Marijuana legalization and road safety: a panel study of US States

by

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A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF REGIONAL AND COMMUNITY PLANNING

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KANSAS STATE UNIVERSITY
Manhattan, Kansas

2019

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Abstract

Policymakers and the public are concerned about the road safety implications of legalizing marijuana. Despite the more than two decades of data since California became the first state to legalize marijuana for medical use, there has been surprisingly little research on this question. This study seeks to address this gap in the literature. Specifically, this research combines twenty-three years of state traffic data with information on the contemporaneous legal status of marijuana, for both medical and recreational use, to estimate two models of road safety. First, while treating both the state and the year as fixed effects, the resulting panel regression model estimates that the legalization of medical or recreational marijuana is not a predictor of the number of fatalities per 100,000 vehicle-miles traveled. Second, due to limitations in the regression model, a difference-in-difference analysis was conducted over the same period and found no relationship between legalization of medical marijuana and the number of fatalities per 100,000 vehicle-miles traveled. These findings suggest that concerns of policy makers and the public that legalizing marijuana will worsen road safety are not ungrounded at this time. According to the models, the recent upward trend of traffic fatality rates nationwide is not a result of medical marijuana legalization. In fact, the legalization of marijuana is not found to be a predictor of traffic fatalities.

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Acknowledgements

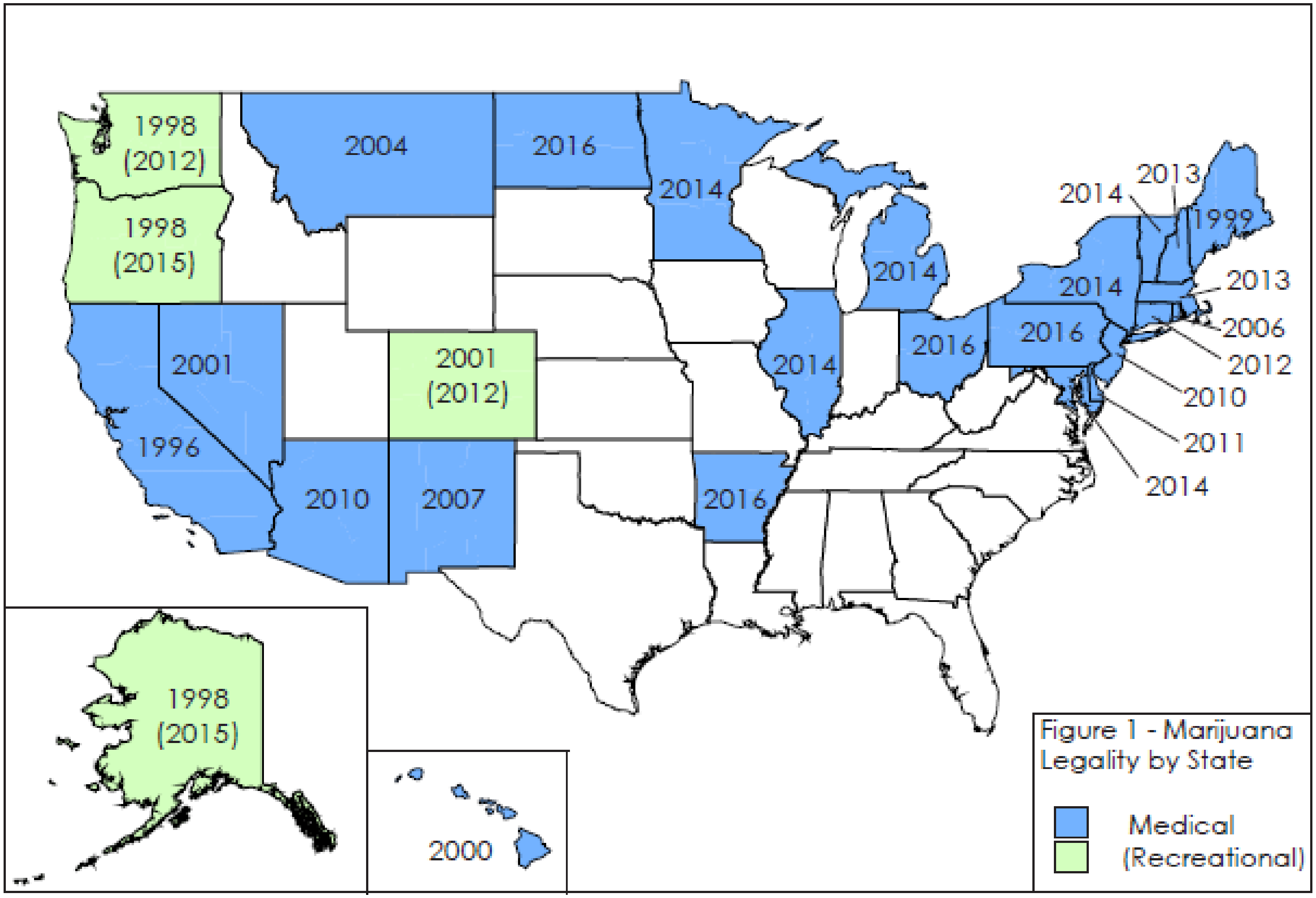
Funding: This work was supported by two Dwight David Eisenhower Transportation Fellowship Program Graduate Fellowships.

