AN ANALYSIS OF POLICIES USING QUASI-EXPERIMENTAL DESIGN: MARIJUANA LEGALIZATION, SAME-SEX MARRIAGES, AND GUN POLICY

A Dissertation

by

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ABSTRACT

Marijuana use, same-sex marriage, and firearm regulations are major societal issues that significantly impact the US health system. While same-sex marriages were legalized throughout the nation by a 2015 Supreme Court ruling, policies regarding guns and marijuana still vary widely among the states. To examine these issues in-depth, this research is designed as a series of three studies utilizing the same econometrics methodology to measure the impact of state-specific policies. A quasi-experimental difference-in-difference approach is used with state-level policy differences to compare the control and treatment states to estimate the effect of each policy (marijuana legalization, same-sex marriage legalization, and firearm regulations) on the dependent variable (number of pediatric poisoning ED visits, number of STI-related ED visits, and number of mass shootings/fatalities/injuries).

The first study analyzes the relationship between state marijuana laws and the frequency of pediatric poisoning cases warranting Emergency Department (ED) visits. Data for the ED visits were derived from State Emergency Department Databases (SEDD) and State Inpatient Databases (SID). Study included 16 US states: Arizona, Arkansas, California, Kentucky, Maryland, Massachusetts, Nebraska, New Jersey, New Mexico, New York, North Carolina, Rhode Island, Utah, Vermont, Washington, and Wisconsin. Of the 16 states, 13 were from SEDD, and 3 states (Arkansas, New Mexico, and Washington) were from SID. Findings suggest that medical marijuana legalization is associated with a 12.2% increase in pediatric poisoning cases, while recreational marijuana legalization results in a 19.9% increase.

The second study assesses the impact of same-sex marriage legalization on sexually transmitted infections (STIs). Data were derived from the State Emergency Department Databases and State Inpatient Databases to determine the number of STI-related ED visits. Study included 16 US states: Arizona, Arkansas, California, Kentucky, Maryland, Massachusetts, Nebraska, New Jersey, New Mexico, New York, North Carolina, Rhode Island, Utah, Vermont, Washington, and Wisconsin. Of the 16 states, 13 were from SEDD, and 3 states (Arkansas, New Mexico, and Washington) were from SID. The impact of same-sex marriage legalization was examined for both the short term (immediately after legalization) and long term (one year after legalization). Findings suggest that legalization is associated with no significant change in STI-related ED visits in the short term, but a 7.4% decrease in visits in the long term.

The third study examines the impact of gun policy on mass shootings, and related fatalities and injuries. For this study, data were derived from the Mass Shooting Tracker. Findings suggest that states that report mentally ill individuals to the National Instant Criminal Background Check System (NICS) have a 46% decrease in mass shooting incidents. Universal background checks for gun purchases are also strongly associated with reduced harm from mass shootings, resulting in 66% fewer deaths and 46% fewer injuries.

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NOMENCLATURE

CAP	Child Access Prevention
GVA	Gun Violence Archive
THC	Tetrahydrocannabinol
BLS	Bureau of Labor Statistics
BEA	Bureau of Economic Analysis
TAMU	Texas A&M University
NPR	National Public Radio
ED	Emergency Department
LGBTQ	Lesbian, Gay, Bisexual, Transgender, Questioning
STI	Sexually Transmitted Infection
STD	Sexually Transmitted Disease
ICD	International Classification of Diseases
HPV	Human papillomavirus
CI	Confidence Interval
SEDD	State Emergency Department Database
SID	State Inpatient Database
HCUP	Healthcare Cost and Utilization Project
CRP	Child-Resistant Packaging
NB	Negative Binomial
NICS	National Instant Criminal Background Check System

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CHAPTER 1

INTRODUCTION

Marijuana legalization, same-sex marriage, and firearm control policy are highly polarizing public policy issues that broadly impact American society, including the healthcare system. Until 2015, when the Supreme Court ruled to legalize same-sex marriage, each state had implemented its own laws regarding these three issues. This caused wide discrepancies across the country, largely dependent on which political party controlled state governments. Democratic lawmakers generally favored legalization of same-sex marriage, stronger gun control laws, and legalization of marijuana for medical or recreational purposes. Republican lawmakers, meanwhile, tended to oppose legalization of same-sex marriage and marijuana consumption, while supporting more relaxed gun laws. This polarization exists at the macro, meso, and micro levels of American society. As in the past, these controversial issues often prompt highly partisan responses from lobbyists, legislators, the media, and the general public. Research indicates these three different policy topics bear striking similarities in terms of stakeholder responses, and how states legislate them.

This dissertation consists of three studies, each designed to address a gap in the research literature by examining the impact of state-specific policies. All three studies utilize the quasi-experimental difference-in-difference design with state-fixed effects methodology to estimate the impact on the outcome variable (number of pediatric poisoning related ED visits, number of STI-related ED visits, number of mass shootings, number of mass shootings related fatalities, and number of mass shootings related injuries). The first study explores the unforeseen impact of marijuana legalization on pediatric poisonings. The consequences of both recreational and medical marijuana are examined. The study also compares rates of pediatric poisoning ED visits in states where marijuana consumption is legal with states where it is illegal. The second study analyzes the impact of same-sex marriage legalization on sexually transmitted infections (STIs). Examining data prior to the 2015 Supreme Court ruling, the study compares the frequency of STI-related ED visits in states that legally recognized same-sex marriages with those that did not. The third study examines how gun policies influence mass shootings. It estimates the impact of multiple policy variables on the occurrence rate of mass shootings, along with shooting-related fatalities and injuries. The result is a better understanding of what state policies have been most effective in curtailing the destruction of mass shootings.

Marijuana Legalization and Pediatric Poisoning

The first study examined the impact of marijuana legalization on pediatric poisoning. According to the National Institute on Drug Abuse (2015), illicit drug use is rising in the United States. For Americans aged 12 or older, 9.4% of the population in 2013 reported using an illicit drug in the past month. This compares to 8.3% in 2002, an increase of about 13% in 11 years. In 2013 about 7.5% of people aged 12 or older reported currently using marijuana, as compared to 5.8% in 2007. This represents an increase in use of about 29% in only 6 years, the fastest rise of any illicit drug during this period. According to the annual National Survey on Drug Use and

Health (NSDUH) conducted by the Substance Abuse and Mental Health Services Administration (SMHSA), 70.3% of new illicit drug users begin with marijuana.

In this study, data on pediatric poisoning-related ED visits were extracted from State Emergency Department Databases (SEDD) and State Inpatient Databases (SID). Study included all the 16 US states that had data available: Arizona, Arkansas, California, Kentucky, Maryland, Massachusetts, Nebraska, New Jersey, New Mexico, New York, North Carolina, Rhode Island, Utah, Vermont, Washington, and Wisconsin. Of the 16 states, 13 were from SEDD, and 3 states (Arkansas, New Mexico, and Washington) were from SID. International Classification of Diseases diagnostic codes (ICD-9 and ICD-10) were used to identify emergency hospital visits related to marijuana use among children aged 9 or younger. Data on the number of ED poisoning cases were aggregated to state-month-year level and are included in the model as a dependent variable. Variation in state-level marijuana laws encouraged implementation of a quasi-experimental design with state fixed-effects. The impact of recreational marijuana legalization and medical marijuana legalization were estimated separately.

Study findings suggest that legalization of medical marijuana is associated with an increase of 12.2% in pediatric poisoning-related ED visits. Legalizing recreational marijuana, meanwhile, was associated with a 19.9% increase in these emergency pediatric cases. In terms of gender-based impact, legalization of medical marijuana was associated with an 11.7% increase in female ED visits and an 11.5% increase for males. Legalization of recreational marijuana did not impact female visits but led to an increase of 21.1% among males.

Same-Sex Marriage Legalization and Sexually Transmitted Infections

The second study examined the impact of legalizing same-sex marriages on sexually transmitted infections (STIs). According to the Centers for Disease Control, STIs are a rising concern among individuals who identify as gay or bisexuals. In 2014, gay and bisexual men, along with other men who have sex with men, accounted for 83% of primary and secondary syphilis cases. HPV (human papillomavirus) is also a serious health problem among sexual minorities. The STI issue is exacerbated by existing health-related disparities for this vulnerable population. Recent research indicates that all sexual minority subgroups experience worse Health-Related Quality of Life (HRQL) than heterosexuals (Charlton et al., 2018). This includes measures of mobility, self-care, usual activities, pain/discomfort and anxiety/depression. The current study also conducted analysis by controlling for employment status and health insurance coverage. Results indicated that even after controlling for these factors, existing sexual orientation-related HRQL disparities did not substantially diminish.

SEED and SID databases were used for analysis. The study's dependent variable was the number of STI-related ED visits, while the key independent variable was same-sex marriage legalization. SEDD and SID databases were used to identify which ED visits were related to STIs for individuals aged 18 or above. Study included 16 US states: Arizona, Arkansas, California, Kentucky, Maryland, Massachusetts, Nebraska, New Jersey, New Mexico, New York, North Carolina, Rhode Island, Utah, Vermont, Washington, and Wisconsin. Of the 16 states, 13 were from SEDD, and 3 states (Arkansas, New Mexico, and Washington) were from SID. Both the short- and long-term impact of same-sex marriage legalization was estimated by adjusting for gender and age. Short-term effect (immediately after legalization) was estimated by a legalization dummy assigned value “1”, and long-term effect (a year after legalization) was estimated by a legalization dummy assigned value “1.’’

Study results indicate that STI-related ED visits increased by 7.4% one year after same-sex marriage became legal in the United States. Over the short term, females experienced a 5.6% increase in ED visits, while men experienced no change. Over the long term, however, marriage legalization was associated with a 5.1% increase in female ED visits and a 9.1% increase among men.

Age also impacted STI-related hospital visits. Individuals aged 18-24 experienced a 5.6% short-term and 7.2% long-term increase in ED visits. Individuals aged 25-40 experienced a 9.3% increase in visits a year after legalization. Adjusting for both gender and age, this marriage policy change led to decreases in STI cases for males aged 18-24, 25-40, and 41-64, by 9.4%, 10.1%, and 9.4%, respectively, a year after legalization. Females aged 18-24 experienced a 7.6% decrease in ED visits over the short term, while those aged 25-40 experienced an 8% decrease over the long term.

The Impact of Firearm Policy on Mass Shootings

The third study estimates the effects of firearm policy on mass shootings. According to the Center of Disease Control’s Web-based Injury Statistics Query and Reporting System (WISQARS), there are an average of more than 31,000 firearm-related fatalities in the United States per year. Although the overall crime rate is similar in the US and other developed countries, the US homicide rate is 7 times higher than the average of the other 22 high-income countries (Richardson et al., 2011). This is because the firearm homicide rate in the US is 20 times greater than in the other countries (Webster et al., 2014).

