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Does Expanding Access to Cannabis Affect Traffic Crashes? County-Level Evidence from Recreational Marijuana Dispensary Sales in Colorado

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Abstract

This article examines the effect of recreational cannabis dispensary sales on traffic crashes by employing difference-in-differences model that exploits the variation in the timing of recreational marijuana dispensary entry across counties within Colorado. Using marijuana-related hospital discharge as a proxy for marijuana use, the results indicate a sizable rise in marijuana-related hospital discharges after the entry of retail cannabis stores. However, there is a lack of evidence that traffic crash incidents are affected by the entry. The preferred estimate suggests that, at 90% confidence level, a large increase in traffic crashes by more than 5% can be ruled out.

JEL Classification: K00, I1, R41, H23

Keywords: Recreational Marijuana Laws, Cannabis Access, Traffic Crashes

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Declarations of interest: none.

1 Introduction

As of 2019, fifteen U.S. states, including the District of Columbia, have legalized the use of marijuana for recreational purposes, allowing a small amount of marijuana to be sold in retail stores. This trend of fully legalizing marijuana reflects the changes in public opinion over marijuana use in the United States. In 2000, only 31% believe that the use of marijuana should be made legal, while the number rise to 53% in 2015 (Pew Research Center, 2015). Nonetheless, concerns over expanding access to marijuana remain, including the potential increase in traffic crashes due to the rise in the prevalence of marijuana use. Indeed, the economic costs of traffic crashes are non-trivial. A recent estimate by the U.S. Department of Transportation suggests that the economic costs of motor vehicle crashes in the United States totaled $242 billion, including $77 billion in lost productivity (Blincoe et al., 2015). When the quality of life valuations were taken into account, the number rose to $836 billion (Blincoe et al., 2015). In this paper, I examine the effect of recreational marijuana dispensary entry on traffic crash incidents using county-level data from Colorado.

There are indeed reasons to believe that expanding access to marijuana would lead to more traffic crash incidents. Marijuana use has been linked to lower neuromotor and neurocognitive performance required to drive safely, leading to an increase in response time and lane weaving, especially among inexperienced drivers (Weinstein et al., 2008; Ronen et al., 2008; Ramaekers et al., 2009; Lenné et al., 2010). As such, driving under the influence of cannabis can increase the risk of being involved in a traffic crash (Asbridge et al., 2005; Li et al., 2012; Rogeberg and Elvik, 2016).

At the same time, increased access to marijuana may not necessarily increase traffic crash incidents. Recent studies have found evidence of substitutability between

marijuana and other substances that can impair driving performance, such as alcohol (Crost and Guerrero, 2012; Miller and Seo, 2018; Dragone et al., 2019; Baggio et al., 2020).[1] If expanding access to marijuana leads to a reduction in alcohol use, the net effect of such policy on traffic crashes could be small or even negative. Recent evidence from medical marijuana laws supports this hypothesis. Although legalizing marijuana for medical purposes has been associated with an increase in driving under the influence of cannabis (Fink et al., 2020), medical marijuana laws are associated with reductions in traffic fatalities (Mark Anderson et al., 2013; Santaella-Tenorio et al., 2017; Cook et al., 2020), mainly due to the decline in traffic fatalities that are alcohol-related (Mark Anderson et al., 2013). The effect of expanding access to cannabis on traffic crash incidents is, therefore, conceptually ambiguous.

I begin the analysis by examining whether recreational cannabis dispensary entry is associated with an increase in marijuana-related hospital discharges, which is an indicator for the prevalence of marijuana use. Using difference-in-differences model that exploits the variation in the timing of recreational marijuana dispensary entry across counties within Colorado, I found evidence of a rise in marijuana-related hospital discharge rate following the entry of retail cannabis stores. The most conservative estimate indicates that marijuana-related discharges per 1,000 hospital discharges increased by 2.97 following the entry of recreational cannabis dispensary, an approximately 30% rise relative to the mean of the adopter counties in the baseline period.

However, despite evidence suggesting the rise in the prevalence of marijuana use after the entry of retail cannabis stores, there is a lack of evidence that traffic crash

[1]Alcohol use has been identified as one of the contributing factors that increase the risk of traffic crash (Shibata and Fukuda, 1994; DiNardo and Lemieux, 2001; Wagenaar et al., 2000; Gonçalves et al., 2012). It is worth noting that not all studies found evidence of substitutability between marijuana and alcohol use (e.g., Pacula, 1998; Williams et al., 2004; Wen et al., 2015). However, a recent review by Subbaraman (2016) found that the plurality of studies supports the substitutability between marijuana and alcohol use.

incidents are statistically significantly affected by the entry. Most of the estimates on traffic crashes are small in magnitude and not statistically significantly different from zero. The preferred estimate suggests that, at 90% confidence level, a large increase (more than 5%) in traffic crashes can be ruled out. There is also a possibility that traffic crash becomes deadlier as more individuals use marijuana after the entry of recreational cannabis dispensaries. However, the results of the analysis on the share of traffic crashes that are fatal suggest that this is not the case.

This paper contributes to a few recent studies that examine the relationship between recreational marijuana laws and traffic fatalities. Overall, the findings so far are still mixed and inconclusive. The state-level analysis by Aydelotte et al. (2017, 2019) found that recreational marijuana laws in Washington and Colorado are associated with an increase in fatal crash rates, especially after the recreational marijuana dispensaries are allowed to be operational in 2014. However, a recent examination by Hansen et al. (2020) that use synthetic control method to address the difficulty of finding appropriate control groups for Colorado and Washington found a lack of evidence that traffic fatalities are affected by the passage of recreational marijuana laws. Interestingly, using a similar synthetic control method, another recent study by Santaella-Tenorio et al. (2020) found evidence of an increase in traffic fatalities after the implementation of recreational marijuana laws in Colorado. The disagreement in the findings between Hansen et al. (2020) and Santaella-Tenorio et al. (2020) partially reflects the difference in choosing the matching variables used to construct the synthetic control. At the same time, it underscores the difficulty of finding/constructing appropriate control groups for Colorado and Washington, especially because traffic fatalities trends in these states are not similar to the rest of the country prior to the legalization of recreational marijuana (Hansen et al., 2020). My analysis complements these

previous works by using county-level variation in the entry of recreational cannabis dispensary within Colorado to examine whether the opening of cannabis retail stores after the legalization of recreational marijuana is associated with an increase in traffic crashes. Since counties within Colorado share similar institutions and characteristics, the effect of recreational marijuana laws can arguably be better identified by using the variation within Colorado than by comparing changes in the outcomes between Colorado and other states.

This paper is also related to the literature that examines whether expanding access to marijuana changes individuals' behavior in regard to cannabis use. Cannabis decriminalization has been associated with an increase in marijuana use (Saffer and Chaloupka, 1999; Damrongplasit et al., 2010), while the evidence on recreational and medical marijuana generally found an increase among adults but not youth (Khatapoush and Hallfors, 2004; Cerdá et al., 2012; Mark Anderson et al., 2015; Chu, 2015; Kerr et al., 2017; Miller et al., 2017; Anderson et al., 2019). One of the main concerns with most studies estimating the effect of expanding access to cannabis on marijuana use is the reliance on the self-reported use. Since cannabis decriminalization/legalization is likely to influence whether a respondent answer truthfully on the survey, the observed increase in self-reported marijuana use after the legalization may simply reflect the change in survey response behavior among those surveyed. In other words, marijuana legalization can affect the measure that researchers used to proxy for actual marijuana use, even though the actual use might not be changed by the legalization. Although I did not rely on self-reported marijuana use in the analysis, my proxy for actual marijuana use, marijuana-related hospital discharges, is still subject to the same concern. For example, marijuana legalization could make cannabis users more comfortable going to the hospital to seek help for an adverse health effect, resulting

in an increase in marijuana-related hospital discharges after legalization. However, since this effect applies to all counties within Colorado regardless of whether a county experienced a cannabis dispensary entry or not, the difference-in-differences model that I use in the analysis by exploiting the variation in the timing of retail cannabis store entry across counties within Colorado will take into account the possibility that cannabis users may become more comfortable to seek help for an adverse event after legalization. Therefore, my analysis complements previous studies that examine the effect of expanding access to cannabis on marijuana use by taking into account the concern that the proxy that one used for actual marijuana use (e.g., self-reported use) can be affected by marijuana legalization even though the actual cannabis use might not be changed by the legalization.

Finally, this paper adds to the literature that examine the socio-economic impacts of expanding access to marijuana. Recent work by Chu and Gershenson (2018) found that medical marijuana legalization is associated with a reduction in the time spent on educational activities among college students. As such, limiting access to marijuana can improve students' academic performances (Marie and Zölitz, 2017). On crime, the evidence is mixed. Dragone et al. (2019) found that recreational marijuana legalization in Washington is associated with a reduction of rape and thefts, while the opening of retail cannabis stores in Denver is associated with an increase in property crimes (Connealy et al., 2020). On the labor market, the creation of the newly legal cannabis industry can increase labor demand, reducing unemployment (Chakraborty et al., 2020). My analysis contributes to these studies by examining the potential effects of recreational marijuana dispensaries on traffic crashes, which is one of the main concerns of expanding access to marijuana.