Chapter 1 - Introduction

An increasing number of states are legalizing cannabis use. Since 1996, when California first legalized medical marijuana, 29 states and the District of Columbia have legalized some form of medical marijuana. Concurrently, states which have already legalized medical marijuana are beginning to open the door to recreational marijuana consumption. Figure 1 displays the legality of marijuana for medicinal and recreational uses, by state, as of 2016.

As more states are legalizing medical and recreational marijuana, increased drugged-driving is a concern among policy makers and the public. Undoubtedly, driving while under the influence of any mind-altering drug is dangerous. However, it is unknown whether making marijuana more accessible increases the public health risk of drugged driving. The goal of this research is to statistically assess the impact of the legalization of marijuana on road safety, specifically fatal crashes.

Figure 1 Marijuana Legalization by Use by State (2016)



Chapter 2 - Literature Review

Marijuana's Impact on the Driver

The dangers of driving under the influence are known. Many policy makers are concerned that legalizing marijuana will lead to more drugged driving. This concern is heightened by reports that indicate marijuana usage before driving is on the rise (Minnesota Population Center, 2016; US Census Bureau, n.d.). Unfortunately, it is difficult to determine when marijuana is consumed or its effect on a consumer over any given period of time (Courrege, 2017; Neavyn, Blohm, Babu, & Bird, 2014). Compared to alcohol, the research on driving while using marijuana is very limited, with almost no information on how different means of ingesting cannabis might affect crash frequency or severity (Robertson, Woods-Fry, & Morris, 2016).

Sewell et al. (Sewell, Poling, & Sofuoglu, 2009) found the detrimental effects of marijuana use vary in a dose-related fashion, but unlike alcohol, because the user has a heightened sense of impairment, they can effectively compensate while driving by utilizing a variety of behavior strategies -- suggesting marijuana consumption is less risky than alcohol consumption prior to driving. However, many studies suggest that marijuana hampers the cognitive skills required to drive in a safe manner (Blows et al., 2005; Larkin, 2015). Some research suggests that it is not the legalization of marijuana that increases a driver's willingness to drive under the influence but instead the driver's perception of the danger is more likely to dissuade driving while high: "Increased perceptions that driving while high is unsafe was associated with significantly lower willingness to drive after using marijuana while increased knowledge of marijuana DUI laws was not associated with these outcomes" (Davis et al., 2016). When conducting a meta-analysis of nine epidemiologic studies, Li et al. (Li et al., 2012) found the estimated odds ratios relating to marijuana use to car crash risk ranged from 0.85 to 7.16 – suggesting both decreased and increased crash risk from marijuana use.

Impact of Marijuana Policy on Crash Risk

There are existing studies that have analyzed crashes before and after marijuana legalization. Tefft et al. (Tefft, Arnold, & Grabowski, 2016) found the prevalence of marijuana in drivers fatally injured in the state of Washington increased from 49 (8 percent of total fatalities) in 2013 to 106 (17 percent of total fatalities) in 2014. In 2016, the Colorado State Patrol Driving Under the Influence of Drugs Program (Rocky Mountain HIDTA, 2017) reported that 76 percent of crash data involved marijuana, 38 percent of which strictly involved marijuana with no other drug present. This shows an increase in drivers having marijuana in their system. However, Santaella-Tenorio et al. (Santaella-Tenorio et al., 2016) found that on average, states with medical marijuana had lower traffic fatality rates than the remaining states, with seven states experiencing immediate reductions in fatalities among 15- to 24-year-old drivers and 25- to 44-year-old drivers. This finding mirrors research that saw reductions in crash fatalities of between eight and eleven percent in the year following medical marijuana legalization, possibly due to large recorded drops in fatalities involving alcohol (Anderson, Hansen, & Rees, 2013). While recreational legalization is more recent, the Highway Loss Data Institute has seen a 2.7 percent increase in insurance claims from Colorado, Washington, and Oregon in comparison to western states that have not legalized recreational cannabis use (The Highway Loss Data Institute, 2017). However, these data did not specify crash severity.

Other Traffic Safety Policies

Studies on the impact on road safety of state policies on drinking and driving, child seat belt use, and graduate drivers' licensing provide methodological guidance for the current work on marijuana legalization impacts.

Voas et al. (Voas, Torres, Romano, & Lacey, 2012) analyzed crash data involving alcohol using logistic regression to identify three predictors for the relative risk of a fatal crash. Fell et al. (Fell, Fisher, Voas, Blackman, & Tippetts, 2008) used a different strategy: instead of studying the causes of the crashes, they studied what reduces the likelihood of crashes. Their study involved a scoring system to assess which states enacted laws that either decreased or increased the likelihood of young people obtaining alcohol. The analysis examined whether the distribution of scores correlates with the ratio of underage drivers involved in fatal car crashes with alcohol involvement. An analysis of variance was used on the annual ratio of drinking to nondrinking drivers younger than 21 in fatal crashes in each state. In a different study evaluating the effectiveness of policies on drunk driving, Eisenberg (Eisenberg, 2003) used a least squares regression with state and year fixed effects for evaluation. Nagata et al. (Nagata, Hemenway, & Perry, 2006) observed the impact a new law reducing the permissible blood alcohol level had on traffic fatalities in Japan. Their study analyzed data using Chi-square tests to compare fatality rates between before and after the law was enacted (Nagata et al., 2006).

