RML with recreational dispensaries on main outcomes (alternative estimator)

Panel (a): Any Marijuana Use



Panel (b): Schizophrenia Rate (per 1,000)



Notes: The graph contains coefficient estimates with 95% confidence intervals for years before and after the change in RML, derived using an OLS two-way fixed effects regression. The regression controls for all covariates, state and time fixed effects, and state-specific linear time trends. Standard errors are clustered at the state level. Data are from the 2002-2019 NSDUH and 2013-2022 MH-CLD, and include all observations aged 18+.

C Testing for Parallel Trends

In this section, I assess the robustness of my event study results to potential violations of the parallel trends assumption. I implement the framework developed by Rambachan and Roth (2023). Below, I briefly summarize their approach and explain how I apply it to my setting.

Rambachan and Roth (2023) begin by defining δ as the counterfactual difference in trends between treated and control groups in the absence of treatment. They then consider a researcher-specified set Δ that defines allowable deviations from parallel trends. For any chosen Δ , they construct robust confidence intervals that account for these possible violations. They propose using two leading specifications for Δ .

The first approach, *Relative Magnitude Bounds*, assumes that deviations from parallel trends in post-treatment periods are not substantially greater than those observed in the pre-treatment period. The set of allowable deviations is given by:

$$\Delta_{RM}(\bar{M}) = \left\{ \delta : \forall t \geq 0, |\delta_{t+1} - \delta_t| \leq \bar{M} \cdot \max_{s < 0} |\delta_{s+1} - \delta_s| \right\}, \quad (3)$$

where \bar{M} scales the allowable post-treatment deviation relative to the largest pre-treatment change. The second specification, *Smoothness Restrictions*, assumes that differential trends evolve smoothly over time by bounding second differences in δ :

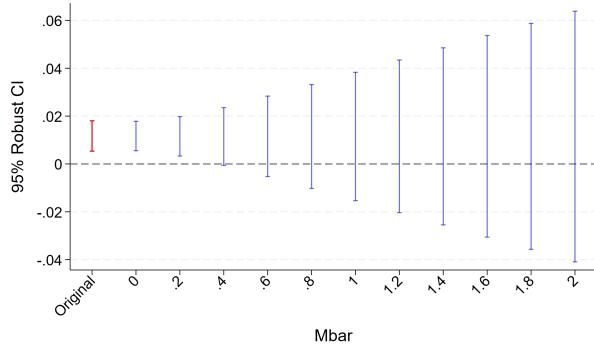
$$\Delta_{SD}(M) = \{ \delta : |(\delta_{t+1} - \delta_t) - (\delta_t - \delta_{t-1})| \leq M, \forall t \}, \quad (4)$$

where $M = 0$ implies a linear trend in the differences between treated and control groups. I apply both methods to assess the sensitivity of my estimated effects derived from equation (2). As (Rambachan & Roth, 2023) emphasize, evaluating the robustness of the full post-treatment effect, rather than focusing solely on the first post-treatment period, offers a more comprehensive test of the parallel trends assumption. Consistent with their approach, I set $\bar{M} = 2$ for the relative magnitude bound, allowing for post-treatment violations up to twice the largest pre-treatment deviation. For the smoothness restriction, I use the default scaling from the `honestDiD` Stata package, which adjusts M based on the scale of the outcome. For one outcome where the ATT estimate fails the $M = 0$ linearity restriction, I also report results for the first post-treatment coefficient as a robustness check.

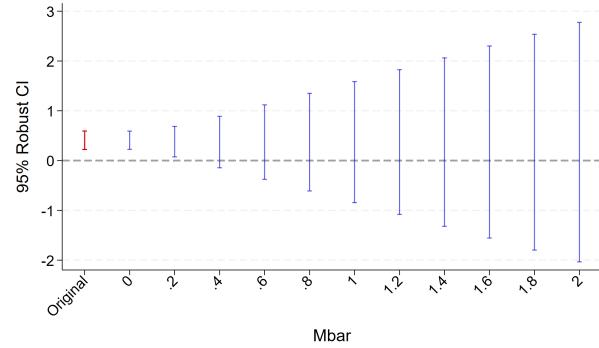
Appendix Figures C1 and C2 report 95% confidence intervals from each test. Figure C1 displays estimates under the relative magnitude restriction. The findings are robust to violations up to 40% of the maximum pre-period deviation for marijuana use and disordered cannabis use, and up to 20% for co-occurring schizophrenia & disordered cannabis use. The schizophrenia treatment episode outcome does not pass the $M = 0$ test for the combined ATT, but the estimate for the first post-treatment period effect (panel e) remains robust, passing the test and tolerating deviations up to 20%. Under the smoothness restriction (figure C2), the results for all outcomes remain consistent, with robustness thresholds comparable to those in the relative magnitude test.