The rest of the paper is constructed as follows. Section 2 briefly describes the

background of marijuana legalization. Section 3 describes the data and the empirical methodology used in the analysis. Section 4 documents the findings. Section 5 concludes.

2 Background

The United States Drug Enforcement Administration classifies cannabis as a Schedule 1 substance, defined as drugs with no currently accepted medical use and a high potential for abuse, making it illegal at the federal level to cultivate, possess, and consume marijuana and its related products. Nevertheless, at the state level, many states have decriminalized its use, beginning with Oregon in 1973. Since then, decriminalization laws have passed in twenty-seven states and the District of Columbia, mainly to reduce punishment for marijuana use and possession (NCSL, 2019).

At the same time, following a new interest in examining the potential therapeutic effects of cannabis, many states began to legalize marijuana for medical purposes. In 1996, California became the first state to effectively remove penalties for qualifying patients to use medical marijuana with the passage of Proposition 215, paving the way for other states to follow suit.[2] As of the writing of the paper, a total of 36 states and the District of Columbia have approved a measure to regulate cannabis for medical use (NCSL, 2021).

The effort to further expand the access to cannabis reached another milestone when Colorado became one of the first states to legalize marijuana for recreational purposes with the passage of Amendment 64 in 2012, making it no longer a state crime for

[2]It is worth noting that Arizona also passed medical marijuana legislation in 1996, but this turned out to be largely symbolic because it required a doctor to issue a prescription (i.e., an order to dispense a medication) in violation of federal law (MPP, 2015). California avoids this issue by specifying that qualifying patients only need a doctor's recommendation (i.e., a statement of a doctor's professional opinion).

anyone aged 21 years old or older to (home) grow, possess, and consume a small amount of marijuana.[3] The Amendment also authorizes the lawful operation of marijuana-related facilities, with the first retail cannabis store opened in January 2014, allowing adults 21 years old and above with a valid ID to buy a small amount of marijuana (one ounce or less) from these dispensaries. To obtain the license to open a recreational cannabis dispensary, an applicant must fulfill requirements such as be 21 or older, be a resident of Colorado for at least two years, and pass criminal background checks. As of 2019, the fees for the initial application are $7,000, while renewal costs $1,800.

The availability of recreational cannabis dispensaries across Colorado's counties accelerated shortly after the first store opened. By the end of 2014, recreational cannabis dispensaries were available in 31 counties in Colorado (Figures 1 and 2). The presence of retail cannabis stores across Colorado's counties continued to expand afterward, albeit at a slower pace. At the end of 2019, retail cannabis stores were present in 40 out of 64 counties in Colorado. Interestingly, despite the expansion of recreational cannabis market during the period, the market for medical marijuana was relatively unaffected. While recreational marijuana sales increased substantially from 14 million USD in January 2014 to 116 million USD in December 2019, medical marijuana sales were relatively stable at around 30 million USD throughout this period (Figure 3).

3 Data

3.1 Colorado's Dispensaries Sales Data

The information on the presence of recreational cannabis dispensary across Colorado's counties over time is obtained from the Marijuana Sales Report, which is made avail-

[3]Medical marijuana has been legal in Colorado since 2000, following the passage of Amendment 20.

able by the Colorado Department of Revenue.[4] Available monthly since January 2014, the report provides the amount of sales (in USD) for counties where there were retail cannabis stores in operation. It is worth noting that the amount of sales in a county can be suppressed for confidentiality requirements. Specifically, the Colorado Department of Revenue released the amount of sales only in counties where there are at least three taxpayers and none of them represents more than 80% of the total. Nevertheless, the Marijuana Sales Report provides the name of all counties where retail marijuana sales are present regardless of whether the amount of sales is suppressed or not, allowing one to infer the presence of retail cannabis stores at a time in the period of analysis.

3.2 Marijuana-Related Hospital Discharges

The statistics of marijuana-related hospital discharges across Colorado's counties are obtained from the Colorado Department of Public Health and Environment (CDPHE).[5] Available from 2004 to 2019, the publicly accessible CDPHE marijuana-related hospital discharges statistics are based on the data from Colorado Hospital Association, which collects information on hospital discharges from participating hospitals throughout the state. A hospital discharge is classified as marijuana-related if its billing code includes the codes for hospitalizations due to marijuana use, abuse, or dependence as well as cannabis poisonings or adverse events. It is worth noting that CDPHE suppressed the data for counties with less than six marijuana-related hospital discharges in the year. I used all county $\times$ year observations in which the data are not suppressed for marijuana-related hospital discharges analysis.

On average, there are 18.9 marijuana-related discharges per 1,000 hospital dis-

[4]The reports can be obtained from https://cdor.colorado.gov/data-and-reports/marijuana-data/marijuana-sales-reports.

[5]The CDPHE marijuana-related hospital discharge is publicly available from https://marijuanahealthinfo.colorado.gov/health-data/colorado-hospital-association-cha-data.

charges in the period of analysis (Table 1). Early adopter counties (i.e. counties with recreational cannabis dispensary entry in January 2014) in general have a much higher marijuana-related hospital discharge rate prior to 2014 relative to late adopter counties with retail cannabis store entry after January 2014.

3.3 Traffic Crashes Data

The statistics on traffic crashes across Colorado's counties from 2004 to 2019 are obtained from the Colorado Department of Transportation (CDOT), which maintains the crash database for the purposes of improving traffic and highway safety.[6] There are two traffic outcomes that I considered in the analysis: traffic crashes per 100,000 population and fatal crashes per 1,000 traffic crashes. While the first outcome measures the prevalence of traffic crashes, the second outcome is used in the analysis to explore the possibility that the increase in marijuana use associated with expanding access to cannabis can make a traffic crash more dangerous.

On average, there are 2594 traffic crashes per 100,000 population across Colorado's counties in the period of analysis (Table 1). Early adopter counties with retail cannabis store entry in January 2014 in general have more traffic crashes per 100,000 in the baseline period relative to late adopter counties with recreational cannabis dispensary after January 2014. However, a traffic crash in the late adopter counties is more likely to result in a fatal crash compared to early adopter counties.

[6]Traffic crashes statistics are obtained from https://www.codot.gov/safety/traffic-safety/crash-data-management/crash-data. Fatal traffic crash statistics are obtained from https://www.codot.gov/safety/traffic-safety/crash-data-management/fatal-crash-data.

3.4 Additional Data Sources

The county-level demographic characteristics are obtained from the U.S. Census Bureau statistics, while the data on economic conditions are based on Local Area Unemployment Statistics from the U.S. Bureau of Labor Statistics. The summary statistics of these county-level characteristics are reported in Table 1. I calculated the employment-to-population ratio and labor force participation rate using the population of 15- to 64-year-olds as the denominator, which is slightly different from the way they are usually defined (e.g., labor force participation rate among 16- to 64-year-olds). This slight difference is due to data limitation; Census only provides the population estimates by age group in five-year age intervals.

In general, early adopter counties with recreational cannabis dispensary entry in January 2014 had slightly better economic conditions relative to the late adopter counties with retail cannabis store entry after January 2014, as measured by its lower unemployment rate and higher labor force participation in the baseline period. On average, the share of Hispanics in late adopters counties is higher than the early adopter counties.

4 Empirical Methodology

To identify the effect of expanding marijuana access, I use the geographic and temporal variation in the recreational cannabis dispensary entry across counties in Colorado. Specifically, I estimate the following model:

$$y_{crt} = \delta_c + \delta_{rt} + \gamma Dispensary_{crt} + X'_{crt}\alpha + \varepsilon_{crt} \tag{1}$$

where y_{crt} is the outcome for Colorado county c that is located in region r at year t.[7] X is a vector of county-level control variables. Since a county's prevalence of marijuana use (which is proxied by marijuana-related hospital discharges) and traffic crash are likely to depend on its demographic characteristics, I add the share of population under 20 years old, the share of individuals aged 20 to 34, the share of female in the population, the share of blacks in the population, and the share of Hispanics in the population as control variables. I also add unemployment rate, employment-to-population ratio, and labor force participation rate as controls since fluctuations in economic conditions have been associated with changes in unhealthy behaviors such as smoking and drinking as well as changes in traffic fatalities (Ruhm, 2000; Ruhm and Black, 2002; Ruhm, 2004). δ_c and δ_{rt} are county and region-by-year fixed effects, respectively. ε is the error term. The main variable of interest is $Dispensary_{crt}$, which takes a value of one if there are recreational cannabis dispensary sales in county c at year t and zero otherwise. The estimated effect of recreational cannabis dispensary entry is given by the coefficient γ. All the regressions are weighted by the county population, and the standard errors are clustered at the county level.

The main assumption for the empirical strategy described above is that in the absence of recreational cannabis dispensary entry, the outcomes in 'treated' and control counties would evolve in similar way (i.e., the parallel trends assumption). It is not possible to test this assumption directly. However, one can provide supporting evidence by checking the pre-trends. Specifically, I estimate an event study model as follows

$$y_{crt} = \delta_c + \delta_{rt} + \sum_{\tau=2}^{5} \beta_{-\tau} Dispensary_{cr,t-\tau} + \sum_{\tau=0}^{5} \beta_{+\tau} Dispensary_{cr,t+\tau} + X'_{crt}\alpha + \varepsilon_{crt} \qquad (2)$$

[7] I define regions based on 14 Colorado Planning Regions from the Colorado State Demography Office (https://demography.dola.colorado.gov/gis/colorado-regions/).

where all the variables are defined in the same way as before. $Dispensary_{cr,t-1}$ is excluded from the model, so that the estimated effects (β) should be interpreted as relative to the year prior to recreational cannabis dispensary entry. It should be noted that for $Dispensary_{cr,t-5}$, the variable is equal to one for $t-5$ and each year prior to $t-5$. For the validity of the empirical strategy described above, there should be no visible difference in the trends prior to the entry of retail cannabis stores.