Like studies involving alcohol, many studies on the impact of child safety seat laws used Chi-square tests to understand the impact of policies on fatalities. Durbin et al. (Durbin, Elliott, & Winston, 2003) used Chi-square tests to find an association between restraint type and risk of injury; logistic regression modeling was used to determine odds ratios of injury (Durbin et al., 2003). To account for bias, the study employed chi-square tests of association and Taylor series linearization estimates of the logistic regression parameter variances (Durbin et al., 2003). In a similar study, Elliott et al. (Elliott, Kallan, Durbin, & Winston, 2006) analyzed traffic fatalities with respect to restraint type by performing chi-square tests to assess the differences in distributions. Again, logistical regression modeling was used to compute the relative risk of fatalities by restraint type (Elliott et al., 2006). In a study comparing effectiveness of child restraint systems, researchers estimated fatality risk ratios using conditional Poisson regression, bootstrapping, multiple imputation, and sensitivity analysis of misclassification bias (Rice & Anderson, 2009).

Another related topic of study is graduated driver licensing (GDL) and traffic fatalities. Dee et al. (Dee, Grabowski, & Morrisey, 2005) used a conditional maximum likelihood approach to negative binomial models to examine the relationship between GDL and traffic fatalities (Dee et al., 2005). In the study, it is noted that Bertrand et al. (Bertrand, Duflo, & Mullainathan, 2004) warns difference-in-difference studies may be reaching overstated precision in their findings; to combat this problem, clustering the standard errors will result in more reliable difference-in-difference estimates (Dee et al., 2005).

These studies, along with others, suggest methods for analyzing crash statistics over time. The methodology used in this study is detailed in the following section.

Chapter 3 - Methodology

This study applies a panel statistical regression to twenty-three years of state-level data on travel, road safety, and the legality of marijuana. The legal status of both medical and recreational marijuana for each state in each year (or proportion of the year) are included in the model as dummy variables. Models are estimated to predict road safety measured as the natural logarithm of the rate of fatalities per 100,000 vehicle-miles traveled. The natural logarithm is used because small changes in the natural log of fatalities per 100,000 vehicle-miles traveled is directly interpretable as percentage change. The goal of this approach is to determine whether the dummy variables for marijuana legalization are statistically significant predictors of road safety and, if so, the direction of that relationship. The equation for the regression model is below, where the dummy variable for marijuana is T_{it} with intercept α_i and confounding variables X_{it}.

$$\hat{y} = \alpha_i + \gamma_t + T_{it} + X_{it}$$

Also applied in this study is a difference-in-differences model. The effect of marijuana legalization on traffic fatalities is captured by comparing the changes over time in states which have legalized marijuana relative to control states which have not legalized marijuana. States which legalized marijuana were matched with control states by comparing five years of fatality data before marijuana legalization and matching those states with control states that had the closest fatality rates during the same period (utilizing sum of squared differences of fatal crash rates). The equation for the difference-in-differences model is below, where Y_{it} is the difference in change in fatality rate between states that have not legalized marijuana $Y_{it}(0)$ and states that have legalized marijuana $Y_{it}(1)$. The regression equation used to find effect for the difference-in-difference term is also below where δ is the treatment (legalized medical marijuana) and $s(i)$ is the group in which i belongs, either the treatment or control group.

$$Y_{it} = a_i + \gamma_t + \delta I(s(i)) + \varepsilon_{it}$$

$$Y_{it} = Y_{it}(0)(1 - Z_{it}) + Y_{it}(1)Z_{it}$$

Utilizing two models of analysis will benefit this study by further limiting the effects of omitted variable bias. The regression model allows states to act as their own controls, pre- and post-marijuana legalization, to estimate road safety. In a difference-in-differences model, by including non-legalized states as a control, any bias caused by variables common to states with legal marijuana and states without legal marijuana is indirectly controlled for, even though these variables are unobserved. Assuming matched-states with and without legalized marijuana would have identical trends over time, non-legalized-states' changes in fatal crash rates can be interpreted as the change legalized states would have experienced, had they not enacted laws legalizing marijuana.

Data Collection

Annual statistics on road fatalities, population numbers, licensed drivers, registered vehicles, and vehicle-miles traveled by US state and the District of Columbia were gathered from the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) for the twenty-three years from 1994 through 2016, inclusive. Blood tests for the presence of marijuana is not standard practice across all jurisdictions in the U.S. Therefore, all fatal traffic crashes were included in the data to remove inconsistencies in reporting drug involvement in fatal traffic crashes. Information on the legal status of marijuana for both medical and recreational purposes were identified for each state and each year (or partial year). State legislation legalizing medical or recreational marijuana was retrieved from ProCon.org, a nonpartisan organization tracking current legislative topics. Additional confounding policy variables were considered, however, only 0.08 *per se* laws were included (see limitations section of this paper). States' 0.08 *per se* laws establishing the illegal blood alcohol concentration level of 0.08 were provided by the Mothers Against Drunk Driving (MADD) Government Affairs Team, an advocacy group with the mission of eliminating impaired driving. These data streams were merged into a single data set with each row representing the conditions for a given state for a given year.

Chapter 4 - Analysis

Since these data represent the records of consistent entities, in this case US states, over time they represent a panel. Because the panel members remain the same, it is possible to control for unobserved or unmeasurable sources of heterogeneity unique to each member. This accounting also reduces the impact of omitted variable bias.