Figure C1: Sensitivity Analysis for Non-parallel Trends (Relative Magnitude Restrictions)

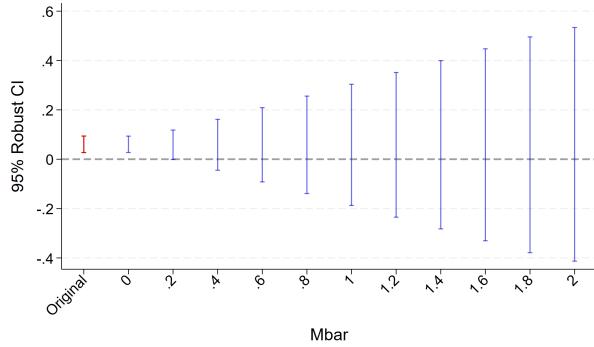
Panel (a): Any Marijuana Use



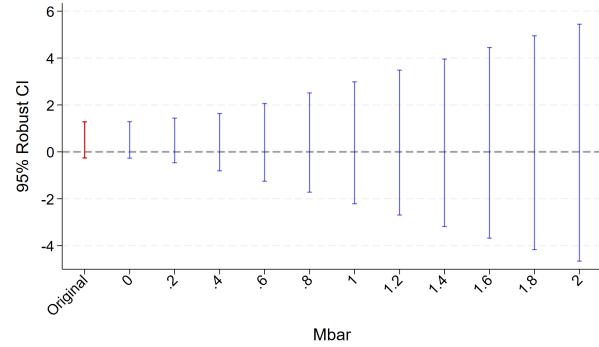
Panel (b): Disordered Cannabis Use



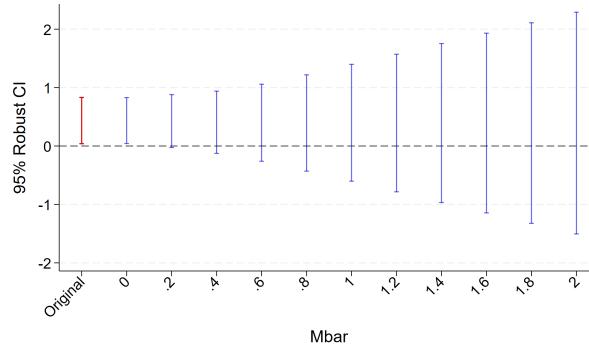
Panel (c): Co-occurring Schizophrenia & CUD



Panel (d): Schizophrenia



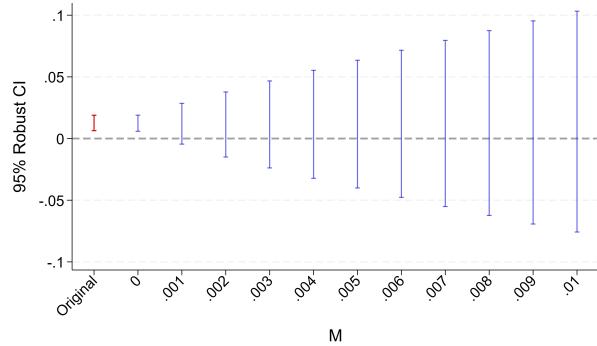
Panel (e): Schizophrenia, First Post-period