5 Results

5.1 Recreational Cannabis Dispensary and Marijuana-Related Hospital Discharges

5.1.1 Findings

I begin by presenting the results for marijuana-related hospital discharge, which is the proxy for marijuana use (Table 2). Column 1 reports the estimate from the model with year and county fixed effects. In column 2, I added controls for economic conditions and demographic characteristics as described in the previous section. In column 3, I added region-by-year fixed effects to control for potential unobserved factors affecting the outcomes that vary across regions over time in Colorado.

The evidence shows that recreational cannabis dispensary entry is associated with an increase in marijuana-related discharges per 1,000 hospital discharges. In the absence of retail cannabis store entry, the marijuana-related discharges per 1,000 hospital discharges would be lower by 6.13 (Column 1). Adding controls for economic conditions and demographic characteristics lowers the point estimate, but it is still statistically significant. Finally, controlling for region-by-year fixed effects lowers the

point estimate slightly to 4.77, but the precision of the estimate is improved, suggesting that these fixed effects have a sizable explanatory power for marijuana-related hospital discharges in Colorado. Evaluated at the mean of adopter counties prior to 2014, this estimate corresponds to approximately a 46% increase.

The main assumption for the validity of the findings in Table 2 is that in the absence of recreational cannabis dispensary entry, the outcomes in treated and control counties would evolve in a similar way. To provide supporting evidence that this assumption is satisfied, Figure 4a reports the results from the event study model. There is a lack of evidence that the main findings in Table 2 are mainly driven by the differential in the trends between treated and control counties prior to the entry of recreational cannabis dispensary.

Overall, the findings suggest that the prevalence of marijuana use, as proxied by marijuana-related hospital discharges, increased following the entry of retail cannabis stores in Colorado. The results from the event study model show that the main findings are not likely to be mainly driven by the differential in the trends between treated and control counties prior to the entry of recreational cannabis dispensary.

5.1.2 Robustness Checks

One concern with the findings above is that the estimates may be driven by an outlier county with much larger retail marijuana sales compared to other counties. Specifically, out of 116 million USD in retail marijuana sales in December 2019, 33 million USD of the sales were made in Denver. As a robustness check, I exclude Denver from the analysis. The results of this exercise are reported in Table 3, and the findings hold qualitatively.

A related concern is that the results may be driven by 'pioneer' counties that ex-

perienced recreational cannabis entry in January 2014, shortly after the first retail cannabis store opened in Colorado. Indeed, these counties have much higher marijuana-related hospital discharge rate in the baseline period compared to the counties with recreational cannabis entry after January 2014 (Table 1). As a robustness check, I exclude these early adopter counties from the analysis, and the results are reported in Table 4. Overall, the main findings hold. In the model controlling for region-by-year fixed effects as well as economic and demographic characteristics (Column 3), the estimate suggests that recreational cannabis dispensary entry is associated with a 2.97 rise in marijuana-related discharges per 1,000 hospital discharges, a 30% increase evaluated at the mean of adopter counties prior to 2014.

Although the analysis so far provides strong evidence that marijuana-related hospital discharge rates rise after the entry of retail cannabis stores, the magnitude of the estimated effects varies sizably from 2.96 (Column 3 of Table 4) to 4.77 (Column 3 of Table 3). I would argue that the estimate obtained by excluding early adopter counties is the better one. The reason for this is as follows. In Figures 4b, I plotted the coefficients of the estimated effects from the event study model that excludes early adopter counties. Comparing this figure to the one obtained from using the whole sample (Figure 4a), the differential in the pre-trends between treated and control counties is smaller when early adopter counties are excluded. In other words, a cleaner identification of the effect of recreational cannabis dispensary entry on marijuana-related hospital discharges is obtained by excluding early adopter counties.

As shown by Goodman-Bacon (2018), the difference-in-differences estimates obtained using variation in treatment timing are likely to be biased away from the 'true' effects toward zero when the treatment effects change over time. In my case, this issue arises due to the effects were partially identified by using counties with recreational

cannabis entry in 2014 as control for counties that experienced recreational cannabis entry after 2014. To address this concern, I re-estimated the effects by excluding counties with recreational marijuana sales after 2014. In this case, all treatment counties were treated in the same year (2014), alleviating the concern of using variation in treatment timing as noted in Goodman-Bacon (2018). The results of this exercise are reported in Table 5. The estimated effects, if any, are slightly larger.

It is worth noting that the main specifications as shown in equation 1 above is not the only way to estimate the effect of recreational dispensary entry. An alternative way is to exploit the difference in treatment intensity across counties in Colorado. Specifically, I estimated the following model:

$$y_{crt} = \delta_c + \delta_{rt} + \phi SalesPerCapita_{crt} + X'_{crt}\alpha + \varepsilon_{crt} \tag{3}$$

where the definition of the variables is the same as before except for $SalesPerCapita_{crt}$. $SalesPerCapita_{crt}$ is defined as the cumulative retail marijuana sales (in USD) in county c as of year t divided by the county's population.[8] This variable takes the value of zero in counties with no retail marijuana sales, and it increases following the entry of recreational marijuana dispensary. The main coefficient of interest ϕ can then be interpreted as the effect of one USD per capita increase in retail marijuana sales on marijuana-related hospital discharges.

[8]As noted before, the Colorado Department of Revenue (CDOR) suppressed retail marijuana sales data for counties with less than three taxpayers or those with at least three taxpayers but one of them represents more than 80% of the total sales. Nevertheless, CDOR reported the total sales for all counties in which the data are suppressed, allowing one to impute the sales in a suppressed county proportionately to the size of the population. Specifically, I impute the sales in a suppressed county by multiplying the total sales from all counties in which the data are suppressed with the ratio of the number of individuals aged 20 and older in the county to the total number of individuals aged 20 and older in all counties in which the data are suppressed. The age range for the ratio is chosen based on the eligibility criteria to legally purchase marijuana (adults 21 years old and above). Ideally, individuals aged 21 and older should be used for the construction of the ratio. However, U.S. Census Bureau only reports the population estimates by age group in five-year age intervals.

The results of this exercise are reported in Table 6. Focusing on the estimates obtained by including economics/demographic controls and region-by-year fixed effects, the result suggests that a one standard deviation increase in retail marijuana sales per capita ($\sim$707 USD/capita) is associated with a 2.6 rise in marijuana-related hospital discharges per 1,000 discharges. Evaluated at approximately the mean of adopter counties before 2014, this estimate corresponds to approximately a 25% increase.

5.2 Recreational Cannabis Dispensary and Traffic Crashes

One of the main concerns with expanding access to cannabis is that the increase in the prevalence of marijuana use will result in more traffic crashes. Indeed, cannabis use has been associated with lower neuromotor and neurocognitive performances required to drive safely, leading to an increase in response time and lane weaving (Weinstein et al., 2008; Ronen et al., 2008; Ramaekers et al., 2009; Lenné et al., 2010). The findings in the previous subsection provide evidence that marijuana use, as proxied by marijuana-related hospital discharges, increased sizably following the recreational marijuana dispensary entry, indicating that the entry of retail cannabis stores may lead to a higher rate of traffic accidents. However, an increase in marijuana use might not necessarily result in more traffic crashes. Recent studies have found evidence of substitutability between marijuana and other substances that can impair driving performance, such as alcohol (Crost and Guerrero, 2012; Miller and Seo, 2018; Dragone et al., 2019; Baggio et al., 2020). If the increase in marijuana use is accompanied by the reduction in the use of other substances, the net effect of expanding access to cannabis on traffic crash incidents could be small or even negative. The rest of the analysis is devoted to examining the potential effect of recreational cannabis entry on traffic crash incidents.

5.2.1 Main Findings

The estimated effects of recreational cannabis dispensary entry on traffic crashes are reported in Table 7. There is a lack of evidence that the entry of retail cannabis stores is associated with an increase in traffic crashes per 100,000 population. In the model using only year and county fixed effect (Panel A of Column 1), the estimated effect is very close to zero. Adding controls for economic/demographic characteristics and region-by-year fixed effect, the estimate suggests that the entry of retail cannabis store is associated with an increase of 85 traffic crashes per 100,000 population (Panel A of Column 3), approximately 3% rise relative to the mean of adopter counties (i.e., counties with recreational cannabis dispensary entry in the analysis period) prior to 2014. Nevertheless, this estimate is not statistically significantly different from zero.