This research explored the variation in road safety as measured by the rate of fatalities per 100,000 vehicle-miles. Figure 2 represents the mean fatality rates per state with error bars representing 95 percent confidence intervals. These data suggest that road safety varies substantially between states with mean rates as low as 0.75 in Massachusetts to as high as 2.15 in Mississippi, with confidence intervals varied by state. Figure 3 represents the mean road safety rate by year. These data show a secular decline in fatality rates from 1995 to 2014 – an impressive improvement in public health, however, rates rose again from 2014 to 2016.

Figure 2 Heterogeneity in Fatality Rates per 100,000 Vehicle-Miles Traveled by State

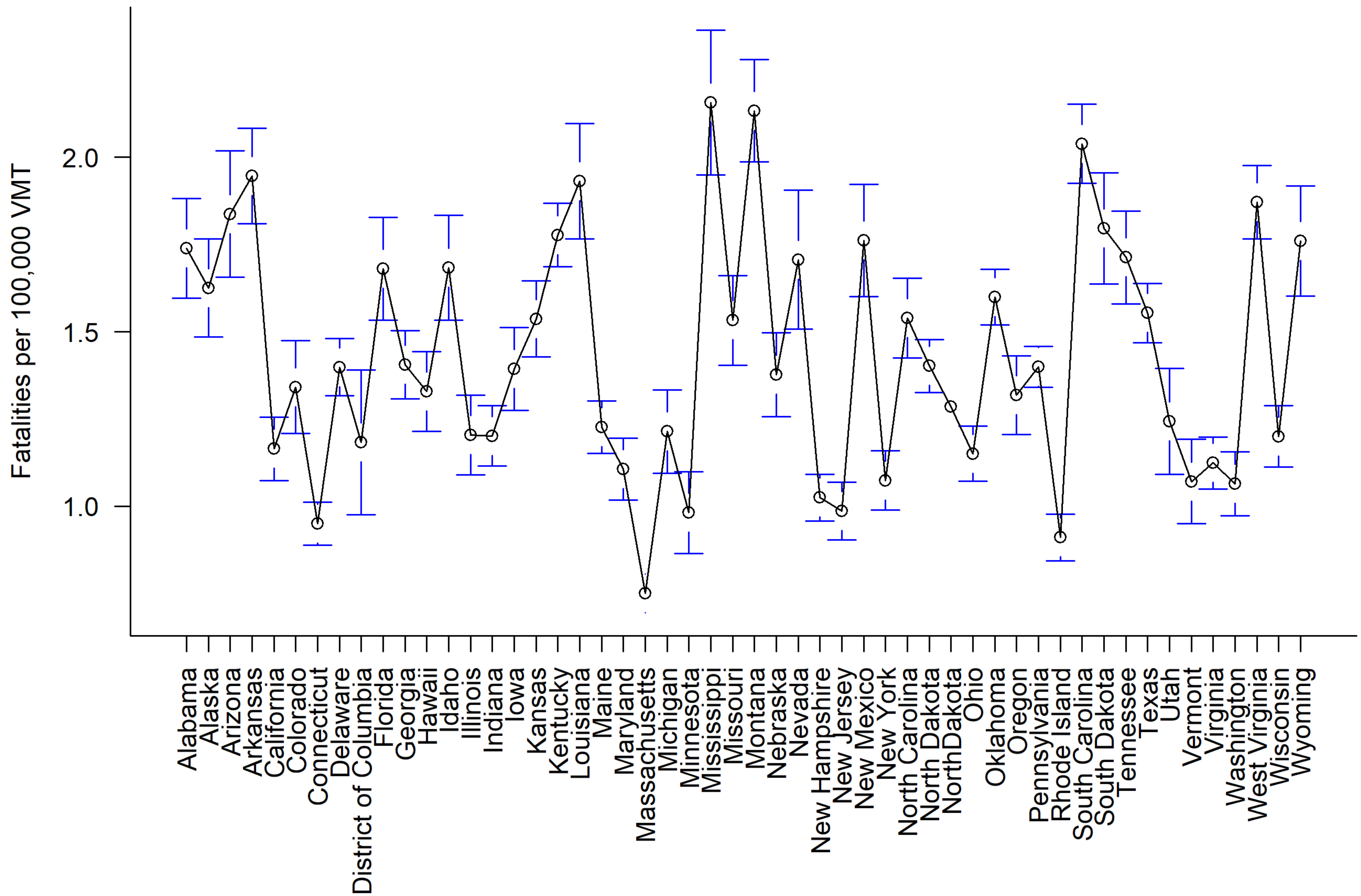
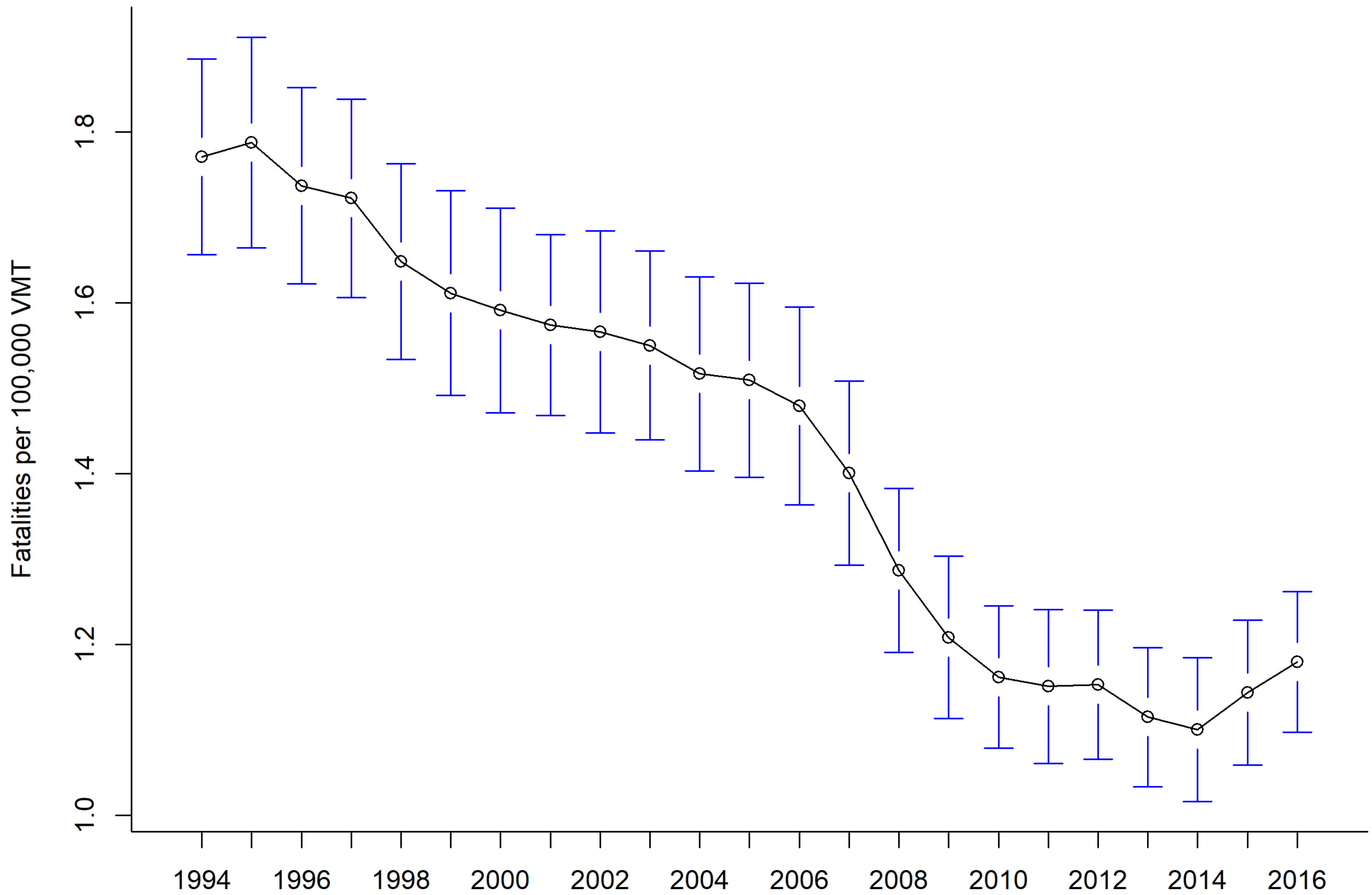