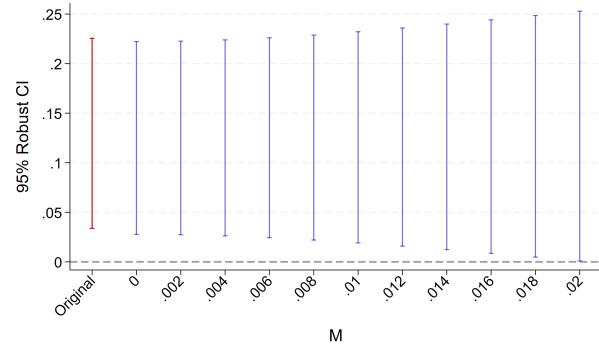
Notes: These graphs display 95% robust confidence intervals for the treatment effects of recreational marijuana dispensary openings on the listed outcomes, estimated using the “relative magnitude bounds” sensitivity analysis framework developed by (Rambachan & Roth, 2023). Panels a through d report results for the average treatment effect on the treated (ATT), calculated as a weighted average of cohort-specific post-period treatment effects (CATTs) across relative event times. For schizophrenia cases (panel d), the ATT fails the restriction test under $M = 0$, so I also report the confidence interval for the first post-treatment coefficient (ϕ_0) as a robustness check. Baseline ATT estimates under parallel trends are shown in red.

Figure C2: Sensitivity Analysis for Non-parallel Trends (Smoothness Restrictions)

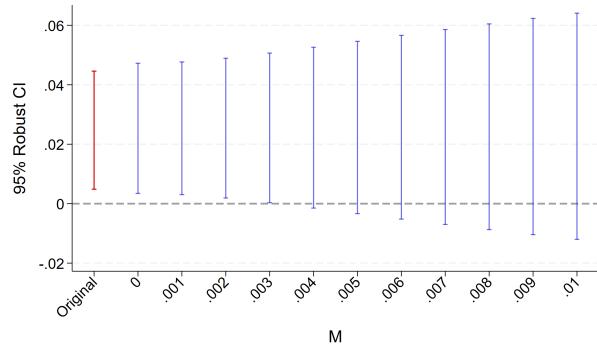
Panel (a): Any Marijuana Use



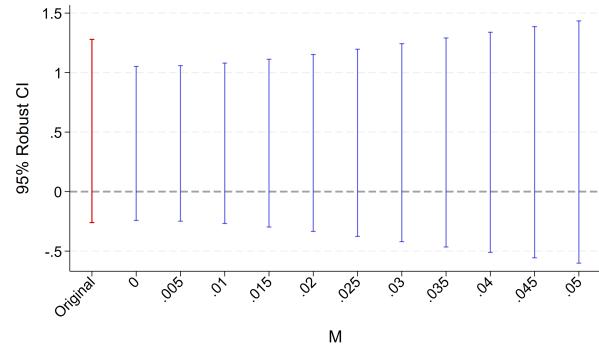
Panel (b): Disordered Cannabis Use



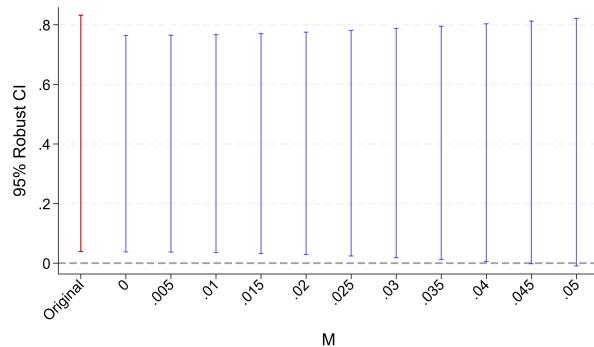
Panel (c): Co-occurring Schizophrenia & CUD



Panel (d): Schizophrenia



Panel (e): Schizophrenia, First Post-period



Notes: These graphs display 95% robust confidence intervals for the treatment effects of recreational marijuana dispensary openings on the listed outcomes, estimated using the “smoothness restriction” sensitivity analysis framework developed by (Rambachan & Roth, 2023). Panels a through d report results for the average treatment effect on the treated (ATT), calculated as a weighted average of cohort-specific post-treatment treatment effects (CATTs) across relative event times. For schizophrenia cases (panel d), the ATT fails the restriction test under $M = 0$, so I also report the confidence interval for the first post-treatment coefficient (ϕ_0) as a robustness check. Baseline ATT estimates under parallel trends are shown in red.