Although the entry of recreational cannabis dispensary is not associated with a statistically significant increase in traffic crashes rate, there is a chance that the rise in marijuana use associated with expanding access to cannabis could make traffic crashes more fatal. To explore this possibility, I examine the effect of retail cannabis store entry on fatal crashes per 1,000 crashes. The results of this exercise are reported in Panel B of Table 6. In the model only with year and county fixed effects, the estimated effect suggests that the entry of recreational cannabis dispensary is associated with a 0.93 rise in fatal crashes per 1,000 crashes. Adding controls for economics/demographic characteristics and region-by-year fixed effects lower the magnitude of the estimated effect to 0.54, approximately 6.5% evaluated at the mean of adopter counties prior to 2014. However, this estimate is not statistically significantly different from zero.[9]

As a way to provide supporting evidence that the parallel trends assumption is

[9]In the robustness check section, the estimated effects on fatal crashes are mostly statistically insignificant and sometimes change sign, further suggesting the lack of relationship between recreational cannabis dispensary entry on the share of traffic crashes that are fatal.

satisfied, Figures 5 and 6 show the results from the event study model. There is a lack of evidence that the main findings are mainly driven by the differential in trends between treated and control counties prior to the entry of retail cannabis stores.

In sum, the results of the analysis suggest that the entry of retail cannabis stores is not associated with a statistically significant change in traffic crashes per 100,000 population in Colorado. At the same time, there is evidence that recreational cannabis dispensary entry is positively associated with an increase in the share of traffic accidents that are fatal. However, this estimate is not statistically significantly different from zero.

5.2.2 Robustness Checks

To make sure that the main findings are not driven by Denver which has a much larger retail marijuana sales compared to other counties, I repeat the analysis with Denver excluded from the sample (Table 8). Excluding Denver does not alter the main finding of a lack of relationship between recreational cannabis dispensary entry and traffic crash. The estimated effects on traffic crashes per 100,000 population become mostly negative and close to zero, while the estimates for fatal crashes correspond closely to those obtained from the main specifications.

As another check, I excluded early adopter counties which experienced recreational cannabis dispensary entry in January 2014 to ensure that the findings are not driven by these pioneer counties. Indeed, as shown in Table 1, early adopter counties in general have different characteristics compared to late adopters with retail cannabis store entry after January 2014. The results of this exercise are reported in Table 9, and the main findings hold qualitatively.

As noted earlier, the difference-in-differences estimates obtained using variation

in treatment timing are likely to be biased away from the 'true' effects toward zero when the treatment effects change over time (Goodman-Bacon, 2018). To alleviate this concern, in Table 10, I report the results when counties with recreational marijuana sales after 2014 are excluded from the analysis so that all treatment counties are treated in the same year (2014). The main findings qualitatively hold; most of the estimates are small in magnitude and not statistically significantly different from zero. My preferred estimate, which is obtained by further restricting the sample to exclude early adopters counties with recreational marijuana dispensary entry in January 2014, suggests that the entry is associated with a small statistically insignificant increase of about 10 crashes per 100,000 population (Column 6 of Table 10). This estimate is quite precise. At 90% confidence level, a large increase in traffic crashes by more than 5% can be ruled out. Unfortunately, the estimate for fatal crashes is imprecise, and an economically meaningful increase in the share of crashes that are fatal cannot be rule out. Nevertheless, most of the estimates are not statistically significantly different from zero and sometimes change sign (in the further analysis below), indicating a lack of relationship between recreational cannabis dispensary entry and the share of traffic incidents that are fatal.

There is a concern that the potential spillover effects to neighboring counties may bias the estimated effect of recreational cannabis dispensary entry on traffic crashes toward zero. Indeed, it is possible that individuals living in counties with no retail cannabis store cross to the neighboring counties with recreational cannabis dispensary to purchase marijuana.[10] To address this concern, I repeat the analysis using only counties that experienced retail cannabis store entry in 2014 (treated group) and

[10]Note that in the presence of spillover effects to neighboring counties, the estimated impact of recreational dispensary entry on marijuana-related hospital discharges would be the lower bound of the effect.

non-adopter counties that did not share a border with adopter counties as of December 2019 (control group).[11] The results of this analysis are reported in Table 11. Although many of the estimates become more imprecisely estimated, reflecting the large reduction in the number of counties included in the analysis, the results still suggest a lack of relationship between recreational cannabis entry and traffic crashes. Focusing on the estimate obtained by including controls for economics/demographic characteristics and region-by-year fixed effects (Column 3 of Panel A), the result shows that the entry of recreational cannabis dispensary is associated with 257 increase in traffic crashes per 100,000 population. However, this estimate is not statistically significant and likely to reflect differential in trends between treated and control counties prior to 2014 (Appendix Figure 1a). Excluding early adopter counties help to reduce this differential in pre-trends (Appendix Figure 1b), and the estimated effect becomes negative and close to zero (Column 6 of Panel A). For fatal crashes, the estimate is negative and statistically significant, suggesting that the entry of recreational cannabis dispensary is associated with a reduction in the share of traffic crashes that are fatal.[12]

Finally, I estimated the effect of retail cannabis store entry on traffic crashes by using alternative specifications that exploit the difference in treatment intensity across counties in Colorado (equation 3). The results of this analysis are reported in Table 12. Focusing on the estimates obtained by including controls for economics/demographic characteristics and region-by-year fixed effects, the results suggest that a one standard deviation increase in retail cannabis sales per capita ($\sim$707 USD/capita) is associated with about 67 increase in traffic crashes per 100,000 population. This estimate is small

[11]There are three counties that did not share a border with adopter counties as of December 2019: Yuma, Kit Carson, and Cheyenne (Figure 1c). Note that including counties that experienced retail cannabis store entry after 2014 would not address the spillover effects concern since the effect will partially be identified by using these counties as control for counties that experienced recreational cannabis entry in 2014.

[12]The event study graph for fatal crashes is shown in Appendix Figure 2.

in magnitude (2.42% evaluated at the mean of adopter counties prior to 2014) and not statistically significantly different from zero. A similar result is found for fatal crashes. A one standard deviation increase in retail cannabis sales per capita is associated with a 0.01 increase in fatal crashes per 1,000 traffic crashes. This estimate is economically small (1.2% evaluated at the mean of adopter counties prior to 2014) and not statistically significantly different from zero.

6 Conclusion

There are efforts in recent years to fully legalize marijuana for recreational purposes. However, the evidence on the potential socioeconomic costs, as well as the prospective benefits, of such policy is still limited. In particular, there is a concern that expanding access to recreational marijuana would lead to more traffic accidents. Using county-level data from Colorado and exploiting the variation in the timing of retail cannabis store entry across Colorado's counties, I examine the effect of recreational cannabis dispensary entry on traffic crash incidents.

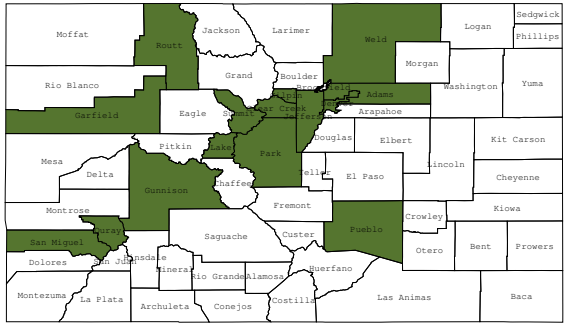
The results of the analysis yield two main findings. First, there is evidence that the entry of recreational cannabis dispensary leads to a higher share of hospital discharges that are marijuana-related, indicating a rise in the prevalence of marijuana use after the entry. The most conservative estimate suggests that the entry of recreational cannabis dispensary is associated with a 2.97 increase in marijuana-related discharges per 1,000 hospital discharges, approximately 30% rise evaluated at the mean of adopter counties in the baseline period. Second, despite the finding suggesting a rise in the prevalence of marijuana use after the entry of retail cannabis stores, there is a lack of evidence that the traffic crash rate is statistically significantly affected by

the entry of recreational cannabis dispensary. Most of the estimates are small in magnitude and not statistically significantly different from zero. The preferred estimate suggests that, at 90% confidence level, a large increase in traffic crashes by more than 5% can be ruled out.

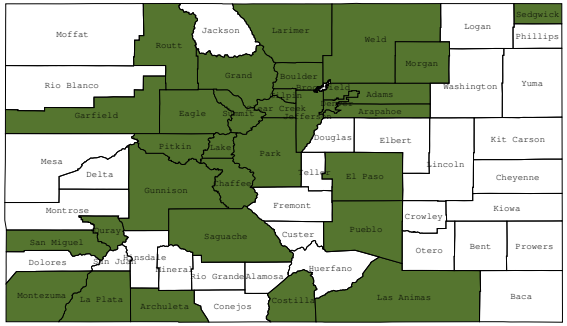
The findings of a lack of relationship between expanding access to marijuana through retail stores and traffic crash may seem counterintuitive, especially since the use of marijuana has been linked to lower neuromotor/neurocognitive performance required to drive safely and a higher risk of being involved in a traffic crash (Asbridge et al., 2005; Weinstein et al., 2008; Rogeberg and Elvik, 2016). However, recent studies have found evidence of substitutability between marijuana and other substances that can impair driving performance, such as alcohol (Crost and Guerrero, 2012; Mark Anderson et al., 2013; Baggio et al., 2020). In this case, the net effect of expanding access to marijuana on traffic crashes could be quite small. The findings in this study are consistent with this hypothesis.