Figure 3 Heterogeneity in Fatality Rates per 100,000 Vehicle-Miles Traveled by Year



The variation in both states and years fatality rates encouraged the consideration of a fixed-effect panel regression model. A random-effects model was also explored, however, an application of the Hausman test yielded a statistically significant Chi-squared value, which suggests that the errors are correlated with the regressors favoring a fixed-effects final formulation. Table 1 presents the results of the panel regression model with fixed-effects for both states and years. The model is significant and accounts for almost ninety percent of the observed variation in fatality rates. Most important, given the focus of this research, legalizing marijuana is not found to be a statistically significant predictor of fatality rates. This finding means that the legalization of marijuana for both medical and recreational purposes is not associated with either a reduction or increase in fatalities per 100,000 vehicle miles traveled. Given the log-linear form of the model, the exponentiated coefficients represent the percentage change in the unlogged dependent variable with a one-unit change in the predictor variable. Therefore, the legalization of marijuana, for medical or recreational purposes, is not associated with an impact on the fatality rate.

Table 1 Panel Regression Model with Fixed Effects for State and Year

Variables	Estimate	Std. Error	t-value	p-score	Significance
Population (log of 1,000 persons)	-0.071	0.028	-2.665	0.008	**
VMT (log of 1,000,000 miles)	-0.225	0.039	-5.844	<0.001	***
Medical Marijuana Dummy	-0.009	0.007	-1.318	0.188	
Recreational Marijuana Dummy	0.008	-0.018	0.488	0.626	
.08 BAC Dummy	0.006	0.007	0.907	0.365	

Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1;

Model Summary Information: Adj. R-Squared = 0.898, F-statistic = 133.4 on 78 and 1094 DF, p-value = 0.000