References

- Ahmed, S., Roth, R. M., Stanciu, C. N., & Brunette, M. F. (2021). The Impact of THC and CBD in Schizophrenia: A Systematic Review [Publisher: Frontiers]. *Frontiers in Psychiatry*, 12. <https://doi.org/10.3389/fpsyg.2021.694394>
- Anderson, D. M., & Rees, D. I. (2023). The Public Health Effects of Legalizing Marijuana. *Journal of Economic Literature*, 61(1), 86–143. <https://doi.org/10.1257/jel.20211635>
- Andréasson, S., Engström, A., Allebeck, P., & Rydberg, U. (1987). CANNABIS AND SCHIZOPHRENIA A Longitudinal Study of Swedish Conscripts. *The Lancet*, 330(8574), 1483–1486. [https://doi.org/10.1016/S0140-6736\(87\)92620-1](https://doi.org/10.1016/S0140-6736(87)92620-1)
- Arranz, S., Monferrer, N., Jose Algora, M., Cabezas, A., Sole, M., Vilella, E., Labad, J., & Sanchez-Gistau, V. (2018). The relationship between the level of exposure to stress factors and cannabis in recent onset psychosis. *Schizophrenia Research*, 201, 352–359. <https://doi.org/10.1016/j.schres.2018.04.040>
- Arseneault, L., Cannon, M., Poulton, R., Murray, R., Caspi, A., & Moffitt, T. E. (2002). Cannabis use in adolescence and risk for adult psychosis: Longitudinal prospective study [Publisher: British Medical Journal Publishing Group Section: Paper]. *BMJ*, 325(7374), 1212–1213. <https://doi.org/10.1136/bmj.325.7374.1212>
- Arseneault, L., Cannon, M., Witton, J., & Murray, R. M. (2004). Causal association between cannabis and psychosis: Examination of the evidence. *The British Journal of Psychiatry*, 184(2), 110–117. <https://doi.org/10.1192/bjp.184.2.110>
- Baggio, M., Chong, A., & Simon, D. (2020). Sex, marijuana and baby booms. *Journal of Health Economics*, 70, 102283. <https://doi.org/10.1016/j.jhealeco.2019.102283>
- Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How Much Should We Trust Differences-In-Differences Estimates?*. *The Quarterly Journal of Economics*, 119(1), 249–275. <https://doi.org/10.1162/003355304772839588>
- Bowers, M., Boutros, N., D'Souza, D. C., & Madonick, S. (2001). Substance Abuse as a Risk Factor for Schizophrenia and Related Disorders [Publisher: Taylor & Francis, Ltd.]. *International Journal of Mental Health*, 30(1), 33–57. Retrieved May 25, 2024, from <https://www.jstor.org/stable/41344961>
- Bowtell, M., Ratheesh, A., McGorry, P., Killackey, E., & O'Donoghue, B. (2018). Clinical and demographic predictors of continuing remission or relapse following discontinuation of antipsychotic medication after a first episode of psychosis. A systematic review. *Schizophrenia Research*, 197, 9–18. <https://doi.org/10.1016/j.schres.2017.11.010>