A Figures and Tables

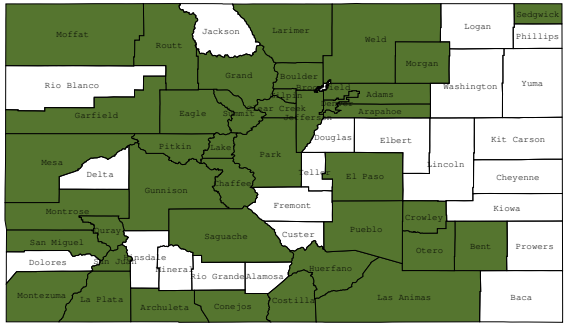
Figure 1: Colorado Counties With Recreational Marijuana Sales



(a) January 2014



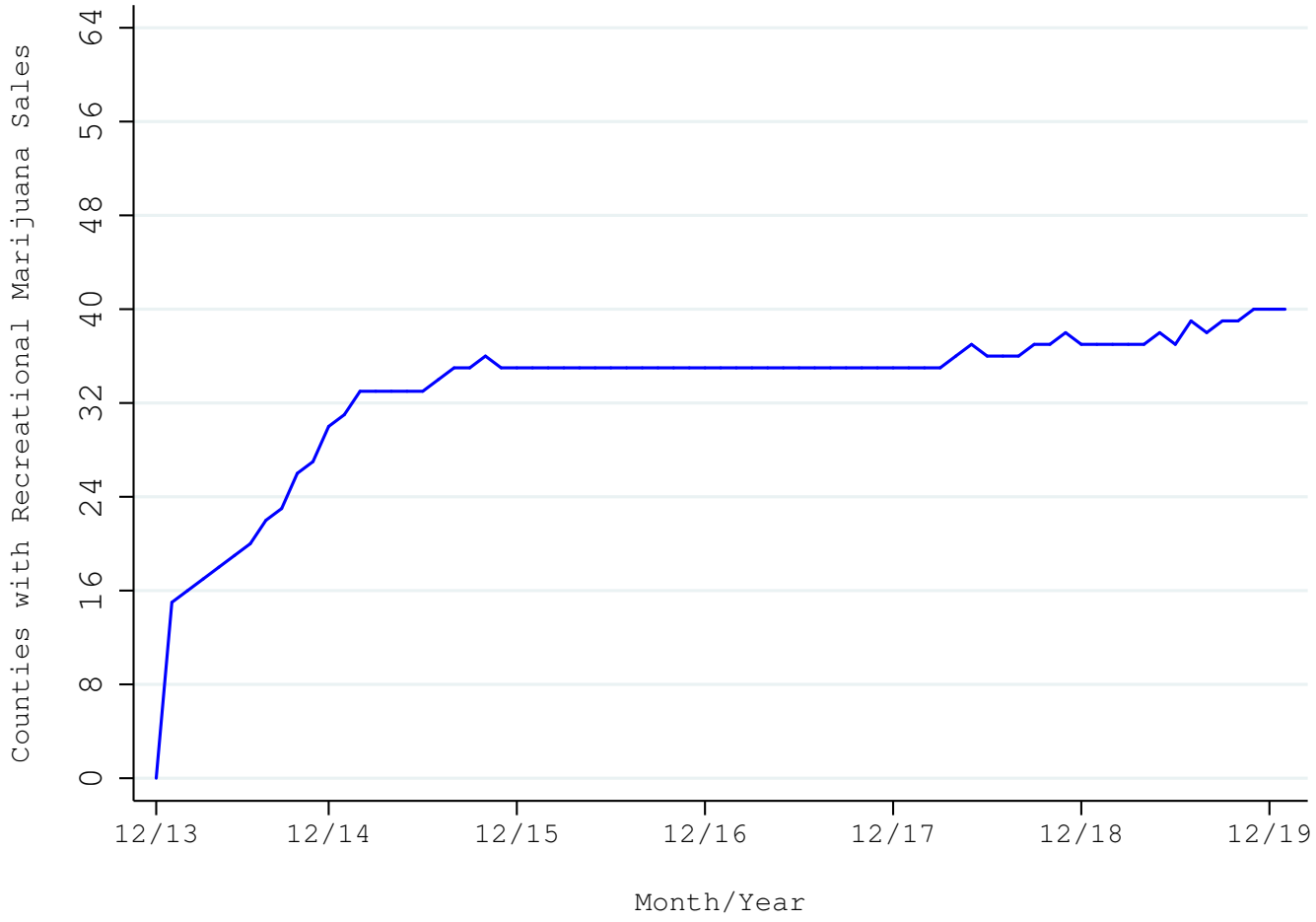
(b) December 2014



(c) December 2019

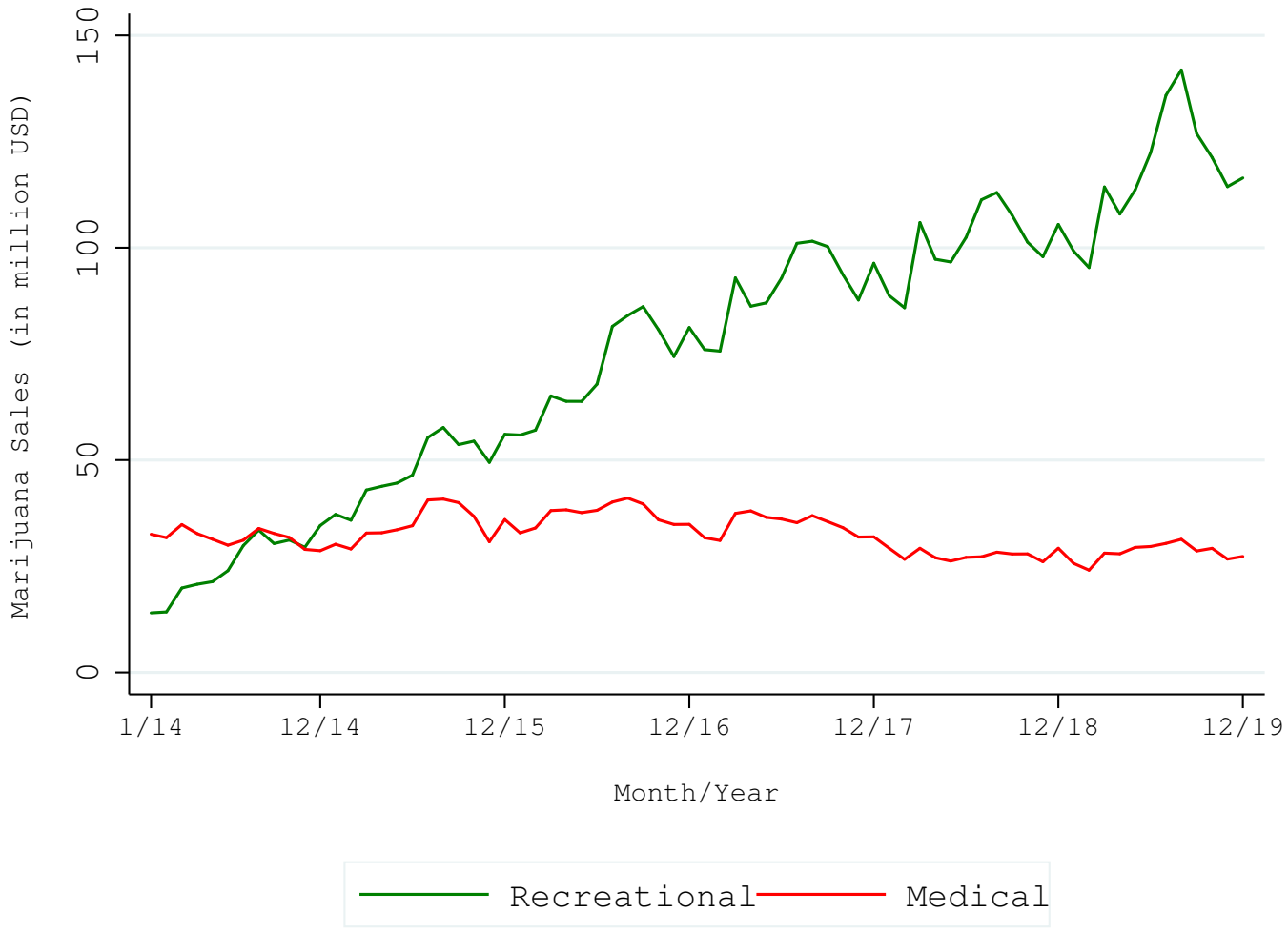
Notes: Green indicates counties with recreational marijuana sales through dispensaries. The information on Colorado Counties with recreational marijuana sales is obtained from Colorado Department of Revenue Marijuana Sales Report 2014-2019.

Figure 2: Number of Colorado Counties With Recreational Marijuana Sales



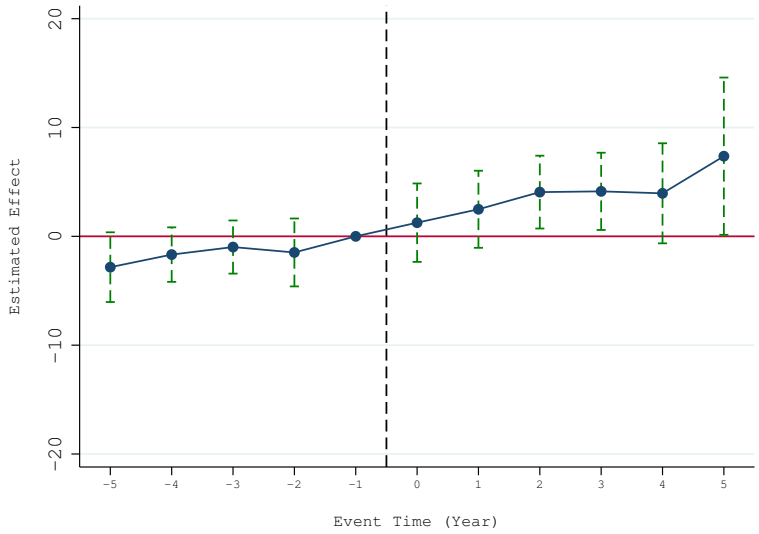
Notes: The statistics are based on Colorado Department of Revenue Marijuana Sales Report 2014-2019.