Since the victims are disproportionately young, gun violence is a leading cause of premature death in this population group. According to the WISQARS (2016), homicide by firearm is the third leading cause of death for age cohorts 15-24 and 25-34. More broadly, firearms remain one of the 10 leading causes of deaths for individuals aged 1 to 64. In addition to fatalities, gun violence also accounts for a large number of non-fatal hospital visits in the general population. In 2010, there were an estimated 337,960 non-fatal violent crimes committed with a firearm in the United States (Truman, 2011). This high rate of gun crime is a long-standing problem in the United States and significantly burdens the overall health system. For example, in 2001 a total of 73,505 people were treated in hospital emergency departments for non-fatal gunshot wounds (Vyrostek et al., 2004).

The study includes a vector of gun policy variables as dummies, with states that have gun control laws referred to as treatment states, and those without such laws referred to as control states. Data was obtained from the Mass Shooting Tracker for the period January 2013 to June 2017. The dates for gun legislation were obtained from the Giffords Law Center to Prevent Gun Violence, and verified by using LegiScan. Impact of policy variables was explored on three dependent variables: number of mass shootings, number of mass shooting fatalities, and number of mass shooting injuries. This study explored the state gun laws that (1) prohibit individuals convicted of domestic violence from possessing a firearm; (2) prohibit individuals with a documented history of mental illness recorded in National Instant Criminal Background Check

System (NICS) from possessing a gun; (3) restrict children's access to guns; (4) require reporting of lost or stolen firearms; (5) mandate universal background checks; (6) ban assault weapons; (7) regulate gun shows or (8) impose a minimum age requirement to possess a handgun. Unemployment rate and per capita income were included as control variables.

Study data indicates that states with universal background checks have 66% fewer deaths and 46% fewer injuries related to mass shooting incidents. States that require reporting of individuals with a history of mental illness to NICS were associated with 46% fewer mass shooting incidents. A high unemployment rate was associated a 13% increase in mass shooting deaths and a 25% increase in mass shooting injuries.

CHAPTER 2

MARIJUANA LEGALIZATION AND PEDIATRIC POISONING

Introduction

In recent years, a growing number of states have legalized recreational and medical marijuana. In 2016 alone, four states legalized recreational marijuana, joining four other states that had done so in the preceding four years (Gilbert, 2016). Increased rates of pediatric poisoning pose a potential unintended consequence of this legalization process. This is a particular risk given the expanded availability of edible forms of marijuana that often resemble candy and other childhood treats. Popular edible marijuana products include brownies, chocolate, ice cream, gummy bears, popsicles (known as “potsicles”), candies, and cookies.

Over the past 25 years the concentration of tetrahydrocannabinol (THC), the psychoactive substance in marijuana plants, has dramatically increased. Research shows that THC concentration levels rose from roughly 4% in 1995 to 12% in 2014. Newer strains are even more potent, with concentrations as high as 20%, resulting in elevated risk of overdose and addiction among children (American Academy of Pediatrics, 2017). The potency of available edible marijuana products also raises the likelihood of pediatric poisoning.

The type and amount of marijuana products an individual can legally purchase varies by state. For example, in Washington state adults can purchase up to one ounce of “bud” (the flowering part of the plant), 16 ounces of edible solids, 72 ounces of marijuana-infused liquids, and 7 grams of concentrates or lotions (Bishop-Henchman et al., 2018). By contrast, in Colorado state residents can purchase up to one ounce of any kind of marijuana product, while non-residents can only purchase a quarter of an ounce.

Legalization has proven very lucrative in states that have taken this step. According to *Business Insider,* in the first year after Washington state legalized recreational marijuana, sales topped $1.4 million (Press, 2015). Edible products accounted for the majority of these revenues, and Montgomery (2017) predicts their popularity will only increase in the future. Based on a report by *Forbes*, sales of marijuana-infused "treats" (such as lollipops and gummy bears) increased by 121% between 2015 and 2016 in Washington. Colorado, meanwhile, saw a three-fold increase in edible product sales over a 2½-year period—from $17 million in the first quarter of 2014 to $53 million in the third quarter of 2016 (Montgomery, 2017). Not enough attention has been paid to how the increasing availability and popularity of edible products can also lead to increased accidental poisoning of children.

Background

Medical and recreational marijuana are currently available in several different forms: vaporizers, high-concentrated products such as drops and lotions, cigarettes, and infused edibles. Revenue from edible forms, the most widely consumed marijuana products, has increased rapidly in recent years. For example, Colorado generated $573 million in recreational marijuana sales in the first year following legalization, with edible products accounting for 45% of the total revenue (Baca, 2016; Steffen, 2016).

Colorado and Washington were the first states to legalize recreational marijuana use. According to data from the Colorado Department of Revenue's Marijuana Enforcement Division and the Washington State Liquor and Cannabis Board, these two states also became the first to pass safety regulations such as child-resistant packaging, warning labels, dose and marketing limitations, and public health media campaigns. This emphasis on safety was spurred by the increase both states have seen in Emergency Department (ED) visits for pediatric poisoning resulting from marijuana use.

Numerous studies have documented the rising incidence of these ED visits and calls to poison control centers about children consuming marijuana. But only a handful of studies have focused on the association between marijuana legalization and pediatric poisoning rates. Richards et al. (2017) conducted a systematic review of studies related to unintentional cannabis ingestion in children. After categorizing the different types of ingestion, they included 44 of 3316 research articles found in their final review. Of the selected studies, 10 reported that lethargy was the most frequent symptom of pediatric cannabis ingestion. The most common ingestion types were resin, cookies, and joints. Other forms of ingestion in this young population included secondhand smoke, medical cannabis, beverages, candies, and hemp oil.

The reviewed studies concluded that states which decriminalize medical and recreational cannabis see a corresponding rise in unintentional marijuana ingestion among children. In assessing past research, the authors used criterion from the Oxford Center for Evidence Based Medicine to measure a study's relative empirical quality. In this systematic review, no studies qualified for the two highest quality designations, Level I or Level II. Instead, 10 studies were designated as Level III quality and 34 studies as Level IV or Level V. Regardless of their empirical quality, the included studies were consistent in their description of cannabis intoxication and of potential dangers associated with unintentional marijuana ingestion in children. As an increasing number of states legalize medical and recreational marijuana, addressing the rise of associated pediatric poisoning is a mounting public health concern.

Spadari et al. (2009) conducted the first retrospective review of unintentional pediatric cannabis ingestion. The researchers examined cases of accidental poisoning in individuals aged 18 or younger, as reported to the Marseille poison center from 1993 to 2007. A total of 93 cases were reviewed, 86% of which involved children younger than 3. The sample included 56 boys and 37 girls. Results showed that the frequency of cases increased over time, with 2/3 of the cases occurring after 2000. Like the review by Richards et al. (2017), Spadari et al. (2009) focused on analyzing data related to unintentional cannabis ingestion. Neither of these studies, however, explored the association between pediatric ingestion and marijuana legalization.

One of the first studies to examine the association between medical marijuana legalization and pediatric ingestion was conducted by Wang et al. (2013). They analyzed the effect of legalization on this young population from January 1, 2005 through December 31, 2011. The study compared the proportion of marijuana ingestion cases among patients younger than 12 years old who sought care at a children’s hospital in Colorado before and after marijuana legalization in October 2009. Data included a total of 1,378 patients younger than 12 years treated for unintentional ingestions. Of these, 790 patients were treated before September 30, 2009, and 588 treated after October 1, 2009. These results suggest that the proportion of marijuana ingestion visits in patients younger than 12 years increased after September 30, 2009, from 0 out of 790 patients to 14 out of 588 patients ($p < 0.001$).

Although analyses showed a significant increase in unintended marijuana ingestion, the study had several limitations. The researchers obtained data from a single tertiary care children's hospital in Colorado, thus limiting the generalizability of findings. Different types of medical facilities might see different types of pediatric poisoning cases in different proportions. Also, they focused on a single state. Health patterns true for Colorado might not be true for other parts of a country as large and diverse as the United States.

In another study, Wang et al. (2014) found that states that decriminalized medical cannabis saw an increase in ED visits for unintended pediatric marijuana exposure. The researchers included all the contiguous US states in their retrospective review of the American Association of Poison Control Centers' National Poison Data System from January 1, 2005 to December 31, 2011. States were designated as non-legal, transitional (if medical marijuana legislation was enacted between 2005 and 2011), or decriminalized (if the law passed before 2005). There were a total of 985 marijuana exposure cases involving children aged 9 or younger. Of these, 486 were from non-legal states, 93 from transitional states, and 396 from decriminalized states. In decriminalized states the poison center call rate per year increased by 30.3%, compared to an 11.5% increase in transitional states. The researchers concluded that despite the low number of overall cases, the rate of pediatric exposure increased most significantly between 2005 and 2011 in states that decriminalized medical marijuana use.

One major study limitation is that calls made to the National Poison Data System may involve a reporting bias. It is likely that individuals who live in states which have legalized marijuana are more aware of poison control centers and the need for swift action in a case of pediatric marijuana ingestion. These individuals are probably more likely to immediately call a poison control center than residents of states where marijuana consumption is illegal. Therefore, it is possible that effects of marijuana legalization were overestimated in the study.

Wang et al. (2016) analyzed the association between recreational legalization and pediatric marijuana poisoning, the only study of its kind. The researchers conducted a retrospective cohort study of hospital admissions and Regional Poison Center (RPC) cases at a children's hospital in Aurora, Colorado between January 1, 2009, and December 31, 2015. They included patients aged 0 to 9 who visited the hospital's ED, urgent care centers, or inpatient units. For the RPC, they focused on pediatric cases involving single-substance marijuana exposures. Colorado exhibited an average increase of 34% in RPC cases per year between 2009 and 2015, while the rest of the United States only increased 19% during this time. The researchers concluded that legalization did affect the incidence of pediatric exposures. These study results had a major limitation, however. Analyses were based on data from a single setting in a single state, suggesting a lack of external validity. Because these results are not necessarily generalizable to other states, further research is needed to explore the association between recreational marijuana legalization and pediatric poisoning.

Such research is part of the broader need to fully examine the unintended consequences of legalization, especially important as medical and recreational use and acceptance spreads across American society. The current study first considers the impact of medical marijuana legalization on pediatric poisoning, then examines the impact of recreational marijuana legalization on these poisonings.