An examination of the difference-in-differences analysis conducted on states with legalized marijuana shows varying changes in traffic fatalities after the legalization of medical marijuana. Each of the following figures displays the change in fatalities per 100,000 vehicle miles traveled (FatalPerVMT) five years prior to medical marijuana legalization and three years after legalization. Figure 4 shows traffic fatalities in Arizona decreasing before legalization in 2010, slightly increasing afterwards, and leveling off; South Dakota and Wyoming experience a slight increase in traffic fatalities in 2010, earlier than Arizona, then decreasing fatality rates in 2011. In Figure 5, Colorado's fatality rate was decreasing similar to Georgia's until 2000 when the rate started to increase, as Iowa did between 1998 and 1999. After marijuana legalization, Colorado's increasing fatality rate leveled and then returned to like-Georgia change between 2003 and 2004; after medical marijuana legalization in Colorado, Iowa experienced changes in fatality rates more similar to Georgia. Washington D.C. is compared with Utah and Virginia in Figure 6. The District of Columbia experienced falling fatality rates before medical marijuana legalization except for an increase in 2007, Utah and Virginia experienced the same. Similarly, all three states experienced increasing fatality rates in 2011 after D.C.'s medical marijuana legalization in 2010, however, fatality rates again decreased in 2012. While no trends are immediately apparent in the figures showing change in fatality rates after medical marijuana legalization, further analysis of the model results will indicate the existence of any relationship between medical marijuana legalization and road safety.

Table 2 represents the results of the difference-in-differences model. The dummy variable "Impacted States" are states effected by legalization of medical marijuana, the dummy variable 'Treatment' represents when legislation legalizing marijuana has been enacted, lastly, 'Interaction Term' is assessing the significance of the difference-in-differences analysis on the legality status of marijuana for states with legislation legalizing medical marijuana. The model shows the legalization of medical marijuana is not a predictor of traffic fatalities because the interaction term is not found to be significant. This means that despite national traffic fatality rates increasing in 2015 and again in 2016, it was not related to medical marijuana legalization.

Table 2 Difference-in-difference Model Results

Variables	**Estimate**	**Std. Error**	**t-value**	**p-score**	**Significance**
Impacted States	-0.183	0.049	-3.714	<0.001	***
Treatment	-0.698	0.052	-1.346	0.178	
Interaction Term	0.033	0.085	0.383	0.701	

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1;

Model Summary Information: Adj. R-Squared = 0.034, F-statistic = 6.83 on 3 and 494 DF, p-value = 0.000