Figure 3: Marijuana Sales in Colorado

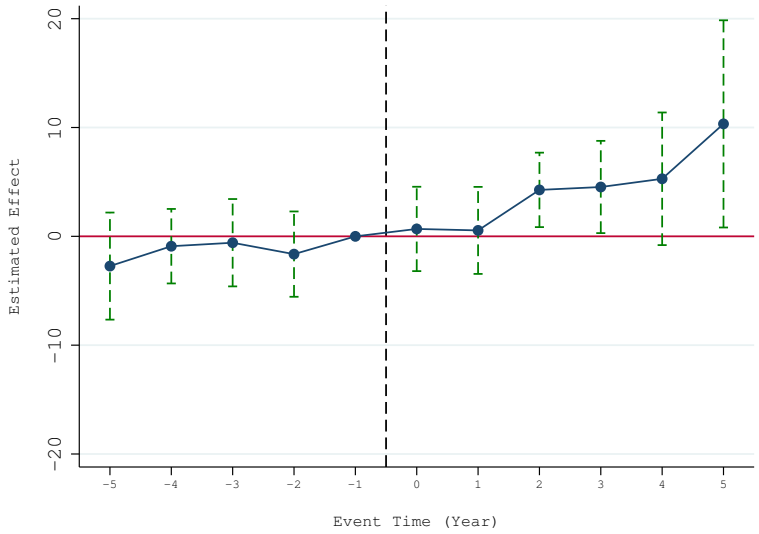


Notes: The statistics are based on Colorado Department of Revenue Marijuana Sales Report 2014-2019.

Figure 4: Effect of Recreational Marijuana Dispensary Entry on Marijuana-Related Hospital Discharges Per 1,000 Discharges



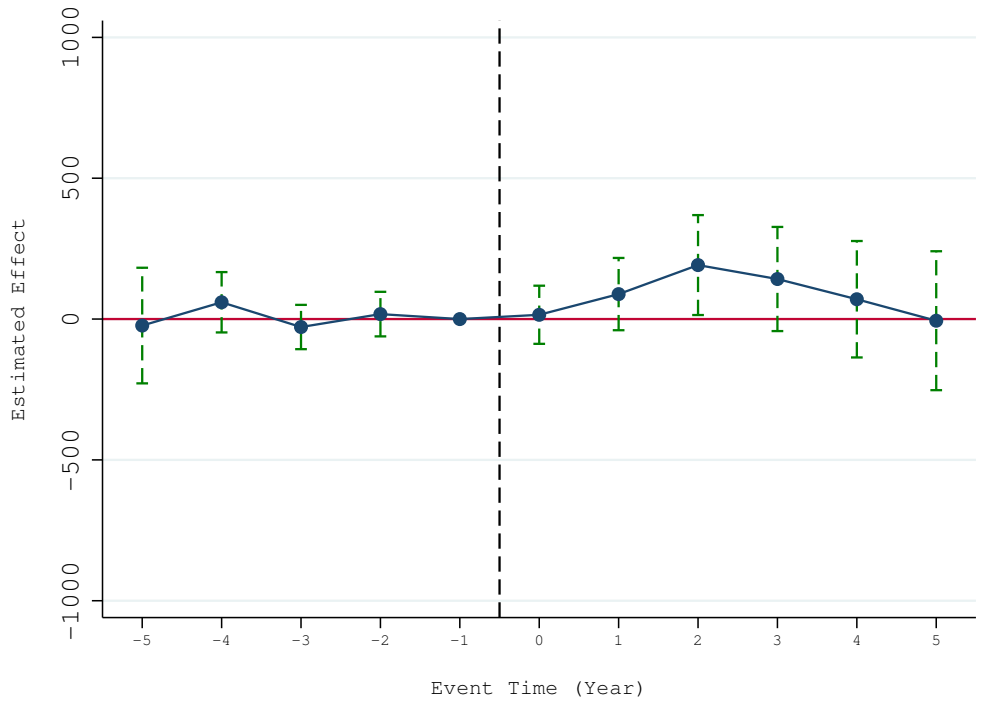
(a) Include Early Adopters



(b) Exclude Early Adopters

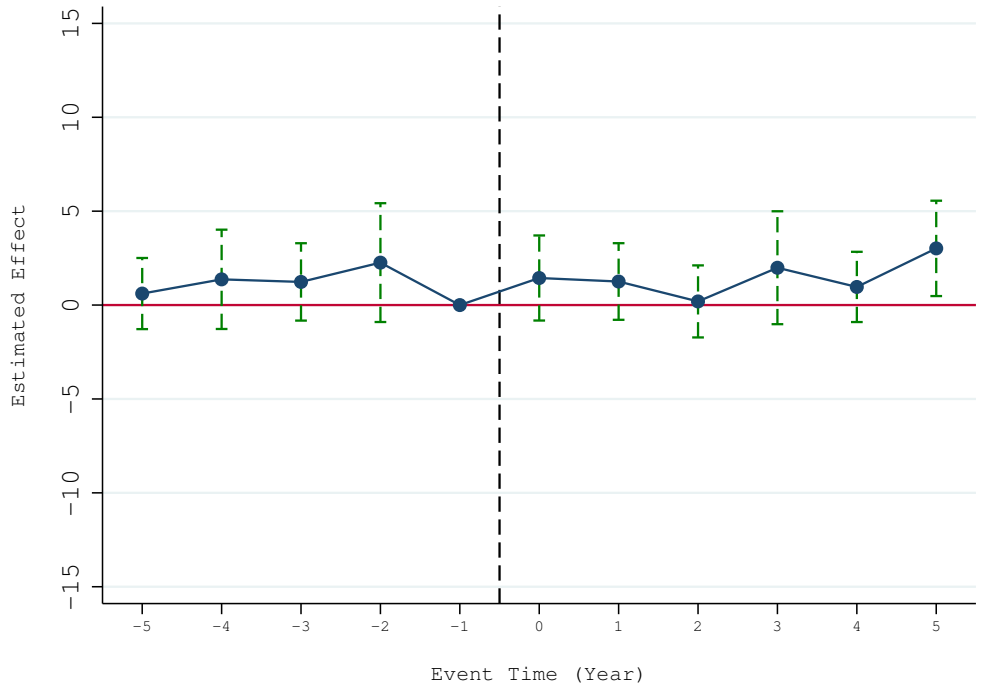
Notes: Data are from Colorado Hospital Association 2004-2019 marijuana-relate hospital discharges. Each point shows the estimated effect of recreational marijuana dispensary entry on marijuana-related discharges per 1,000 hospital discharges relative to the year prior to the entry (the omitted year). Early adopters are counties with recreational cannabis dispensary entry in January 2014. All regressions include controls for labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics, county fixed effects, and region-by-year fixed effects. 95% confidence intervals constructed with standard errors clustered at the county level are provided in the figures. The regressions are weighted by county population.

Figure 5: Effect of Recreational Marijuana Dispensary Entry on Traffic Crashes per 100,000 Population



Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. Each point shows the estimated effect of recreational marijuana dispensary entry on traffic crashes per 100,000 population relative to the year prior to the entry (the omitted year). All regressions include controls for labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics, county fixed effects, and region-by-year fixed effects. 95% confidence intervals constructed with standard errors clustered at the county level are provided in the figures. The regressions are weighted by county population.

Figure 6: Effect of Recreational Marijuana Dispensary Entry on Fatal Crashes per 1,000 Crashes



Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. Each point shows the estimated effect of recreational marijuana dispensary entry on fatal traffic crashes per 1,000 crashes relative to the year prior to the entry (the omitted year). All regressions include controls for labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics, county fixed effects, and region-by-year fixed effects. 95% confidence intervals constructed with standard errors clustered at the county level are provided in the figures. The regressions are weighted by county population.