Past studies examining the association between medical/recreational marijuana and pediatric exposures have all concluded that pediatric poisoning cases have increased significantly since the legalization of marijuana in either form. However, these findings are based on purely descriptive studies; none utilized inferential-based methodologies. The current study adds to the knowledge base by using a quasi-experimental design to investigate the association between legislation and poisoning rates. The study also utilizes data from far more ED visits than previous studies. This larger dataset increases the power of study analysis and renders estimates more reliable. Most importantly, unlike past research, the current study analyzes data from multiple states and estimates the average impact of marijuana legalization in both forms. The result is greater external validity and generalizability of findings across multiple settings. Various states can use this research when formulating policies to minimize the unintended harmful consequences of marijuana legalization.

Methods

Hypotheses

The study hypothesized that marijuana legalization, whether recreational or medical, would impact pediatric poisoning-related ED visits. Recreational and medical marijuana policy changes were analyzed separately. A quasi-experimental design was used to compare the treatment states with the control states before and after legalization was implemented.

Data

This study used both the State Emergency Department Database (SEDD) and the State Inpatient Database (SID) to compile data on hospital visits by children due to marijuana poisoning. SEDD captures visits to hospital-affiliated Emergency Departments that do not result in hospitalizations, while SID includes information about patients who are initially seen in the hospital ER and then admitted to the facility. All emergency visits from SEDD that corresponded to the relevant ICD codes were included. Hospital visits included in SID were first subdivided by the type of visit (emergency or not), and then extracted if they matched the relevant ICD codes. The study included 16 US states that had data available: Arizona, Arkansas, California, Kentucky, Maryland, Massachusetts, Nebraska, New Jersey, New Mexico, New York, North Carolina, Rhode Island, Utah, Vermont, Washington, and Wisconsin. Information on 13 of these states came from SEDD, while information for Arkansas, New Mexico, and Washington came from SID.

The ICD codes that were used to separate the cases for each state at month level are provided in Table 1. ICD-9 codes were used until October 2015, at which point the Healthcare Cost and Utilization Project (HCUP) began to use ICD-10 codes. The study therefore used ICD-9 search criteria to generate equivalent ICD-10 codes, as other researchers have done when the study period included use of both codes at different points (Wang et al, 2016).

Table 1: Relevant Causes and ICD Codes for Pediatric Poisoning Related ED-Visits

Cause	ICD – 9	ICD - 10
Cannabis Abuse	305.2	F12
Poisoning for Psychodysleptics	969.9	T40
Accidental Poisoning by Psychodysleptics	E854.1	N/A
Poisoning by Drugs, Medicinal, and biological substances	960 - 979	T36-50
Accidental Poisoning by Drugs, Medicinal Substances, & Biologics	E850 - E858	N/A

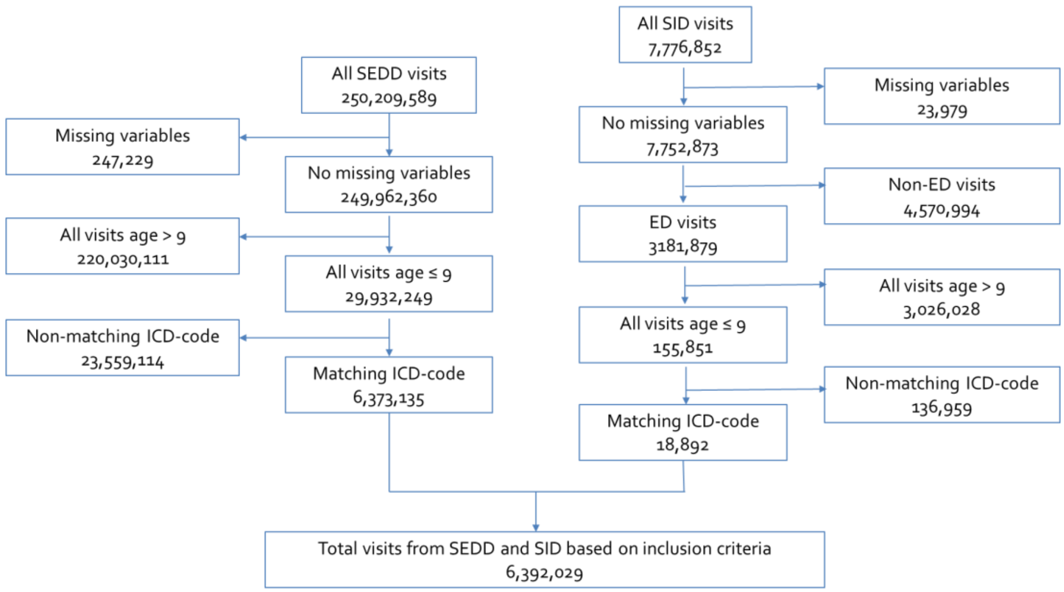
The inclusion criteria were patients 0-9 years of age who visited an ED (inpatient or outpatient) with a primary ICD-9 code for one of the following conditions: cannabis abuse (305.20); poisoning for psychodysleptics (969.9); accidental poisoning by psychodysleptics (E854.1); poisoning by drugs, medicinal, and biological substances (960-979); or accidental poisoning by drugs, medicinal substances, and biologics (E850-E858). Equivalent ICD-10 codes were: F12 (305.20), T40 (969.6), and T36-50 (960-979, E850-E858). Data related to the dates of marijuana legalization were obtained from the National Conference of State Legislatures website (ncsl.org). This organization provides up-to-date information related to medical and recreational marijuana legalization across the nation.

This study used the dates when legalization laws became effective, not when they were passed by state legislatures. For medical marijuana legalization, the effective date corresponded to the day when the first dispensary opened and citizens could legally obtain cannabis. For example, in the case of New York, the state legalized medical marijuana in June 2014, but the first dispensary did not open until January 2016. New York was thus designated as a control state because legalization did not become effective until one month after the study period ended. Similarly, New Jersey legalized medical marijuana in 2010, but the first dispensary did not open until August 2012.

A total of 16 states were included in the study. Five states legalized medical marijuana before the study period began (California, New Mexico, Rhode Island, Vermont, and Washington). Three states legalized medical marijuana during the study period: Arizona, Massachusetts, and New Jersey. Arizona legalized medical cannabis in November 2010, while study period data on Arizona extends from 2007 to 2015. Legalization towards the end of 2010 thus provides an almost equal number of observations before and after the policy was enacted. This aids the model in examining the variation in pediatric poisoning ED visits more fully as they relate to legalization. Massachusetts, meanwhile, legalized medical marijuana in January 2013, and data for the state extends from 2007 to 2013. Therefore, this study had only 12 months of post-legalization data to examine. (As opposed to 84 months of pre-legalization data.) New Jersey opened its first marijuana dispensary in August 2012, while state data is available from 2007 to 2014. That translates into 68 months of pre-treatment data and 28 months of post-treatment data.

No states had legalized recreational marijuana prior to the study period. Washington, which legalized recreational marijuana in December 2013, was the only treatment state in the study. Because data for Washington extends from 2007 to 2014, there are 83 months of pre-treatment data, and 13 months of post-treatment data.

Figure 1: ED Visits for Pediatric Marijuana Poisoning - Data Flowchart



Regression Models

Because information from SEDD and SID are provided in count form, a count data model was used for this study. The dependent variable was a count of pediatric poisoning cases with marijuana ingestion as a primary diagnosis (based on ICD-9 and ICD-10 codes) for a particular month, year, and state. Using a state-year-month level of observation allowed the effect of legalization to be fully captured, and provided more observations compared to state-year level. A negative binomial distribution was used instead of a Poisson distribution, as marijuana poisoning-related ED visits were not normally distributed, and the conditional mean value differed from the conditional variance for state-year-month. Since a count data model was used, an exposure variable was included to define the number of times such ED visits could have occurred.

$$Y_{jimt} = f(L_{imt}, S_i, M_m, T_t)$$

In the above equation, Y_{jimt} represents the total number of cases related to marijuana exposures for category 'j' (all the cases and gender-adjusted) in state 'i' at month 'm' and time 't'; L_{imt} represents whether marijuana is legalized or not, taking value '1' if legalized and '0' if otherwise; S_i controls for state-fixed effects (hence it only changes with state 'i'); M_m is a vector of month dummy variables, controlling for the month effect; and T_t controls for year effects, and is a vector of year dummies. Exposure variable was the total number of ED visits per state-year-month by patients aged 9 or younger.

$$Y_{jimt} = \alpha + \beta_l . L_{imt} + \varphi . S_i + \sigma . M_m + \mu . T_t + \varepsilon_{imt}$$

Where β_l represents estimates for the impact of marijuana legalization, either recreational or medical, on pediatric poisoning visits. Fixed effects for state, month, and year are represented by $\varphi, \sigma,$ and $\mu,$ respectively. Models were estimated in terms of IRR.

The study design used two different regressions to separate the effect of recreational and medical marijuana legalization. The first model examined recreational marijuana legalization separately to determine the impact of this policy change. This meant that Washington, the only state to legalize recreational marijuana within the study period, was compared to the control states that had only legalized medical marijuana use. Because the only policy difference between the treatment state (WA) and the 7 control states (AZ, CA, MA, NJ, NM, RI, and VT) was recreational marijuana legalization, the effect of medical marijuana was factored out. This provided the marginal effect of recreational marijuana legalization.

By contrast, the second model focused solely on medical marijuana legalization. This meant that treatment states included those which had legalized medical marijuana but not recreational cannabis. (As a result, Washington was not included in this group.) The control states included those which had not legalized medical marijuana. This model design helped to separate the effect of medical marijuana legalization on pediatric poisoning. In this study, there were 7 treatment states (AZ, CA, MA, NJ, NM, RI, and VT), and 9 control states (AR, KY, MA, MD, NC, NE, NY, UT, and WI).

Additionally, falsification analyses on tuberculosis and influenza were conducted to confirm the model design and check the robustness of the study. Since changes in marijuana laws should not influence other kinds of ED visits, these analyses should provide nonsignificant results that confirm the robustness of the study design. All the analyses were conducted in Stata version 13 (StataCorp LP, College Station, TX).

Results

Table 2 shows the descriptive statistics for the data. Study period was not the same for all states due to data availability issues. The shortest study period was three years, and the longest was 8 years. 13 of the 16 states in the data had a study period greater than 6 years, and all the study periods were between 2007-2015. The average number of pediatric marijuana poisoning visits per 100 ED visits vary from 10.93 to 32.45, with Arkansas being the lowest, and Vermont being the highest. Furthermore, the data shows that for each state, number of male visits are higher than female visits.

As shown in Table 3, at a 5% significance level the results from difference-in-difference analysis suggest that pediatric exposure cases increased significantly after both types of marijuana legalization. Medical marijuana legalization was associated with a 12.2% increase in exposure cases, while recreational legalization was associated with a 19.9% increase. The results indicate that the marginal effect of recreational legalization is larger than that of medical legalization.