- Brown, J., Cohen, E., & Felix, A. (2023). Economic Benefits and Social Costs of Legalizing Recreational Marijuana. *The Federal Reserve Bank of Kansas City Research Working Papers*. <https://doi.org/10.18651/RWP2023-10>
- Callaway, B., & Sant'Anna, P. H. C. (2021). Difference-in-Differences with multiple time periods. *Journal of Econometrics*, 225(2), 200–230. <https://doi.org/10.1016/j.jeconom.2020.12.001>
- Caulkins, J. P., Kilmer, B., Kleiman, M. A. R., MacCoun, R. J., Midgette, G., Oglesby, P., Pacula, R. L., & Reuter, P. H. (2015). Consequences of Marijuana Use. In *Considering Marijuana Legalization* (pp. 27–48). RAND Corporation. Retrieved May 25, 2024, from <http://www.jstor.org/stable/10.7249/j.ctt15zc545.11>
- Chadwick, B., Miller, M. L., & Hurd, Y. L. (2013). Cannabis Use during Adolescent Development: Susceptibility to Psychiatric Illness [Publisher: Frontiers]. *Frontiers in Psychiatry*, 4. <https://doi.org/10.3389/fpsyg.2013.00129>
- Choi, A., Dave, D., & Sabia, J. J. (2019). Smoke Gets in Your Eyes: Medical Marijuana Laws and Tobacco Cigarette Use. *American Journal of Health Economics*, 5(3), 303–333. https://doi.org/10.1162/ajhe_a_00121
- Dave, D., Liang, Y., Pesko, M. F., Phillips, S., & Sabia, J. J. (2023). Have recreational marijuana laws undermined public health progress on adult tobacco use? *Journal of Health Economics*, 90, 102756. <https://doi.org/10.1016/j.jhealeco.2023.102756>
- Dave, D. M., Liang, Y., Muratori, C., & Sabia, J. J. (2022, December). The Effects of Recreational Marijuana Legalization on Employment and Earnings. <https://doi.org/10.3386/w30813>
- Degenhardt, L., Hall, W., & Lynskey, M. (2003). Testing hypotheses about the relationship between cannabis use and psychosis. *Drug and Alcohol Dependence*, 71(1), 37–48. [https://doi.org/10.1016/S0376-8716\(03\)00064-4](https://doi.org/10.1016/S0376-8716(03)00064-4)
- Di Forti, M., Iyegbe, C., Sallis, H., Kolliakou, A., Falcone, M. A., Paparelli, A., Sirianni, M., La Cascia, C., Stilo, S. A., Marques, T. R., Handley, R., Mondelli, V., Dazzan, P., Pariante, C., David, A. S., Morgan, C., Powell, J., & Murray, R. M. (2012). Confirmation that the AKT1 (rs2494732) Genotype Influences the Risk of Psychosis in Cannabis Users. *Biological Psychiatry*, 72(10), 811–816. <https://doi.org/10.1016/j.biopsych.2012.06.020>
- Di Forti, M., Marconi, A., Carra, E., Fraietta, S., Trotta, A., Bonomo, M., Bianconi, F., Gardner-Sood, P., O'Connor, J., Russo, M., Stilo, S. A., Marques, T. R., Mondelli, V., Dazzan, P., Pariante, C., David, A. S., Gaughran, F., Atakan, Z., Iyegbe, C., ... Murray, R. M. (2015). Proportion of patients in south London with first-episode psychosis attributable to use of high potency cannabis: A case-control study. *The Lancet Psychiatry*, 2(3), 233–238. [https://doi.org/10.1016/S2215-0366\(14\)00117-5](https://doi.org/10.1016/S2215-0366(14)00117-5)