Figure 4 Impact of Medical Marijuana on Arizona's Fatality Rate

Figure 4 Impact of Medical Marijuana on Arizona's Fatality Rate

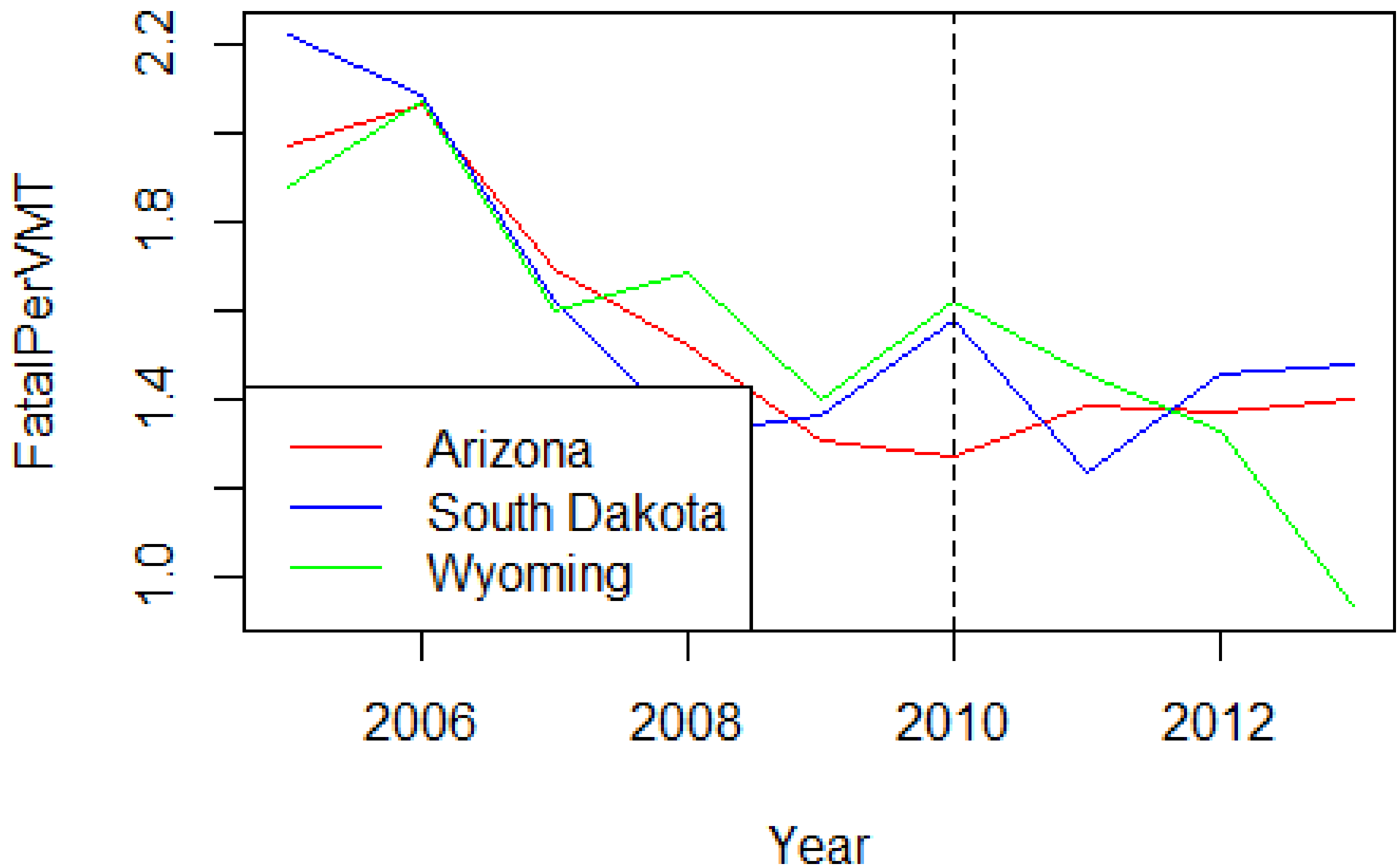


Figure 5 Impact of Medical Marijuana on Colorado's Fatality Rate

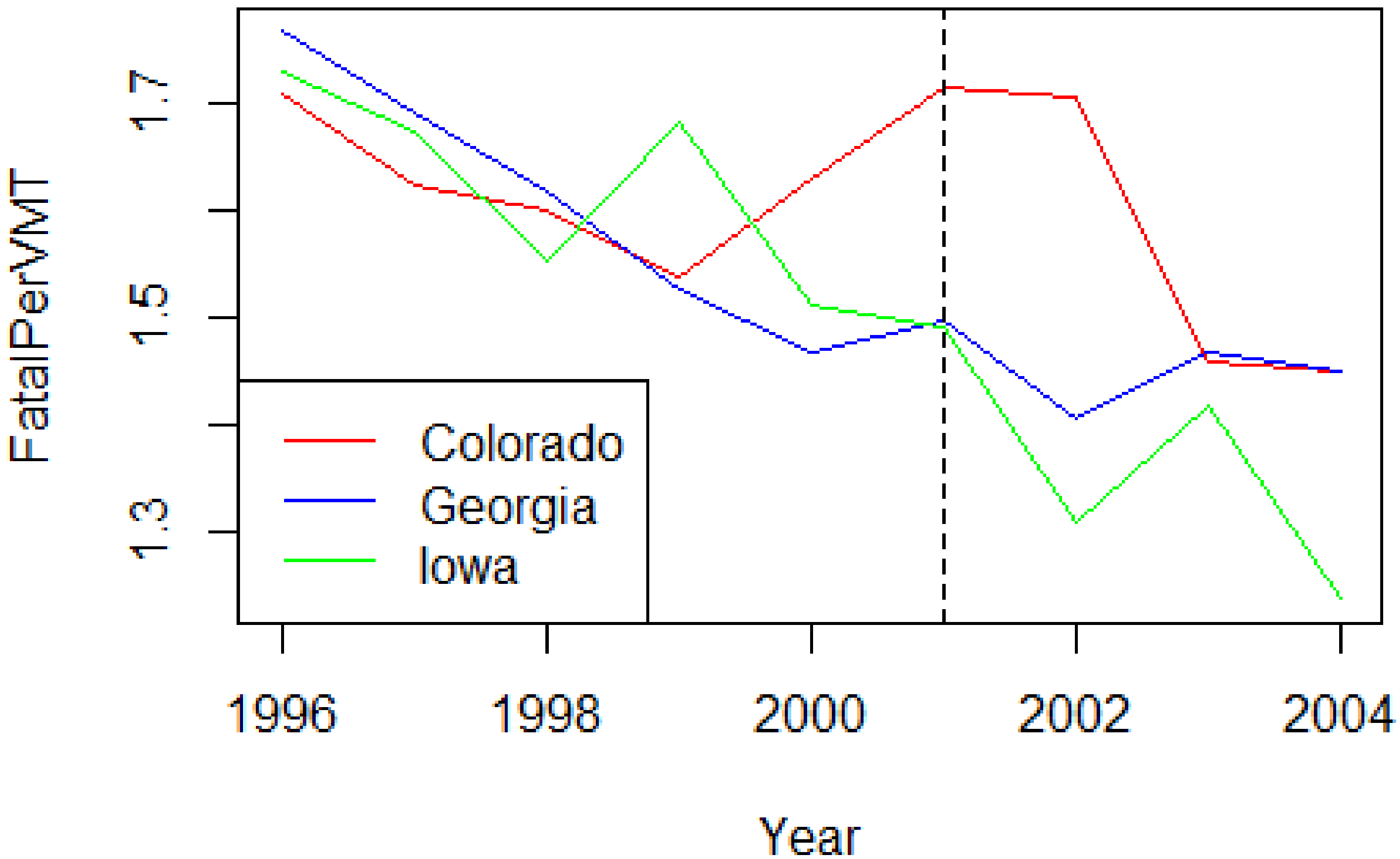
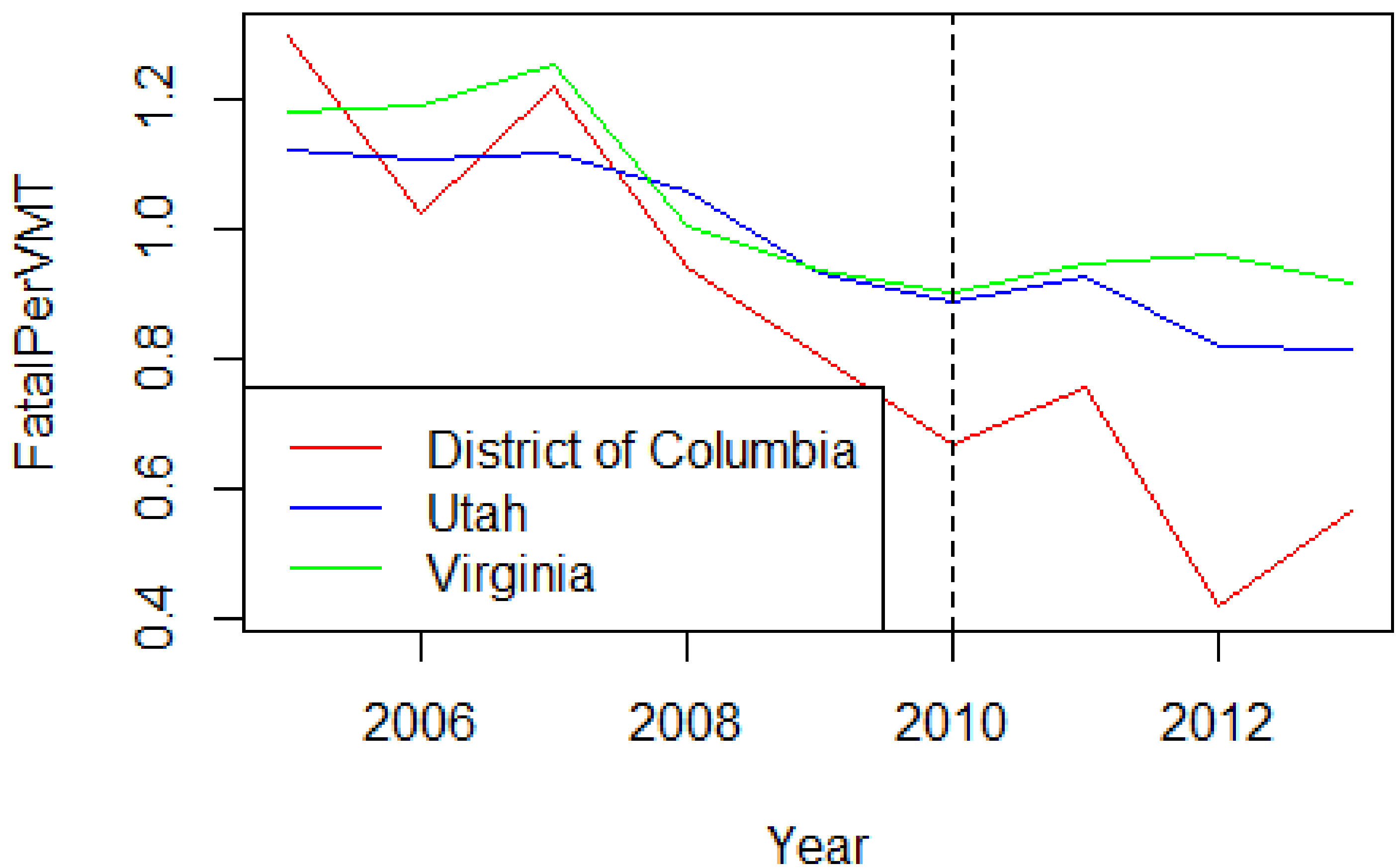