Table 2: Descriptive Statistic of Pediatric Poisoning Cases: 16 US States, 2007 – 15

State	Years	Average number of cases per 100 ED visits	Total Number of Cases	Females	Males
Arkansas	2012 - 14	10.925	2432	975	1457
Arizona	2007 - 15	21.277	609225	260305	348838
California	2007 - 11	20.956	1204229	496594	684766
Kentucky	2008 - 15	20.165	426984	185755	241165
Massachusetts	2007 - 13	25.906	358441	153807	204619
Maryland	2008 - 11	26.366	127083	54536	72543
North Carolina	2007 - 15	18.223	754685	325984	428673
Nebraska	2007 - 15	24.967	113958	48833	65110
New Jersey	2007 - 14	21.331	727271	308866	418404
New Mexico	2008 - 14	11.493	4593	1978	2613
New York	2007 - 14	21.342	1683301	716327	966930
Rhode Island	2007 - 14	22.683	74689	31935	42753
Utah	2007 - 13	30.035	73022	31247	41757
Vermont	2007 - 14	32.448	37604	16201	21402
Washington	2007 - 14	12.675	11867	4952	6907
Wisconsin	2007 - 15	24.132	182643	78137	104502

Gender-adjusted estimates were also examined. For females aged 9 or younger, medical marijuana legalization was associated with an 11.7% increase in pediatric exposures, while recreational legalization had no effect. For males, medical marijuana legalization was associated with an 11.5% increase in pediatric exposures, while recreational legalization was associated with a 21.1% increase. Thus, medical marijuana legalization had a slightly stronger impact on females, while males were more impacted by recreational marijuana legalization.

Table 3: Medical and Recreational Marijuana Legalization: 16 US States, 2007 – 2015

	Medical Marijuana Legalization		Recreational Marijuana Legalization	
Category	**IRR (95% CI)**	**p-value**	**IRR (95% CI)**	**p-value**
<9	1.122 (1.063, 1.184)	<0.001	1.199 (1.033, 1.390)	0.017
<9 & female	1.117 (1.059, 1.179)	<0.001	1.176 (0.997, 1.387)	0.055
<9 & male	1.115 (1.057, 1.175)	<0.001	1.211 (1.040, 1.410)	0.014

IRR: Incidence Rate Ratio, CI: Confidence Interval

Category <9 means that all the cases related to pediatric poisoning for those aged <9 are included, <9 & female means that data was subset to adjust for gender, which means only females under 9 are included.

Results are from 6 models: (1) All pediatric poisoning cases for medical marijuana legalization, (2) Only females <9 for medical marijuana legalization, (3) Only males <9 for medical marijuana legalization, (4) All pediatric poisoning cases for recreational marijuana legalization, (5) Only females <9 for recreational marijuana legalization, (6) Only males <9 for recreational marijuana legalization,

Falsification analyses on tuberculosis and influenza, which were conducted by utilizing the same model design as the one used for this study, provided statistically non-significant results for each of the diagnosis.

Table 4: Falsification Analysis

	Medical Marijuana Legalization		Recreational Marijuana Legalization	
Diagnosis	**IRR (95% CI)**	**p-value**	**IRR (95% CI)**	**p-value**
Tuberculosis	0.888 (0.666, 1.184)	0.416	1.005 (0.647, 1.562)	0.981
Influenza	0.948 (0.758, 1.186)	0.640	0.554 (0.192, 1.600)	0.275

IRR: Incidence Rate Ratio, CI: Confidence Interval

Discussion

Study analyses revealed that both medical and recreational marijuana legalization are associated with an increase in pediatric exposures. In terms of gender differences, medical marijuana legalization had a similar impact on both males and females aged 9 or younger, with only a 0.2% higher effect on females. However, legalization of recreational marijuana had very different impact on boys and girls. Overall, recreational marijuana legalization led to a greater number of pediatric exposure cases than did medical marijuana legalization. State policymakers and voters need to be aware of this reality when considering policy changes regarding cannabis use.

Wang et al. (2016) conducted one of the few previous studies examining the effects of marijuana legalization on pediatric poisoning. They found that after recreational marijuana legalization, the number of Regional Poison Center cases in Colorado involving pediatric cannabis ingestion increased by an average of 34% per year. Results from the current study show a somewhat lower estimate for Washington state, where recreational legalization increased pediatric ED visits for cannabis poisoning by 19.9%. Furthermore, Wang et al (2013) found that implementation of the medical marijuana law in Colorado also increased pediatric exposures. The current study found a similar increase in cases of pediatric cannabis poisoning after medical marijuana legalization.

The current study has some limitations. First, the analyses focused exclusively on medical and recreational marijuana legalization policies and did not control for other factors that might impact poisoning cases. Second, while state fixed effects controlled for policy differences between states, there might be confounders that were not controlled for by this methodology. Future research should take this complicating factor into account. Third, ICD codes for poisoning by psychodysleptics were used as a proxy for marijuana-related ED visits, but there is no way to ensure that all these poisonings were solely due to marijuana ingestion. Nevertheless, there were no policy changes at the state level that could affect psychodysleptic drug consumption by children except for marijuana legalization. Thus, ingestion rate changes over the study period are likely attributable primarily to cannabis use. Finally, study includes data from 16 states, which hinders the external validity of the findings.

Conclusions

Based on current study estimates and those by Wang et al. (2013; 2016), it is likely that as more states legalize medical and recreational marijuana there will be an increase in the number of pediatric poisoning cases. Even though Colorado and Washington state have already put safety policies into place—including child-resistant packaging (CRP), warning labels, dose and marketing limitations, and public health awareness campaigns—research suggests these measures have not curtailed the rise in pediatric marijuana ingestion. Policymakers must formulate more effective methods to warn adult marijuana users of the dangers of leaving edible cannabis products within the reach of children. Additionally, child endangerment laws could be tightened to specifically include edible marijuana poisoning of children. More effective measures are also needed at the national level so that states legalizing marijuana in the future have evidence-based safety protocols and structures in place from the first day of legalization.

CHAPTER 3

SAME-SEX MARRIAGE LEGALIZATION AND SEXUALLY TRANSMITTED INFECTIONS

Introduction

On June 26, 2015, the US Supreme Court ruled that state-legislated bans on same-sex marriages were unconstitutional, thereby legalizing these marriages across the nation (Liptak, 2015). Before this ruling, states created their own laws to address the controversial issue of same-sex marriages. In the 11 years prior to 2015 there was a gradual acceptance of LGBTQ rights in this area. Massachusetts had legalized same-sex marriages in 2004, the first state to do so. By the time of the Supreme Court's ruling, 33 of the 48 states in the contiguous United States had already legalized same-sex marriages. In 26 states, this had occurred since 2012. This suggests the Supreme Court had, at least to some degree, taken into account rapidly expanding public and political acceptance of this new social norm when rendering its landmark decision.

There have been prior studies that discuss the effects of legalization on overall public health for both LGBTQ and general populations. These studies have often focused on the benefits gained when employer-sponsored health coverage is extended to spouses in same-sex marriages. However, a review of the literature reveals no prior research that has analyzed the impact of legalization on STI-related ED visits. The current study addresses this gap in the scholarly knowledge base.

Background

Significant research has examined the increased wellbeing enjoyed by individuals in same-sex marriages resulting from recent federal or state antidiscrimination and equal access laws. But little research has focused specifically on the impact of same-sex marriage legalization on the overall physical health of the LGBTQ population (Buffie, 2011).

Hatzenbuehler et al. (2012) examined the effect of same-sex marriage laws on healthcare use and expenditures in sexual minority men using a quasi-experimental design. The paper was published before the Supreme Court's 2015 ruling legalizing same-sex marriages across the nation. The researchers used a quasi-experimental design to analyze prospective data from 1,211 sexual minority male patients in a community-based health center in Massachusetts. Their findings revealed that the mean number of medical care visits during the 12 months after legalization was 2.26, compared to 2.61 in the 12 months preceding legalization. Similarly, costs were also lower in the 12 months after legalization versus the 12 months before legalization ($233.09 vs. $259.32). The study concluded that by conferring legal protections to same-sex couples, a marriage policy change may reduce medical care utilization and costs among sexual minority men. These benefits also seem to correspond to a decline in the occurrence of STIs.

A major study limitation was the limited sample size used to conduct the analysis. The researchers included 1,211 individuals as representative of the overall sexual minority male population. Data was also derived from only 12 months of pre- and post-treatment analysis. It is probable that the full effect of marriage legalization was not observed in the first 12 months of legalization. A lagged variable—perhaps 1-year post-legalization—would have accounted for any delayed effects. This is an avenue of inquiry that future research should address.

Dee et al. (2008) was the first study to explore the influence of same-sex marriages on risky sexual behaviors that can lead to STIs. The researchers used data from the World Health Organization's (WHO) Computerized Information System for Infectious Diseases (CISID). The CISID contains annual surveillance data on several infectious diseases for the 52 countries in the WHO European Region during the years 1980 to 2003. The study examined the European data using a difference-in-difference approach with country and year fixed effects. The study hypothesized that legal recognition of same-sex partnerships would reduce sexual promiscuity. Trend graphs for different countries showed that the nations which provided legal recognition experienced decreased rates of syphilis, gonorrhea, and HIV over time. Syphilis rates declined by approximately 43% in these countries. The declines in gonorrhea and HIV rates were smaller and statistically insignificant.

One major study complication is ongoing migration between these countries, resulting in a spillover effect. For example, if a county legalized same-sex partnerships, conferring them with equal social benefits and protections as heterosexual partnerships, then it might be expected that LGBTQ individuals would increase migration to that country. This is especially true given the freedom of inter-nation movement enjoyed by citizens of the European Union. The authors address this issue by discussing country-specific residency and citizenship requirements to obtain public benefits. They also note that any increase in syphilis rates after the law's enactment would require an implausibly large in-migration. However, there is no way to confirm that there was no spillover effect.

Francis et al. (2012) used US state-level panel data from 1981 to 2008 to analyze the relationship between same-sex marriage laws and STIs. They employed OLS (Ordinary Least Squares) and dynamic panel models. The dependent variable was the natural log of the syphilis or gonorrhea rate in state-year. The independent variables included same-sex marriage laws, and a 1-year lag of the dependent variable. The model also included state and time fixed effects. Rate of syphilis was considered as the proxy for risky homosexual behavior as 64% of syphilis cases are attributable to men having sex with men (CDC, 2010a). Rate of gonorrhea was considered as the proxy for risky heterosexual behavior because more than 90% of gonorrhea cases are attributable to sex between men and women (CDC, 1997).