- Dragt, S., Nieman, D. H., Schultze-Lutter, F., Meer, F. v. d., Becker, H., Haan, L. d., Dingemans, P. M., Birchwood, M., Patterson, P., Salokangas, R. K. R., Heinimaa, M., Heinz, A., Juckel, G., Reventlow, H. G. v., French, P., Stevens, H., Ruhrmann, S., Klosterkötter, J., & Linszen, D. H. (2012). Cannabis use and age at onset of symptoms in subjects at clinical high risk for psychosis [Publisher: John Wiley & Sons, Ltd]. *Acta Psychiatrica Scandinavica*, 125(1), 45–53. <https://doi.org/10.1111/j.1600-0447.2011.01763.x>
- D'Souza, D. C., Abi-Saab, W. M., Madonick, S., Forselius-Bielen, K., Doersch, A., Braley, G., Gueorguieva, R., Cooper, T. B., & Krystal, J. H. (2005). Delta-9-tetrahydrocannabinol effects in schizophrenia: Implications for cognition, psychosis, and addiction. *Biological Psychiatry*, 57(6), 594–608. <https://doi.org/10.1016/j.biopsych.2004.12.006>
- D'Souza, D. C., Sewell, R. A., & Ranganathan, M. (2009). Cannabis and psychosis/schizophrenia: Human studies. *European Archives of Psychiatry and Clinical Neuroscience*, 259(7), 413–431. <https://doi.org/10.1007/s00406-009-0024-2>
- Elser, H., Humphreys, K., Kiang, M. V., Mehta, S., Yoon, J. H., Faustman, W. O., & Matthay, E. C. (2023). State Cannabis Legalization and Psychosis-Related Health Care Utilization. *JAMA Network Open*, 6(1), e2252689. <https://doi.org/10.1001/jamanetworkopen.2022.52689>
- Ferdinand, R. F., Sondeijker, F., Van Der Ende, J., Selten, J.-P., Huizink, A., & Verhulst, F. C. (2005). Cannabis use predicts future psychotic symptoms, and vice versa [eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1360-0443.2005.01070.x>]. *Addiction*, 100(5), 612–618. <https://doi.org/10.1111/j.1360-0443.2005.01070.x>
- Fergusson, D. M., Horwood, L. J., & Swain-Campbell, N. R. (2003). Cannabis dependence and psychotic symptoms in young people. *Psychological Medicine*, 33(1), 15–21. <https://doi.org/10.1017/S0033291702006402>
- Gage, S. H., Hickman, M., & Zammit, S. (2016). Association Between Cannabis and Psychosis: Epidemiologic Evidence. *Biological Psychiatry*, 79(7), 549–556. <https://doi.org/10.1016/j.biopsych.2015.08.001>
- Goodman-Bacon, A. (2021). Difference-in-differences with variation in treatment timing. *Journal of Econometrics*, 225(2), 254–277. <https://doi.org/10.1016/j.jeconom.2021.03.014>
- Green, B., Young, R., & Kavanagh, D. (2005). Cannabis use and misuse prevalence among people with psychosis. *British Journal of Psychiatry*, 187(4), 306–313. <https://doi.org/10.1192/bjp.187.4.306>
- Harley, M., Kelleher, I., Clarke, M., Lynch, F., Arseneault, L., Connor, D., Fitzpatrick, C., & Cannon, M. (2010). Cannabis use and childhood trauma interact additively to increase the risk of psychotic symptoms in adolescence. *Psychological Medicine*, 40(10), 1627–1634. <https://doi.org/10.1017/S0033291709991966>

- Henquet, C., Krabbendam, L., Spaunen, J., Kaplan, C., Lieb, R., Wittchen, H.-U., & van Os, J. (2005). Prospective cohort study of cannabis use, predisposition for psychosis, and psychotic symptoms in young people. *BMJ : British Medical Journal*, 330(7481), 11. <https://doi.org/10.1136/bmj.38267.664086.63>
- Ho, B.-C., Barry, A. B., Koeppe, J. A., Macleod, J., Boyd, A., David, A., & O'Leary, D. S. (2023). Recreational Marijuana Use, Adolescent Cognitive Development, and Schizophrenia Susceptibility. *Biological Psychiatry Global Open Science*, 3(2), 222–232. <https://doi.org/10.1016/j.bpsgos.2022.01.008>
- Hollingsworth, A., Wing, C., & Bradford, A. C. (2020). Comparative Effects of Recreational and Medical Marijuana Laws On Drug Use Among Adults and Adolescents. <https://doi.org/10.2139/ssrn.3400519>
- Houston, J. E., Murphy, J., Adamson, G., Stringer, M., & Shevlin, M. (2007). Childhood Sexual Abuse, Early Cannabis Use, and Psychosis: Testing an Interaction Model Based on the National Comorbidity Survey. *Schizophrenia Bulletin*, 34(3), 580–585. <https://doi.org/10.1093/schbul/sbm127>
- Kadakia, A., Catillon, M., Fan, Q., Williams, G. R., Marden, J. R., Anderson, A., Kirson, N., & Dembek, C. (2022). The Economic Burden of Schizophrenia in the United States [Publisher: Physicians Postgraduate Press, Inc.]. *The Journal of Clinical Psychiatry*, 83(6), 43278. <https://doi.org/10.4088/JCP.22m14458>
- Kim, C., Bai, Y., Cao, P., Ienciu, K., & Chum, A. (2024). The impact of recreational cannabis legalization on cannabis-related acute care events among adults with schizophrenia. *Social Psychiatry and Psychiatric Epidemiology*. <https://doi.org/10.1007/s00127-024-02773-4>
- Lebowitz, M. S., Appelbaum, P. S., Dixon, L. B., Girgis, R. R., & Wall, M. M. (2021). Experimentally exploring the potential behavioral effects of personalized genetic information about marijuana and schizophrenia risk. *Journal of Psychiatric Research*, 140, 316–322. <https://doi.org/10.1016/j.jpsychires.2021.05.066>
- Livne, O., Shmulewitz, D., Sarvet, A. L., Wall, M. M., & Hasin, D. S. (2022). Association of Cannabis Use–Related Predictor Variables and Self-Reported Psychotic Disorders: U.S. Adults, 2001–2002 and 2012–2013 [Publisher: American Psychiatric Publishing]. *American Journal of Psychiatry*, 179(1), 36–45. <https://doi.org/10.1176/appi.ajp.2021.21010073>
- Marconi, A., Di Forti, M., Lewis, C. M., Murray, R. M., & Vassos, E. (2016). Meta-analysis of the Association Between the Level of Cannabis Use and Risk of Psychosis. *Schizophrenia Bulletin*, 42(5), 1262–1269. <https://doi.org/10.1093/schbul/sbw003>