Table 1: Counties' Summary Statistics

	All Years All Counties	Baseline Rates (Before 2014) Counties With Rec. Marijuana Sales		
		Early Adopters	Late Adopters	Both
Marijuana-Related Discharges Per 1,000 Hospital Discharges	18.888	12.415	8.900	10.207
	(14.609)	(6.339)	(4.622)	(5.580)
Traffic Crashes per 100,000 Population	2594.475	3056.583	2593.936	2767.429
	(1650.259)	(1549.530)	(1333.341)	(1434.007)
Fatal Crashes per 1,000 Crashes	11.573	6.586	9.169	8.201
	(13.872)	(6.448)	(10.019)	(8.929)
Recreational Marijuana Sales Per Capita (USD)	185.431	-	-	-
	(707.354)			
Unemployment Rate (%)	5.136	6.057	6.730	6.478
	(2.433)	(2.139)	(2.514)	(2.400)
Employment-to-Population Ratio (15- to 64-year-olds)	0.782	0.776	0.731	0.748
	(0.142)	(0.075)	(0.144)	(0.125)
Labor Force Participation Rate (%) Among 15- to 64-year-olds	0.822	0.825	0.783	0.799
	(0.139)	(0.070)	(0.146)	(0.125)
Share of Population Below 20 Years Old	0.240	0.242	0.245	0.244
	(0.043)	(0.041)	(0.042)	(0.042)
Share of 20- to 34-year-olds in the Population	0.181	0.205	0.186	0.193
	(0.047)	(0.058)	(0.044)	(0.050)
Share of Female in the Population	0.482	0.482	0.478	0.480
	(0.036)	(0.018)	(0.049)	(0.041)
Share of Blacks in the Population	0.017	0.016	0.020	0.018
	(0.024)	(0.026)	(0.028)	(0.028)
Share of Hispanics in the population	0.191	0.181	0.237	0.216
	(0.141)	(0.136)	(0.157)	(0.152)

Notes: Standard deviations are reported in the parentheses. The 2004-2019 marijuana hospital discharges estimates are based on Colorado Hospital Association data obtained from Colorado Department of Public Health and Environment. The 2004-2018 traffic crashes/fatalities estimates are based on the statistics from Colorado Department of Transportation. The 2014-2019 recreational marijuana sales estimates are based on marijuana sales reports from Colorado Department of Revenue. Unemployment rate estimates are based on Local Area Unemployment Statistics from U.S. Bureau of Labor Statistics. The 2004-2019 Demographics and population estimates are based on the statistics from U.S. Census Bureau. Early adopters are counties with recreational cannabis dispensary entry in January 2014. Late adopters are counties with recreational cannabis dispensary entry after January 2014.

Table 2: Effect of Recreational Cannabis Dispensary Entry on Marijuana-Related Hospital Discharges

	Marijuana-Related Discharges Per 1,000 Discharges		
	(1)	(2)	(3)
Recreational Cannabis Dispensary Entry	6.129**	5.501**	4.765***
	(2.397)	(2.149)	(1.363)
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Mean of Dependent Variable for Adopter Counties Prior to 2014	10.21	10.21	10.21
Observations	699	699	699

Notes: Data are from Colorado Hospital Association 2004-2019 marijuana-related hospital discharges. The estimates show the effects of recreational marijuana dispensary entry on marijuana-related discharges per 1,000 hospital discharges. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 3: Effect of Recreational Cannabis Dispensary Entry
on Marijuana-Related Hospital Discharge (Robustness - Excluding Denver)

	Marijuana-Related Discharges Per 1,000 Discharges		
	(1)	(2)	(3)
Recreational Cannabis Dispensary Entry	5.949**	5.507**	4.704***
	(2.453)	(2.221)	(1.392)
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Mean of Dependent Variable for Adopter Counties Prior to 2014	10.01	10.01	10.01
Observations	683	683	683

Notes: Data are from Colorado Hospital Association 2004-2019 marijuana-related hospital discharges. The estimates show the effects of recreational marijuana dispensary entry on marijuana-related discharges per 1,000 hospital discharges. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 4: Effect of Recreational Cannabis Dispensary Entry
on Marijuana-Related Hospital Discharge (Robustness - Excluding Early Adopters)

	Marijuana-Related Discharges Per 1,000 Discharges		
	(1)	(2)	(3)
Recreational Cannabis Dispensary Entry	6.663**	5.691**	2.965***
	(2.858)	(2.520)	(1.087)
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Mean of Dependent Variable for Adopter Counties Prior to 2014	8.90	8.90	8.90
Observations	508	508	508

Notes: Data are from Colorado Hospital Association 2004-2019 marijuana-related hospital discharges. The estimates show the effects of recreational marijuana dispensary entry on marijuana-related discharges per 1,000 hospital discharges. Early adopters are counties with recreational cannabis dispensary entry in January 2014. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 5: Effect of Recreational Cannabis Dispensary Entry on Marijuana-Related Hospital Discharge
(Robustness - Excluding Counties With Recreational Marijuana Sales After 2014)

	Include Early Adopters			Exclude Early Adopters		
	(1)	(2)	(3)	(4)	(5)	(6)
Recreational Cannabis Dispensary Entry	7.999***	7.824***	5.264***	9.025***	8.425***	3.182*
	(1.919)	(1.964)	(1.495)	(2.369)	(2.231)	(1.646)
Mean of Dependent Variable for Adopter Counties Prior to 2014	10.46	10.46	10.46	8.66	8.66	8.66
Controls:						
Year Fixed Effects	Yes	Yes	No	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes	No	No	Yes
Observations	588	588	588	397	397	397

Notes: Data are from Colorado Hospital Association 2004-2019 marijuana-related hospital discharges. The estimates show the effects of recreational marijuana dispensary entry on marijuana-related discharges per 1,000 hospital discharges. Early adopters are counties with recreational cannabis dispensary entry in January 2014. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 6: Effect of Recreational Cannabis Dispensary Entry
on Marijuana-Related Hospital Discharge (Robustness - Using Sales Per Capita)

	Marijuana-Related Hospital Discharges Per 1,000 Discharges		
	(1)	(2)	(3)
Recreational Cannabis Sales Per Capita	0.00219**	0.00249**	0.00374***
	(0.00099)	(0.00115)	(0.00116)
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Mean of Dependent Variable for Adopter Counties Prior to 2014	10.21	10.21	10.21
Observations	699	699	699

Notes: Data are from Colorado Hospital Association 2004-2019 marijuana-related hospital discharges. The estimates show the effects of one USD per capita increase in retail marijuana sales on marijuana-related discharges per 1,000 hospital discharges. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 7: Effect of Recreational Cannabis Dispensary Entry on Traffic Crashes

	(1)	(2)	(3)
Panel A (Outcome: Crashes per 100,000 Population)			
Recreational Cannabis Dispensary Entry	-0.398	4.432	85.696
	(106.984)	(83.686)	(88.214)
Mean of Dependent Variable for Adopter Counties Prior to 2014	2767.43	2767.43	2767.43
Panel B (Outcome: Fatal Crashes per 1,000 Crashes)			
Recreational Cannabis Dispensary Entry	0.927*	0.738	0.538
	(0.513)	(0.589)	(0.516)
Mean of Dependent Variable for Adopter Counties Prior to 2014	8.20	8.20	8.20
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Observations	1024	1024	1024

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. The estimates show the effects of recreational marijuana dispensary entry on traffic crashes. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 8: Effect of Recreational Cannabis Dispensary Entry on Traffic Crashes
(Sensitivity Check - Excluding Denver)

	(1)	(2)	(3)
Panel A (Outcome: Crashes per 100,000 Population)			
Recreational Cannabis Dispensary Entry	19.538	-35.980	-0.480
	(108.566)	(86.093)	(72.499)
Mean of Dependent Variable for Adopter Counties Prior to 2014	2752.29	2752.29	2752.29
Panel B (Outcome: Fatal Crashes per 1,000 Crashes)			
Recreational Cannabis Dispensary Entry	0.957*	0.752	0.589
	(0.516)	(0.590)	(0.529)
Mean of Dependent Variable for Adopter Counties Prior to 2014	8.36	8.36	8.36
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Observations	1008	1008	1008

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. The estimates show the effects of recreational marijuana dispensary entry on traffic crashes. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 9: Effect of Recreational Cannabis Dispensary Entry on Traffic Crashes
(Sensitivity Check - Excluding Early Adopters)

	(1)	(2)	(3)
Panel A (Outcome: Crashes per 100,000 Population)			
Recreational Cannabis Dispensary Entry	7.761	13.529	61.333
	(113.340)	(90.624)	(88.728)
Mean of Dependent Variable for Adopter Counties Prior to 2014	2593.94	2593.94	2593.94
Panel B (Outcome: Fatal Crashes per 1,000 Crashes)			
Recreational Cannabis Dispensary Entry	0.912*	0.823	0.647
	(0.543)	(0.668)	(0.665)
Mean of Dependent Variable for Adopter Counties Prior to 2014	9.17	9.17	9.17
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Observations	784	784	784

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. The estimates show the effects of recreational marijuana dispensary entry on traffic crashes. Early adopters are counties with recreational cannabis dispensary entry in January 2014. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 10: Effect of Recreational Cannabis Dispensary Entry on Traffic Crashes
(Robustness - Excluding Counties With Recreational Marijuana Sales After 2014)

	Include Early Adopters			Exclude Early Adopters		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A (Outcome: Crashes per 100,000 Population)						
Recreational Cannabis Dispensary Entry	-22.646	-32.627	107.164	-6.860	-15.448	10.440
	(111.472)	(93.134)	(98.822)	(120.500)	(101.718)	(74.451)
Mean of Dependent Variable for Adopter Counties Prior to 2014	2830.37	2830.37	2830.37	2618.30	2618.30	2618.30
Panel B (Outcome: Fatal Crashes per 1,000 Crashes)						
Recreational Cannabis Dispensary Entry	1.081*	0.720	0.536	1.073*	0.802	0.349
	(0.552)	(0.627)	(0.471)	(0.589)	(0.764)	(0.798)
Mean of Dependent Variable for Adopter Counties Prior to 2014	7.05	7.05	7.05	7.48	7.48	7.48
Controls:						
Year Fixed Effects	Yes	Yes	No	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes	No	No	Yes
Observations	880	880	880	640	640	640