Study findings suggest that same-sex marriage laws have a modest positive association with the syphilis rate, with legalization resulting in fewer cases of the disease. In contrast, none of the regressions revealed a statistically significant change (at a 5% level) in the gonorrhea rate. However, a statewide ban on same-sex marriage was associated with a 16.3% increase in the syphilis rate, while a ban on both marriage and civil unions was associated a 20.8% increase. The authors acknowledge that deciding whether to include or exclude data from California can significantly alter study results. When excluding California data, none of the results showed significance for the syphilis rate at a 5% level. Thus, the researchers concluded that even with results indicating a modest positive association, it is not clear whether this change can be attributed to same-sex marriage legalization.

A limitation of this study is the time span covered. Even though it includes 28 years as the study period, most state laws legalizing same-sex marriage were implemented after 2008. It is therefore essential to conduct analysis during a period with suitable variation in state marriage laws to fully capture their impact. The current study includes data from 2007 to 2015, capturing data from the 26 states that legalized same-sex marriages between 2012 and 2015.

Legalization produces significant economic and social benefits, improving the quality of life for the general population after implementation (Buffie, 2011). For example, Dee et al., (2008) and Francis et al., (2012) report that legalization of same-sex marriages decreases the rate of STIs in the LGBTQ population while also lowering overall national healthcare costs. By contrast, before the Supreme Court's 2015 legalization decision, the number of STI-related visits to EDs increased during 2008-10 and 2011-13 by more than 38%. During the same time periods, total ED visits for all reasons increased by only 2% (Pearson et al. 2012). This contrast underlines the importance of the current study, which analyzes the influence of marriage legalization on STI-related ED visits.

No known prior research utilizes a quasi-experimental design like the current study to analyze the impact of same-sex marriage legalization on STI-related ED visits in the United States. The study adds to the legalization research literature by conducting analysis using difference-in-difference methodology. It also utilizes a larger STI-related dataset than previous studies. Although the current study period is shorter than those of Dee (2008) and Francis et al. (2012), it does include the period when the most states were legalizing same-sex marriages. It thus provides pre- and post-treatment study periods (before and after the 2015 Supreme Court decision). Study findings will clarify the association between same-sex marriage legalization and STI-related ED visits for future researchers. This study addresses the gap in the literature by examining the effects of legalization on STI-related ED visits using an inference-based approach.

Methods

Hypothesis

The hypothesis tested in this study is that legalization of same-sex marriages will impact the number of STI occurrences. This is based on the assumption that legalization increases acceptance of the LGBTQ community among the general public, and that this acceptance results in greater LGBTQ access to quality healthcare. The institution of marriage can also help keep two individuals together, reducing the likelihood of multiple partners and thereby lowering the occurrence of STIs.

A quasi-experimental design was employed to compare the treatment states that legalized same-sex marriages to control states that did not. Data was examined both before and after instances of state legalization to determine the impact of this policy change.

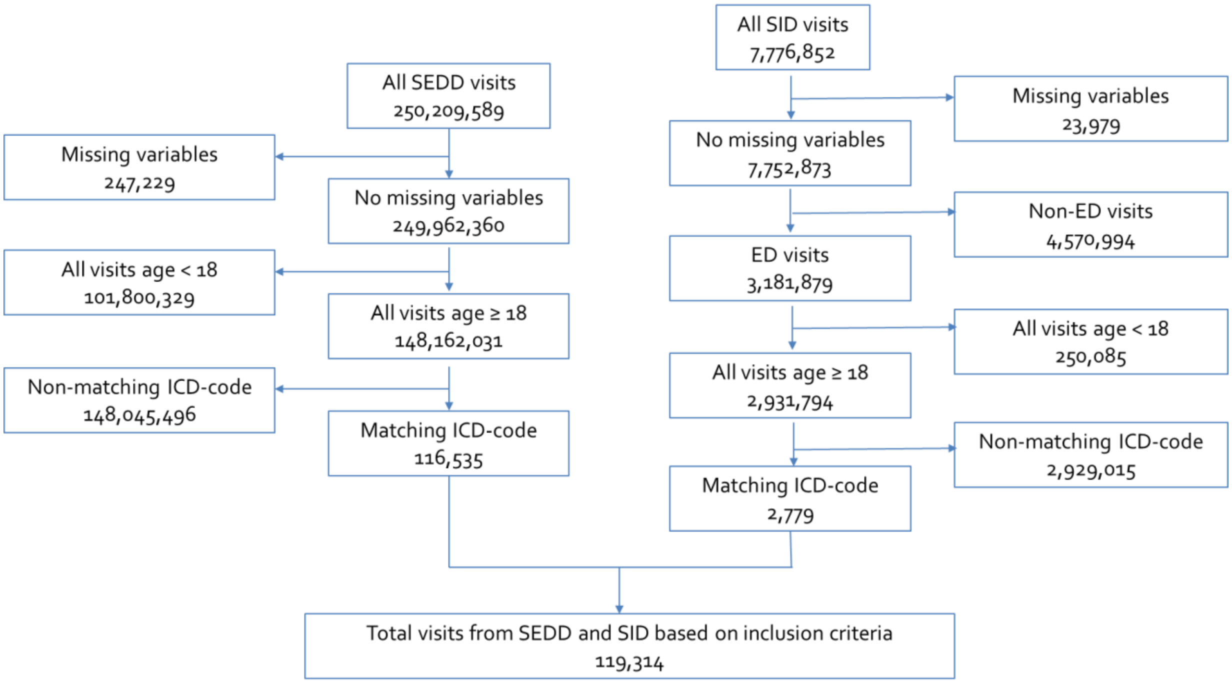
Data

Data on ED visits were obtained from the State Emergency Department Database (SEDD) and the State Inpatient Database (SID). The inclusion criteria were patients >=18 years of age, visiting the ED (inpatient or outpatient) with a primary ICD-9 code for one of the following conditions: syphilis and other venereal diseases (090-099); high-risk cervical human papillomavirus (795.05); high-risk vaginal HPV (795.15); low-risk vaginal HPV (795.19); high-risk anal HPV (796.75); and low-risk anal HPV (796.79). Because hospital coding changed to ICD-10 in October 2015, the equivalent ICD-10 codes were used from that point onwards. The equivalent ICD-10 codes were: 090-099 (A50-A64), 795.05 (R87.810), 795.15 (R87.811), 795.19 (R87.628), 796.75(R85.81), and 796.79 (R85.82). The study included 16 US states: Arizona, Arkansas, California, Kentucky, Maryland, Massachusetts, Nebraska, New Jersey, New Mexico, New York, North Carolina, Rhode Island, Utah, Vermont, Washington, and Wisconsin. Data for 13 of these states came from SEDD, while data for Arkansas, New Mexico, and Washington came from SID.

Same-sex marriage legalization dummy was generated based on data from ProCon (gaymarriage.procon.org). ProCon discusses the pros and cons on a wide array of issues related to (but not limited to) healthcare, sex, gender, and politics. ProCon provides a timeline of same-sex marriage developments and court rulings. The timeline covers from 1970, when the first same-sex couple applied for a license to marry in Minnesota, to the present. For the dependent variable (number of STI-related ED visits), cases with relevant ICD codes from 2007 – 2015 were aggregated to the state-year-month level to capture the number of STI-related ED visits per state-year-month. (Available years of data varied by state.)

As shown in Table 5, 16 states were included in the dataset. Of these, 13 had legalized same-sex marriages before the Supreme Court ruling in June 2015. Eleven of the 16 states legalized same-sex marriages during the study period. One state (Massachusetts) had legalized the practice before the study period, and 4 states did not legalize it during the study period. The study thus has pre- and post-treatment data on 11 states, information that helps determine the variation in STI-related ED visits associated with same-sex marriage legalization.

Figure 2: ED Visits for STIs - Data Flowchart



Regression Models

For this study, a difference-in-difference model design with a negative binomial distribution was utilized with state fixed effects. The policy change variable was same-sex marriage legalization, which took a value of “1” if the state had legalized same-sex marriages and “0” otherwise.

In this model, the dependent variable was the number of STI cases (based on ICD-9 and ICD-10 codes) for a particular month, year, and state. Using a state-year-month level of observation allowed the effect of legalization to be fully captured, and provided more observations compared to state-year level. The negative binomial design was implemented because STI-related ED visits were not normally distributed, and the conditional mean value differed from the conditional variance for state-year-month. Since count data was used in the model, an exposure variable was included to define the number of times STI cases could have occurred.

The model specifications took the following form:

$$Y_{jimt} = f(L_{imt}, S_i, M_m, T_t)$$

Where Y_{imt} represents the total number of cases related to STIs for category ‘j’ in state ‘i’ at month ‘m’ and time ‘t’; L_{imt} represents whether same-sex marriage is legalized or not, taking the value of ‘1’ if legalized, and ‘0’ if otherwise; S_i controls for state-fixed effects (hence it only changes with state ‘i’); M_m is a vector of month dummy variables, controlling for the month effect; and T_t controls for year effects, and is a vector of year dummies. The exposure variable was total number of ED visits per state-year-month by patients aged 18 years and older.

$$Y_{jimt} = \alpha + \beta_l . L_{imt} + \varphi . S_i + \sigma . M_m + \mu . T_t + \varepsilon_{imt}$$

Where β_l represents estimates for the impact of same-sex marriage legalization on STI related ED visits. Fixed effects for state, month, and year are represented by $\varphi, \sigma,$ and $\mu,$ respectively. Models were estimated in terms of Incidence Rate Ratio (IRR).

The analysis used two different versions of the same model. The first model examined the effect of same-sex marriage legalization on the percentage change in STI cases. Because new policies can take time to influence change, the initial model identification was modified to include a 1-year lag of the policy variable to determine the long-term impact of legalization. In the first model, value 1 was assigned to the legalization dummy on the date of same-sex marriage legalization in the various states. The second model added another legalization dummy to measure the impact of legalization 12 months after the date of policy implementation.

The effect of same-sex marriage legalization was examined among different population subgroups. First, separate analyses were conducted based on gender. Second, the impact of same-sex marriage was examined for four different age cohorts: 18-24, 25-40, 41-64, and 65+ years. Finally, the study adjusted for both gender and age cohorts to determine the impact of legalization on both males and females within each age group.

To confirm the model design and check the robustness of the analyses, falsification analyses were performed on tuberculosis and hypertension. Since legalizing same-sex marriages should not influence ED visits unrelated to STIs, these analyses should provide nonsignificant results that confirm the robustness of the model. All the analyses were conducted in Stata version 13 (StataCorp LP, College Station, TX).