- Martland, N., Martland, R., Cullen, A. E., & Bhattacharyya, S. (2020). Are adult stressful life events associated with psychotic relapse? A systematic review of 23 studies. *Psychological Medicine*, 50(14), 2302–2316. <https://doi.org/10.1017/S0033291720003554>
- Mathur, N. K., & Ruhm, C. J. (2023). Marijuana legalization and opioid deaths. *Journal of Health Economics*, 88, 102728. <https://doi.org/10.1016/j.jhealeco.2023.102728>
- Miller, S., & Wherry, L. R. (2018). The Long-Term Effects of Early Life Medicaid Coverage [Publisher: University of Wisconsin Press Section: Article]. *Journal of Human Resources*. <https://doi.org/10.3388/jhr.54.3.0816.8173R1>
- Moore, T. H. M., Zammit, S., Lingford-Hughes, A., Barnes, T. R. E., Jones, P. B., Burke, M., & Lewis, G. (2007). Cannabis use and risk of psychotic or affective mental health outcomes: A systematic review. *370*.
- Mueser, T., Miles, M., & Hill, D. (2000). Substance Use Disorder in Hospitalized Severely Mentally Ill Psychiatric Patients: Prevalence, Correlates, and Subgroups. *Schizophrenia Bulletin*, 26(1).
- Murray, R. M., Quigley, H., Quattrone, D., Englund, A., & Di Forti, M. (2016). Traditional marijuana, high-potency cannabis and synthetic cannabinoids: Increasing risk for psychosis [_eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/wps.20341>]. *World Psychiatry*, 15(3), 195–204. <https://doi.org/10.1002/wps.20341>
- Ortega, A. (2023a). The highs and the lows: Recreational marijuana laws and mental health treatment [_eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/hec.4726>]. *Health Economics*, 32(10), 2173–2191. <https://doi.org/10.1002/hec.4726>
- Ortega, A. (2023b). Medicaid Expansion and mental health treatment: Evidence from the Affordable Care Act [_eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/hec.4633>]. *Health Economics*, 32(4), 755–806. <https://doi.org/10.1002/hec.4633>
- Rambachan, A., & Roth, J. (2023). A More Credible Approach to Parallel Trends [Publisher: Oxford University Press (OUP)]. *Review of Economic Studies*, 90(5), 2555–2591. <https://doi.org/10.1093/restud/rdad018>
- Ranganathan, M., Skosnik, P. D., & D’Souza, D. C. (2016). Marijuana and Madness: Associations Between Cannabinoids and Psychosis [Publisher: Elsevier]. *Biological Psychiatry*, 79(7), 511–513. <https://doi.org/10.1016/j.biopsych.2016.02.007>
- Ringen, P. A., Lagerberg, T. V., Birkenæs, A. B., Engn, J., Færden, A., Jónsdóttir, H., Nesvåg, R., Friis, S., Opjordsmoen, S., Larsen, F., Melle, I., & Andreassen, O. A. (2008). Differences in prevalence and patterns of substance use in schizophrenia and bipolar disorder [Edition:

2007/12/10 Publisher: Cambridge University Press]. *Psychological Medicine*, 38(9), 1241–1249. <https://doi.org/10.1017/S003329170700236X>