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. The estimates show the effects of recreational marijuana dispensary entry on traffic crashes. Early adopters are counties with recreational cannabis dispensary entry in January 2014. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 11: Effect of Recreational Cannabis Dispensary Entry on Traffic Crashes
(Sensitivity Check - Addressing Potential Spillover to Neighboring Counties)

	Include Early Adopters			Exclude Early Adopters		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A (Outcome: Crashes per 100,000 Population)						
Recreational Cannabis Dispensary Entry	155.559	-523.567	256.822	172.094	-368.771	-14.615
	(124.432)	(456.477)	(153.726)	(135.682)	(270.106)	(225.946)
Mean of Dependent Variable for Adopter Counties Prior to 2014	2849.59	2849.59	2849.59	2642.59	2642.59	2642.59
Panel B (Outcome: Fatal Crashes per 1,000 Crashes)						
Recreational Cannabis Dispensary Entry	1.958	3.329	-5.411***	1.960	3.093	-5.938*
	(7.002)	(8.155)	(1.740)	(7.193)	(9.183)	(3.148)
Mean of Dependent Variable for Adopter Counties Prior to 2014	6.98	6.98	6.98	7.38	7.38	7.38
Controls:						
Year Fixed Effects	Yes	Yes	No	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes	No	No	Yes
Observations	528	528	528	288	288	288

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. The estimates show the effects of recreational marijuana dispensary entry on traffic crashes. Early adopters are counties with recreational cannabis dispensary entry in January 2014. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 12: Effect of Recreational Cannabis Dispensary Entry on Traffic Crashes
(Sensitivity Check - Using Sales Per Capita)

	(1)	(2)	(3)
Panel A (Outcome: Crashes per 100,000 Population)			
Recreational Cannabis Sales per Capita	-0.08113**	0.01274	0.09414
	(0.03517)	(0.07856)	(0.12113)
Mean of Dependent Variable for Adopter Counties Prior to 2014	2767.43	2767.43	2767.43
Panel B (Outcome: Fatal Crashes per 1,000 Crashes)			
Recreational Cannabis Sales per Capita	-0.00010	0.00009	0.00014
	(0.00018)	(0.00019)	(0.00025)
Mean of Dependent Variable for Adopter Counties Prior to 2014	8.20	8.20	8.20
Controls:			
Year Fixed Effects	Yes	Yes	No
County Fixed Effects	Yes	Yes	Yes
County's Econ. Conditions and Demographic Characteristics	No	Yes	Yes
Region-by-Year Fixed Effects	No	No	Yes
Observations	1024	1024	1024

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. The estimates show the effects of one USD per capita increase in retail marijuana sales on traffic crashes. Controls for county's economic conditions and demographic characteristics include labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics. The regressions are weighted by county population. Heteroskedastic- and clustered-robust standard errors at the county level in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$

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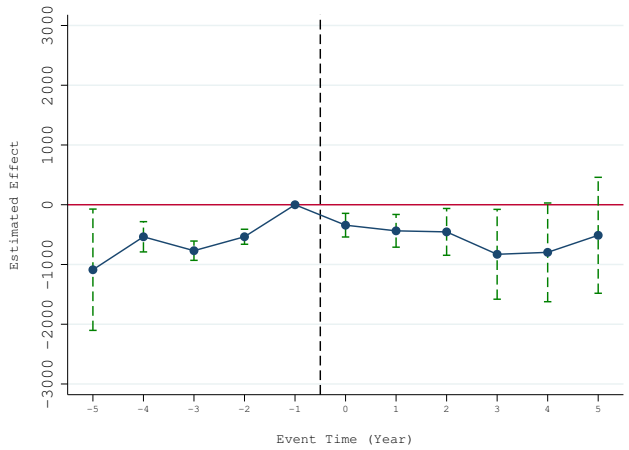
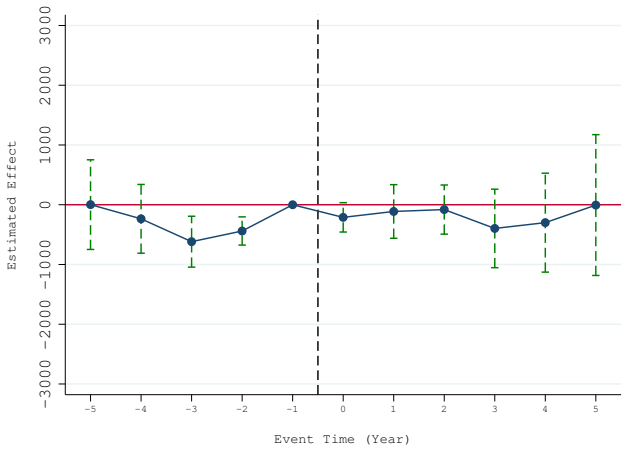
Appendix

Figure 1: Effect of Recreational Marijuana Dispensary Entry on Traffic Crashes per 100,000 Population (Addressing Potential Spillover)



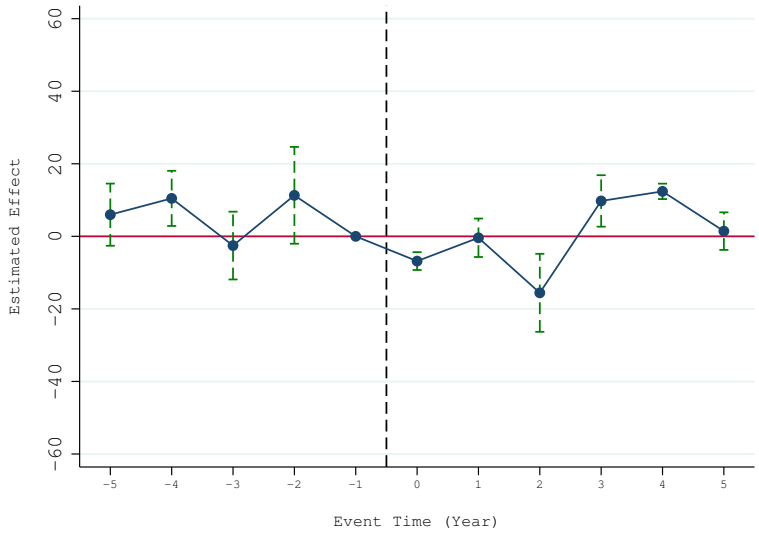
(a) Include Early Adopters



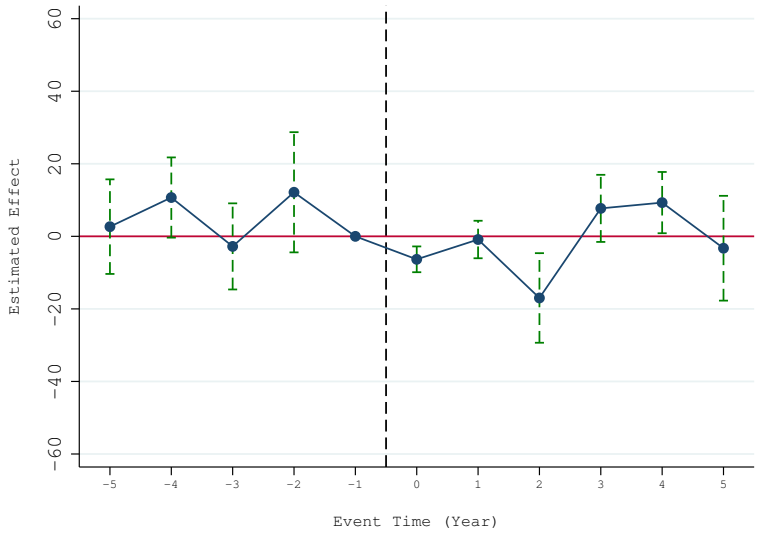
(b) Exclude Early Adopters

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. Each point shows the estimated effect of recreational marijuana dispensary entry on traffic crashes per 100,000 population relative to a year prior to the entry (the omitted year). Early adopters are counties with recreational cannabis dispensary entry in January 2014. All regressions include controls for labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics, county fixed effects, and region-by-year fixed effects. 95% confidence intervals constructed with standard errors clustered at the county level are provided in the figures. The regressions are weighted by county population.

Figure 2: Effect of Recreational Marijuana Dispensary Entry on Fatal Crashes per 1,000 Crashes (Addressing Potential Spillover)



(a) Include Early Adopters



(b) Exclude Early Adopters

Notes: Data are from Colorado Department of Transportation 2004-2019 traffic crash statistics. Each point shows the estimated effect of recreational marijuana dispensary entry on fatal traffic crashes per 1,000 crashes relative to a year prior to the entry (the omitted year). Early adopters are counties with recreational cannabis dispensary entry in January 2014. All regressions include controls for labor force participation rate, unemployment rate, employment-to-population ratio, share of population under 20 years old, share of 20- to 34-year-olds in the population, population share of female, population share of blacks, population share of hispanics, county fixed effects, and region-by-year fixed effects. 95% confidence intervals constructed with standard errors clustered at the county level are provided in the figures. The regressions are weighted by county population.