Results

Table 5: Descriptive Statistic for STI-Related ED Visits: 16 US States, 2007 – 2015

State	Years	No. of observations before legalization	No. of observations after legalization	No. of observations one year after legalization	Date effective	STI cases per 10,000 ED visits before legalization	STI cases per 10,000 ED visits after legalization
Arkansas	2012 - 14	36	0	0	06/26/2015	7.979	N/A
Arizona	2007 - 15	94	14	2	10/17/2014	4.624	6.313
California	2007 - 11	60	0	0	06/28/2013	4.475	N/A
Kentucky	2008 - 15	90	6	0	06/26/2015	4.875	6.520
Massachusetts	2007 - 13	0	84	84	05/17/2004	N/A	4.609
Maryland	2008 - 11	48	0	0	01/01/2013	11.092	N/A
North Carolina	2007 - 15	93	15	3	10/10/2014	8.984	9.086

Table 5 Continued

State	Years	No. of observations before legalization	No. of observations after legalization	No. of observations one year after legalization	Date effective	STI cases per 10,000 ED visits before legalization	STI cases per 10,000 ED visits after legalization
Nebraska	2007 - 15	102	6	0	06/26/2015	5.885	8.084
New Jersey	2007 - 14	82	14	2	10/21/2013	12.043	14.101
New Mexico	2008 - 14	72	12	0	12/19/2013	12.503	12.763
New York	2007 - 14	45	41	29	07/24/2011	10.485	10.833
Rhode Island	2007 - 14	79	17	5	08/01/2013	5.037	5.379
Utah	2007 - 13	84	0	0	10/06/2014	2.052	N/A
Vermont	2007 - 14	32	64	52	09/01/2009	2.127	1.990
Washington	2007 - 14	71	25	13	12/02/2012	7.855	11.390
Wisconsin	2007 - 15	93	15	3	10/06/2014	5.176	5.665

Based on the descriptive statistics from Table 5, the rate of STI cases per total ED visits increased for almost all the states that had observable data after legalization. The one exception was Vermont, where the STI rate decreased by 7.6% from 2.13 to 1.99 per 10,000 total ED visits. Washington saw the greatest increase of STI-related ED visits after legalization, a rise of 45% from 7.86 to 11.39

Table 6: Short-Term Effect: 16 US States, 2007 – 2015

	Short-term effect	
Category	IRR (95% CI)	p-value
All	0.939 (0.906, 0.973)	0.001
Male	0.953 (0.914, 0.995)	0.027
Female	0.924 (0.885, 0.966)	<0.001
18-24	0.915 (0.875, 0.957)	<0.001
25-40	0.958 (0.914, 1.003)	0.068
41-64	0.967 (0.905, 1.032)	0.309
65+	0.912 (0.782, 1.065)	0.245
Male 18-24	0.930 (0.878, 0.985)	0.013
Male 25-40	0.965 (0.913, 1.021)	0.218
Male 41-64	0.978 (0.904, 1.057)	0.570
Male 65+	0.831 (0.675, 1.022)	0.079

Table 6 Continued

	Short-term effect	
Category	IRR (95% CI)	p-value
Female 18-24	0.901 (0.853, 0.952)	<0.001
Female 25-40	0.952 (0.894, 1.013)	0.123
Female 41-64	0.942 (0.837, 1.061)	0.325
Female 65+	1.026 (0.813, 1.294)	0.828

IRR: Incidence Rate Ratio, CI: Confidence Interval

Short-term effect means that legalization dummy takes value '1'

immediately after the state legalizes same-sex marriages.

Each row represents a separate model, total of 15 models.

Models were adjusted for age, gender, and age-gender combinations.

Results from the first model (Table 6) showed that overall STI cases decreased significantly after legalization in the short-term. Same-sex marriage legalization was associated with a decrease of 6.1% in STI-related ED visits when not controlling for age or gender. When adjusting for gender, visits decreased by 4.7% for males and 7.6% for females. In terms of age cohorts, while visits for the 18-24 age group decreased by 8.5%, there was no statistically significant change for other age groups. When the study controlled for both age and gender, males aged 18-24 years had a decrease of 7% in STI-related ED visits, and females aged 18-24 years had a decrease of 9.9%. Apart from this finding, none of the other gender-age subgroups exhibited a statistically significant change.

Table 7: Short-Term and Long-Term Effect: 16 US States, 2007 – 2015

	Short-term		Long-term	
Category	IRR (95% CI)	p-value	IRR with one-year lag (95% CI)	p-value
All	0.968 (0.931, 1.007)	0.111	0.926 (0.887, 0.967)	<0.001
Male	0.990 (0.946, 1.037)	0.683	0.909 (0.864, 0.956)	<0.001
Female	0.944 (0.900, 0.990)	0.019	0.949 (0.901, 0.999)	0.045
18-24	0.944 (0.899, 0.992)	0.022	0.928 (0.879, 0.979)	0.007
25-40	0.996 (0.947, 1.047)	0.869	0.907 (0.859, 0.957)	<0.001
41-64	0.982 (0.914, 1.053)	0.608	0.959 (0.889, 1.035)	0.287
65+	0.922 (0.783, 1.087)	0.335	0.966 (0.808, 1.155)	0.705
Male 18-24	0.968 (0.909, 1.030)	0.308	0.906 (0.845, 0.970)	0.005
Male 25-40	1.007 (0.948, 1.070)	0.819	0.899 (0.842, 0.960)	0.001
Male 41-64	1.014 (0.932, 1.103)	0.749	0.906 (0.828, 0.992)	0.034
Male 65+	0.847 (0.680, 1.056)	0.140	0.940 (0.742, 1.192)	0.611
Female 18-24	0.924 (0.870, 0.981)	0.010	0.940 (0.880, 1.003)	0.060
Female 25-40	0.982 (0.918, 1.051)	0.605	0.920 (0.856, 0.989)	0.024
Female 41-64	0.908 (0.797, 1.034)	0.144	1.105 (0.963, 1.267)	0.156
Female 65+	1.025 (0.801, 1.311)	0.844	1.003 (0.765, 1.317)	0.981

IRR: Incidence Rate Ratio, CI: Confidence Interval. Each row represents a separate model, total of 15 models.

Short-term effect means that legalization dummy takes value ‘1’ immediately after the state legalizes same-sex marriages.

Long-term effect means that legalization dummy takes value ‘1’ year after the state legalizes same-sex marriages.

The second model (Table 7) included the same short-term effects as the first model (a legalization dummy that attains value “1”’ when same-sex marriage is legalized), but added another dummy variable that represents value “1” a year after the legalization of same-sex marriages. Results from this model show that there was no statistically significant change in STI-related ED visits in the short-term, but a year after legalization visits decreased by 7.4%. When adjusting for gender, visits after one year decreased by 9.1% for males and 5.1% for females. Legalization had no immediate effect on males, but females experienced a 5.6% decrease in visits. In terms of age cohorts, visits for the 18-24 age group decreased by 5.6% in the short term; there was no statistically significant short-term change for other age cohorts. One year after legalization, ED visits decreased by 7.2% for the 18-24 age cohort and by 9.3% for the 25-40 age cohort. No statistically significant long-term effects were found for the other two age groups. When controlling for both age and gender, only females aged 18-24 showed a short-term decrease (of 7.6%). For males a year after legalization, the 18-24 age group experienced a decrease of 9.4% in ED visits, the 25-40 age group experienced a decrease of 10.1%, and the 41-64 age group experienced a decrease of 9.4%. No other statistically significant gender-age effects were found.

Table 8: Falsification Analysis (Model 1: Short-term effect)

	Short-term effect	
Diagnosis	**IRR (95% CI)**	**p-value**
Hypertension	0.989 (0.971, 1.007)	0.232
Tuberculosis	0.958 (0.795, 1.156)	0.657

IRR: Incidence Rate Ratio, CI: Confidence Interval

Table 9: Falsification analysis (Model 2: Short-term and Long-term effect)

	Short-term		Long-term effect	
Diagnosis	**IRR (95% CI)**	**p-value**	**IRR with one year lag (95% CI)**	**p-value**
Hypertension	0.996 (0.975, 1.016)	0.670	0.984 (0.962, 1.006)	0.152
Tuberculosis	0.934 (0.762, 1.146)	0.513	1.074 (0.863, 1.337)	0.521

IRR: Incidence Rate Ratio, CI: Confidence Interval

The results of the falsification analyses are shown in Table 8 and Table 9. As can be seen, there was no statistically significant effect in the diagnosis of either disease following the legalization of same-sex marriages.

Discussion

The descriptive analysis showed that all states except for Vermont had an increase in STI-related ED visits (compared to total ED visits) following the legalization of same-sex marriages. Although this suggests that STI visits increased after legalization, previous research indicates that these visits were already trending upwards before legalization (Pearson et al., 2012). Taking this into account, a difference-in-difference model was used to examine the effect of legalization while controlling for state and time-fixed effects.

Analysis revealed that different population subsets responded in different ways to legalization, both in the short and long terms. Overall, STI-related ED visits decreased in the long term after the legalization of same-sex marriages. Estimates for males mirror the overall trend: no effect in the short term, but decreased STI-related ED visits in the long term. Females, on the other hand, experienced decreases in both the short and long term. The policy change thus impacted females more quickly than males. This aligns with data published by Pew Research which suggests that women are more likely to marry a same-sex partner than men (DeSilver, 2013).

Analysis by different age cohorts showed that individuals in the 18-24 age group had a decrease in the number of ED visits both in the short and long term. Within the 24-40 age group, there was a long-term decrease in STI visits but no effect in the short term. This suggests older individuals responded more slowly to the policy change than younger adults. There were no effects in the 41-64 age cohort, which had lower baseline levels of sexual activity than the younger age groups.

The combined age and gender analysis showed only a long-term effect among males in the 18-24, 25-40, and 41-64 age groups. This suggests that adult males of all ages changed their risky sexual behaviors more slowly than females in response to this new social policy. Among females, there were both short- and long-term decreases in STI-related ED visits within the 18-24 age group. The only other statistically significant effect for females was a decrease in the long-term rate of ED visits for the 24-40 age group. As with males, older female age groups appeared to change behaviors more slowly after the policy change.

By focusing only on same-sex marriage legalization as it relates to STI occurrences, the current study did not control for any possible confounders. This approach assumed that marriage legalization would be the only difference between treatment and control states that would impact emergency STI cases within the study period. The study also assumed that time and state fixed effects would account for the remaining time or state variant changes occurring over this period. Nevertheless, more research is needed to control for any possible confounders. In addition, study includes data from only 16 states, which hinders the external validity of the findings.

Conclusions

Study results suggest that there is a negative association between same-sex marriage legalization and ST-related ED visits. Age-adjusted analysis revealed that younger age groups are likely to have a quicker and stronger response to legalization in terms of risky sexual behavior modification. As to gender-adjusted analysis, females responded more swiftly than males. However, while males experienced no change in STI visits in the short term, they experienced a larger decrease in ED visits over the long term than females. Finally, a gender-age adjustment revealed both males and females had a stronger policy-related response in the younger age groups. (Though in the short term only younger females saw a difference in ED visit frequency.)