Roth, J., Sant'Anna, P. H. C., Bilinski, A., & Poe, J. (2023, January). *What's Trending in Difference-in-Differences? A Synthesis of the Recent Econometrics Literature* (tech. rep. No. arXiv:2201.01194) (arXiv:2201.01194 [econ, stat] type: article). arXiv. Retrieved January 16, 2024, from <http://arxiv.org/abs/2201.01194>

Sabia, J. J., Dave, D., Alotaibi, F., & Rees, D. I. (2024). The effects of recreational marijuana laws on drug use and crime. *Journal of Public Economics*, 234, 105075. <https://doi.org/10.1016/j.jpubeco.2024.105075>

Sabia, J. J., Dave, D. M., Alotaibi, F., & Rees, D. I. (2021, July). Is Recreational Marijuana a Gateway to Harder Drug Use and Crime? <https://doi.org/10.3386/w29038>

Sevy, S., Robinson, D. G., Holloway, S., Alvir, J. M., Woerner, M. G., Bilder, R., Goldman, R., Lieberman, J., & Kane, J. (2001). Correlates of substance misuse in patients with first-episode schizophrenia and schizoaffective disorder [eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1600-0447.2001.00452.x>]. *Acta Psychiatrica Scandinavica*, 104(5), 367–374. <https://doi.org/10.1111/j.1600-0447.2001.00452.x>

Simeone, J. C., Ward, A. J., Rotella, P., Collins, J., & Windisch, R. (2015). An evaluation of variation in published estimates of schizophrenia prevalence from 1990–2013: A systematic literature review. *BMC Psychiatry*, 15(1), 193. <https://doi.org/10.1186/s12888-015-0578-7>

Sun, L., & Abraham, S. (2021). Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. *Journal of Econometrics*, 225(2), 175–199. <https://doi.org/10.1016/j.jeconom.2020.09.006>

Vadhan, N. P., Corcoran, C. M., Bedi, G., Keilp, J. G., & Haney, M. (2017). Acute effects of smoked marijuana in marijuana smokers at clinical high-risk for psychosis: A preliminary study. *Psychiatry Research*, 257, 372–374. <https://doi.org/10.1016/j.psychres.2017.07.070>

Van Os, J. (2002). Cannabis Use and Psychosis: A Longitudinal Population-based Study. *American Journal of Epidemiology*, 156(4), 319–327. <https://doi.org/10.1093/aje/kwf043>

Vignault, C., Massé, A., Gouron, D., Quintin, J., Asli, K. D., & Semaan, W. (2021). The Potential Impact of Recreational Cannabis Legalization on the Prevalence of Cannabis Use Disorder and Psychotic Disorders: A Retrospective Observational Study [Publisher: SAGE Publications Inc]. *The Canadian Journal of Psychiatry*, 66(12), 1069–1076. <https://doi.org/10.1177/0706743720984684>

Vita, A., & Barlati, S. (2018). Recovery from schizophrenia: Is it possible? *Current Opinion in Psychiatry*, 31, 1. <https://doi.org/10.1097/YCO.0000000000000407>

- Wang, G. S., Button, C., Wilks, A., Schwam, D., Tung, G., & Pacula, R. L. (2022). Impact of cannabis legalization on healthcare utilization for psychosis and schizophrenia in Colorado. *International Journal of Drug Policy*, 104, 103685. <https://doi.org/10.1016/j.drugpo.2022.103685>
- Weiser, M., Knobler, H. Y., Noy, S., & Kaplan, Z. (2002). Clinical characteristics of adolescents later hospitalized for schizophrenia [eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/ajmg.10647>]. *American Journal of Medical Genetics*, 114(8), 949–955. <https://doi.org/10.1002/ajmg.10647>
- Wen, H., Hockenberry, J. M., & Cummings, J. R. (2015). The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. *Journal of Health Economics*, 42, 64–80. <https://doi.org/10.1016/j.jhealeco.2015.03.007>
- Zammit, S., Lewis, G., Dalman, C., & Allebeck, P. (2010). Examining interactions between risk factors for psychosis. *British Journal of Psychiatry*, 197(3), 207–211. <https://doi.org/10.1192/bjp.bp.109.070904>