Figure 6 Impact of Medical Marijuana on Washington D.C.'s Fatality Rate



Limitations

While the models employed for analysis are designed to control for omitted variable bias, there are apparent limitations to this study. Medicinal marijuana legalization has been a feature of state policy for over two decades, however, the introduction of recreational legalization is still rather new. The number of states that have legalized recreational marijuana may not offer a substantially robust sample to fully estimate the impact of recreational cannabis on traffic safety. Future work might explore these connections to minimize risk from drugged driving and increase road safety. Confounding variables are another limitation. The amount of legislation passed at the state-level to increase traffic safety is considerable, most of which was not included in this study. States' 0.08 *per se* laws were incorporated into this study but many other policies such as child safety seat requirements, graduated drivers licensing programs, changing the maximum speed limits on highways, and other state-level policies were not included in this study. Future research should incorporate as much legislation at the state-level as possible. Additionally, changes in law enforcement tactics may have a significant effect on traffic safety, for example: an increase in sobriety checkpoints. Future studies should explore how state legislation and enforcement tactics impact fatal traffic crashes. Lastly, access to marijuana varies by state. For example, medical marijuana in some states is available in the form of cannabis flower while other states only allow access to non-psychoactive cannabis pills. The ideal data set would include all state-level legislation impacting road safety, changes in law enforcement policies regarding road safety, consideration for access to various forms of marijuana, and more traffic data for states with legalized recreational marijuana.

Chapter 5 - Conclusion

The goal of this study was to determine whether marijuana legalization, either medical or recreational, has any statistically significant impact on the rate of fatal traffic crashes. The results of the analysis suggest that there is no statistically relationship between marijuana legalization and fatal crashes. These findings suggest that concerns of policy makers and the public that legalizing marijuana will worsen road safety are not entirely founded. According to the difference-in-differences model, the recent upward trend of traffic fatality rates nationwide is not a result of medical marijuana legalization. In fact, the legalization of marijuana is not found to be a predictor of traffic fatalities.

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