Study results suggest future policies should focus on encouraging a higher degree of acceptance towards the LGBTQ community. Such policies would hopefully produce a healthier overall environment for sexual minority individuals, which in turn could reduce ED visits related to STIs and associated costs for the American healthcare system. This could also potentially reduce the risk of STIs in the larger general population.

CHAPTER 4

THE IMPACT OF FIREARM POLICY ON MASS SHOOTINGS

Introduction

Gun violence in the United States produces an enormous financial burden through lost wages, large medical bills, higher taxes for added law enforcement, and lower property values due to the threat of crime (Singletary, 2018). Research estimates that the total cost of gun violence in the US is about $229 billion annually, with $221 billion in indirect costs and $8.6 billion in direct medical expenses (Follman et al., 2015). However, per capita cost of gun violence differs significantly by state as a result of state-specific laws and firearms access. For example, Hawaii's per capita cost of gun violence is $234, approximately one-sixth of the cost in Wyoming (Howell et al. 2010).

Past research has focused primarily on how state-level variations in open carry and concealed carry laws impact firearm-related fatalities and injuries. As a result, there is limited research specifically examining mass shootings. This research gap is further complicated by the fact that policies regulating general firearm use do not necessarily impact mass shootings. For example, states that implement a stand-your-ground law governing use of firearms in a self-defense capacity should not witness any impact on mass shootings. By contrast, states that prohibit individuals convicted of a domestic violence misdemeanor from possessing any kind of firearm would likely experience an impact on both mass shootings and general firearm-related homicides. Given these policy complexities, more research focused directly on mass shootings is needed.

Adding urgency is the fact that, in general, mass shootings in the United States are becoming deadlier. In 2007, a shooter on the campus of Virginia Tech University killed 32 people over the course of several hours (Criss, 2017). In 2012, 20 children and 6 adults were murdered at Connecticut's Sandy Hook elementary school (Criss, 2017). In June 2016, a shooter murdered 49 people at Orlando's Pulse nightclub (Criss, 2017). Finally, in 2017, the deadliest mass shooting in US history occurred in Las Vegas. A shooter used rapid-firing military-style rifles to kill 58 people and wound at least 515 (Criss, 2017). A study by Cohen et al (2014) found that between 1982 and 2011 a mass shooting occurred roughly once every 200 days in the US. This frequency accelerated significantly between 2011 and 2014, with one mass shooting occurring every 64 days (Cohen et al., 2014). In 2015, the US averaged one mass shooting per day in 2015, an upward trend that has continued since then (Ingraham, 2015).

The type of weapons used in mass shootings also varies greatly. AR-15-style rifles have been used in some of the deadliest mass shootings. In other cases, shooters have attached bump stocks to semi-automatic rifles to simulate automatic fire, increasing the rounds fired and associated lethality (Wegmann, 2017). Yet the most commonly used weapon in mass shootings is a pistol (Statista, 2018).

This study examines the impact of gun policy on mass shooting-related fatalities and injuries. It includes all the gun policy variables related to mass shootings that were hypothesized to influence outcome (number of mass shootings, number of mass shootings related fatalities, and number of mass shootings related injuries). This study explored the state gun laws that (1) prohibit individuals convicted of domestic violence from possessing a firearm; (2) prohibit individuals with a documented history of mental illness recorded in National Instant Criminal Background Check System (NICS) from possessing a gun; (3) restrict children's access to guns; (4) require reporting of lost or stolen firearms; (5) mandate universal background checks; (6) ban assault weapons; (7) regulate gun shows or (8) impose a minimum age requirement to possess a handgun.

Data were derived from the Mass Shooting Tracker, a record of all mass shootings since the beginning of 2013. The study analysis began by determining the definition of a mass shooting. Consideration was given to three different definitions that have been widely used by researchers to track mass shootings:

1. "Four or more killed by a lone shooter in a public place, including shooter only if shooter is killed by police or bystanders)" – Mother Jones (Follman et al., 2018)
2. "Four or more shot and/or killed in a single event [incident], at the same general time and location, not including the shooter" – Gun Violence Archive (GVA)
3. "Four or more shot and/or killed in a single event [incident], at the same general time and location, including the shooter" – Mass Shooting Tracker (MST)

This study used the definition provided from the MST when collecting and analyzing data. It is worth noting that all mass shooting research conducted before 2013 would have obtained data from Mother Jones. This was the only organization gathering data on mass shootings prior to 2013, with data stretching back to 1982. The GVA and MST both started tracking mass shootings in 2013. Since then, the GVA has expanded into data collection for other gun crimes, while the MST remained focused on mass shootings.

According to Mother Jones, an event is considered a mass shooting if 4 or more victims are killed by a lone shooter in a public place. (This number includes shooter only if he or she is killed by police or bystanders.) By contrast, the MST defines a mass shooting as an event where 4 or more people are shot and/or killed at the same general time and location. (This total of 4 people can include the shooter.) Mother Jones thus defines mass shootings in narrower terms, looking solely at death totals. Based on this definition, there have been a total of 48 mass shootings from January 2013 to March 2019. Using the much broader MST definition—which includes people shot but not killed—there have been 2445 mass shootings during this same time period. Thus, depending on which definition is used for research purposes, mass shootings might be regarded as a full-blown public health crisis (per MST criteria) or merely a serious public health problem (per Mother Jones criteria).

Recently, studies have focused on differentiating between these two definitions of mass shootings. For research purposes, an event meeting the Mother Jones criteria is described as a mass killing, while an event meeting the MST criteria is described as a mass shooting. Eric Fleegler (2019) used similar criteria to differentiate between mass shootings and mass killings, suggesting the MST and Mother Jones definitions are describing events of a different public health magnitude.

Background

This study included a vector of gun policy variables, consisting of laws related to assault weapon bans, child access prevention, domestic violence, gun shows, mental health, minimum age for purchase, universal background checks, and reporting of lost or stolen firearms. A literature review was conducted to determine the existence of evidence linking these laws to the frequency and lethality of mass shootings. Each gun policy variable was searched in PubMed, ScienceDirect, and EconLit. In addition, some papers were identified via literature cited in papers identified through the search. Only articles that conducted quantitative analysis and presented estimates based on empirical findings were considered. This included articles that both favored and opposed stricter gun control policies. In addition, articles for each policy variable cited by the Giffords Law Center to Prevent Gun Violence were also considered. Regardless of the source, only articles focusing specifically on mass shootings were eligible for inclusion. The findings for each category of gun control policy are summarized below.

In addition to research on mass shootings, many studies have examined associations between specific policy variables and gun violence in general. According to Cook (2014), banning the manufacture of assault rifles is not a particularly effective violence reduction strategy because many such weapons manufactured before the ban takes effect continue to be bought and sold. Even a manufacturing ban lasting 10 years is not long enough to eliminate all these pre-existing assault weapons (p. 135).

A further complication surrounds reporting individuals with a documented history of mental illness to the NICS. As Cook (2014) points out, the majority of states that mandate such reporting do not have a reliable system in place for carrying this out. As a result, individuals with a history of mental illness are often still able to obtain firearms (p. 145). In a related study, Lott (2010) found that laws prohibiting people with a criminal history or documented mental illness from purchasing a gun are associated with an extremely small and statistically insignificant change in accidental deaths (p. 164). Again, this might be attributable to unreliable systems of reporting in many states.

By contrast, when a reliable NICS reporting system is in place, a positive public safety impact is seen. In 2007, Connecticut began compiling data on individuals disqualified due to mental illness and reporting this information to NICS. Prior to this time, when the state was not reporting to NICS, mental health disqualification measures had no statistically significant impact on violent crime rates. The 2007 policy change proved quite effective (Cook, 2014, pp. 159-160). After Connecticut began reporting to NICS, the rate of violent offending by individuals with a history of mental illness decreased by 31% (Webster and Wintemute, 2015, p. 25). This occurred at a 5% significance level. Proper state-mandated NICS reporting is a policy initiative that can clearly improve public safety and health for all citizens.

Lott has conducted extensive research on the impacts of gun show regulations. His early work, using state-level data from 1977-2000, found that such regulations reduced the number of gun shows by an estimated 24%. At the same time, however, murder and robbery rates actually rose (Lot, 2010, p. 330). According to Lott's review, there exists no empirical research linking gun show regulations to decreased crime rates; instead, the evidence points to the opposite conclusion (pp. 329-330). Other state-level gun control policies produced similar results. Safe-storage or child access prevention laws were associated with a statistically significant increase of almost 9% in rapes and robberies, and a 5.6% increase in burglaries (Lott, 2010, p. 199). Background checks and waiting periods had little if any impact in deterring crime (Lott, 2010, p. 166).

Webster and Wintemute (2015) conducted a review of past research on policies designed to keep firearms away from high-risk individuals. Initially, states only prohibited individuals with a history of domestic violence misdemeanors from purchasing guns, but many states now also prohibit persons subject to restraining orders for domestic violence. Analysis of past research indicates these expanded restrictions have reduced gun-related violence. Domestic Violence Restraining Order (DRVO) firearm prohibition was associated with an 8% reduction in intimate partner homicide rates (Webster and Wintemute, 2015, p. 23). The authors looked at another study that used city-level data to control for policies that could have impacted the intimate partner homicide rate. This study found DRVO prohibitions were associated with a 19% reduction in intimate partner homicides. By contrast, domestic violence misdemeanor restrictions or firearm confiscation laws had no impact on homicide rates (Webster and Wintemute, 2015, p. 24).

More recently, Morrall (2018) conducted a review of methodologically rigorous research on gun policy and its impact on several outcome variables related to fatal and non-fatal injuries. Evidence was ranked at five different levels: (i) *no evidence* when no studies that met inclusion criteria found any impact on outcome variables; (ii) *inconclusive evidence* when studies found an inconsistent impact or there was only one study and its findings were inconclusive; (iii) *limited evidence* when at least one study reported statistically significant impact on injuries; (iv) *moderate evidence* when two or more studies found significant effects in the same direction, and no contrary evidence existed in other studies with equivalent or better methodology; and (v) *supportive evidence* if at least three studies found impact in same direction using at least two independent datasets. Morrall's review concluded that there is supportive evidence that child access prevention laws or safe-storage laws reduce self-inflicted fatal or non-fatal firearm injuries among youth. Such laws also reduce other unintentional firearm injuries and fatalities among children. In addition, there exists limited evidence that these regulations reduce unintentional firearm injuries among adults. In terms of intentional self-harm reduction, there is moderate evidence that these laws reduce firearm suicides among youth, and limited evidence that they reduce total (firearm and non-firearm) suicides in this population.

Morrall (2018) also evaluated background checks, minimum age gun purchase policies, and laws prohibiting individuals with a history of mental illness from accessing firearms. He found moderate evidence that background checks reduce gun-related suicides and homicides, and limited evidence that background ground checks reduce overall suicide and violent crime rates. Meanwhile, there is moderate evidence that laws prohibiting individuals with certain mental illness diagnoses from buying or owning firearms reduce violent crime, and limited evidence that they reduce homicides. There is also limited evidence that these mental health laws reduce firearm suicides and total suicides. As for mandating a minimum age of 21 to buy a gun, there is limited evidence that such a policy reduces firearm-related suicides among youth.

Assault Weapon Ban

In 1994 the manufacture of assault weapons was banned in the US for 10 years after Congress passed the Public Safety and Recreational Firearms Use Protection Act. However, Congress failed to renew the ban when it expired in 2004 (Plumer, 2012).

Initially after the ban went into effect, the number of injuries and fatalities related to mass shootings actually increased. But starting in the late 1990s, these injuries and fatalities started to decline, reaching record lows in 2002. Although several researchers attributed this eventual decline to the assault weapon ban, Koper (2004) argued: "We cannot clearly credit the ban with any of the nation’s recent drop in gun violence. And, indeed, there has been no discernible reduction in the lethality and injuriousness of gun violence." One reason the ban might have had less impact than expected is because assault weapons are used in less than 3% of all mass shootings (Lopez, 2018).

Despite this fact, the number of mass shooting-related deaths have increased since the ban expired in 2004. And when assault rifles are used, the results are often especially horrific. An assault weapon was used in the 2017 Las Vegas mass shooting, the deadliest such incident in US history. Assault weapons were also used in the recent high-profile mass shootings in Orlando and San Bernardino. Not surprisingly, a review of mass shootings between 2009 and 2015 by ‘Everytown for Gun Safety’ found that when assault weapons or large ammunition-capacity weapons were used, 155% more people were shot and 47% more killed than when other types of guns were used.

DiMaggio et al. (2019) found that mass shootings were 70% less likely to occur during the 10-year federal assault weapon ban period. Examining data from 1981–2017, the researchers reached their conclusions using both linear and Poisson regression models. Both models revealed an approximately 70% reduction in mass shootings, confirming the robustness of this finding. Based on these estimates, the researchers determined that an assault weapon ban for the entire period of 1981-2017 would have prevented 314 of the 448 mass shooting-related deaths that occurred prior to 1994 or after 2004.

Gius (2013) found that "both state and federal assault weapon bans have statistically significant and negative effects on mass shooting fatalities." His study used the Poisson regression model to estimate the effects of state and federal assault weapon bans on mass shooting fatalities. Control variables included: percentage of population that is black; population density; percentage of population that has a 4-year college degree; per capita median income; annual unemployment rate; percentage of total population aged 18-24; percentage of population aged 25-34; and per capita prison population.

It is important to note that the author obtained data on mass shootings (dependent variable) from Mother Jones, a major source for this information (as noted earlier). Mother Jones utilizes the most restrictive definition of a mass shooting, whereas the Mass Shooting Tracker (MST) uses a much broader definition. As a result, it is possible that studies such as Gius (2013), which rely on Mother Jones data, underestimate the total number of actual mass shootings.

Gius (2013) hypothesized that states enacting bans on the possession of assault weapons would see a decrease in the number of fatalities or injuries related to mass shootings. This study included multiple controls related to population age groups, race, education, and income, but did not include controls for other gun policies enacted during the same time period. As a result, it is possible that during the study period laws other than assault weapon bans were implemented in various states, and not controlling for them could misleadingly conflate study findings. Gius (2013) identified 57 public mass shooting incidents in the US over a period of 29 years from 1982 to 2011, an average of 1.97 incidents per year. Put differently, there were an average of 0.04 mass shootings annually per-state over the study period.

From a broader public safety perspective, Lott (2010) examined the impact of assault weapon bans on crime rates in general. He used two different methods to estimate the impact of both state and federal bans. The first method measured the before-and-after average crime *rate*, while the second method measured the before-and-after crime rate *trends*. Examining trends revealed the statistically significant impact of a ban on the crimes of murder and robbery. Estimates indicate that each additional year the assault weapon ban remained in effect, both murder and robbery rates increased by approximately 3%. (It is essential to note that these analyses are descriptive in nature and do not imply causality.)

Gius (2017), meanwhile, found that assault weapon bans reduced the incidence of school shootings. The study implemented a Poisson, two-way fixed effects model to examine the period 1990 to 2014. Results suggest that these bans reduced school shootings over time by 54.4%. Gius included multiple state and federal gun policies in the study model in addition to a state assault weapon ban. Independent variables included: state assault weapon ban; state background checks; state concealed weapons laws; federal background checks; and control variables. The model adjusted for state- and year-fixed effects. Except for the assault weapon ban, none of the other policies had a statistically significant effect on school shootings.

Child Access Prevention

High schools and university campuses are among the most common locations for mass shootings. In many school shootings, children used firearms owned by a family member as a weapon. To combat this, Child Access Prevention (CAP) laws impose restrictions that encourage adults to be more cautious in storing their firearms out of reach of children. However, these CAP laws vary significantly from state to state. These various prevention measures can be divided into two broad categories:

1. States Preventing Persons from Intentionally, Knowingly, and/or Recklessly Providing Firearms to Minors
2. Laws Imposing Criminal Liability when a Child Gains Access as a Result of Negligent Storage of a Firearm

This second category can be further divided into four main type of negligent storage laws.

1. Negligent storage of unloaded firearms
2. Criminal liability when a child "may" or "is likely to" gain access to the firearm
3. Criminal liability for allowing a child to gain access, regardless of whether the child uses the firearm
4. Criminal liability only if the child uses or carries the firearm

Currently, there is no federal CAP law, and 23 states have no CAP law at all. In this study, the 27 states with CAP laws were designated as treatment states and those without CAP laws as control states. A key point is that some states use a combination of the CAP laws listed above. In addition, states have modified these laws in conjunction with their particular political environment. (It is beyond the scope of this study to account for each possible variant of the CAP law.) The major difference between the two main categories of CAP laws is that states preventing persons from providing firearms to a minor have a weaker standard for criminal liability when a child gains access to a gun. Of the 26 states in the contiguous US with CAP laws, 13 states fall into each of the two categories. Among negligent storage laws, the most common variant is imposing criminal liability only if a child uses or carries a firearm. Seven states follow this practice.

Grossman et al. (1999) estimated that more than 75% of the firearms used in youth suicide attempts and unintentional injuries were stored in the residence of the victim or someone related to them. Reviews by Webster et al. (2004) and Miller et al. (1999) found that the risk of suicide was higher in homes where guns were kept loaded and/or unlocked. In terms of policy, Cummings et al. (1997) concluded that CAP laws have been effective at reducing youth suicides and unintentional firearm deaths and injuries to children.

Vossekuil et al. (2004) reported that in 17 (68%) of the 37 school shootings from 1974 to 2000, the shooter obtained the gun from his/her home or that of a relative. The data also revealed that until 1992, there was at most one school shooting per year. From 1992 onwards, every year saw at least two shooting incidents, with 1999 having the highest number at six. The study used descriptive methods; hence, it does not imply any causality between improper gun storage and increased likelihood of school shootings. But it does suggest that implementing or tightening

CAP laws make it harder for potential attackers to gain access to weapons in their own home or that of a relative.

In contrast to these findings, a RAND (n.d) review of available literature concluded that the effects of the CAP laws on mass shootings were inconclusive and uncertain. The RAND review found only one study—Lott (2003)—that directly examined the impact of CAP laws on mass shootings. Lott (2003) used Poisson regression models to estimate the effect of laws requiring the safe storage of guns on the incidence of multiple-victim public shootings. His findings suggest that there are no effects of safe storage laws on the total number of multiple-victim public shooting incidents and their consequent casualties.

Domestic Violence

A history of committing domestic violence has been associated with the potential to become a mass shooter. Fulton (2017) reported that individuals with a history of domestic violence committed more than 50% of all mass shootings in the United States over a recent two-year period. The advocacy group "Everytown for Gun Safety" (n.d), estimated that perpetrators of domestic violence accounted for only about 10% of all firearm-related violence between 2009 and 2016, but accounted for 54% of the mass shootings. The correlation between domestic violence and the likelihood of being a mass shooter is thus quite robust.

Given this reality, restricting access to firearms for such individuals might plausibly reduce the number of mass shootings. However, there is no known research focusing specifically on how domestic violence laws affect mass shootings. The current study examines this association, designating states that prohibit individuals convicted of misdemeanor domestic violence from possessing firearms as treatment states.

Gun Shows

A major firearm control issue in recent years is the gun show “loophole” which allows individuals to purchase firearms from unlicensed sellers without undergoing any background check. The office of the Inspector General of the U.S. Department of Justice (2007) reported that the number of gun shows across the country ranged from 2000 to 5200 per year. Many mass shooters, such as the two students at Columbine High School, used firearms bought at gun shows.

The gun show loophole has been closed in California, Colorado, Illinois, New York, Oregon, and Rhode Island by state laws requiring a universal background check for all firearm sales (The Coalition to Stop Gun Violence, 2018). In other states, laws have imposed various restrictions on sales at gun shows without requiring a universal background check. In the current study, states with any type of gun show sales regulations were classified as treatment states.

Mental Health

A major area of recent public policy debate is whether to prohibit individuals diagnosed with mental health disorders from carrying firearms. Appelbaum (2013) has suggested that understanding the proper relationship between mental illness and the likelihood of being a mass shooter is crucial when formulating gun policies. While federal law prohibits the sale of firearms to individuals with a history of specified mental health conditions, it does not currently require states to report these individuals to the National Instant Criminal Background Check System (NICS). It is left to the discretion of each state whether to legally mandate such reporting. These policy variations can help determine how many mentally ill individuals possess firearms in any particular state.

One of the most significant shooting incidents involving a shooter with a history of mental illness was at Virginia Tech University in 2007. After that event, several states passed laws that make reporting to the NICS mandatory in cases of mental illness. Based on data from the Federal Bureau of Investigation (2014), between the Virginia Tech shooting on April 16, 2007 and January 31, 2014, the number of mental health cases in the NICS database increased by more than 700%.

Despite the general recognition that individuals with mental health issues are more likely to perpetuate mass shootings, research is lacking which assesses the effectiveness of NICS reporting laws in reducing the number of mass shootings. The current study aims to bridge that research gap. All states that require reporting of individuals with a history of mental illness to the NICS are designated as treatment states.

Minimum Age

Statistics from the FBI (2013) indicate that individuals who are 18-24 years old account for a higher percentage of homicide and violent crime arrests than any other age cohort. This data supports the theory that minimum age requirements for firearm purchases can potentially reduce the chances of mass shootings on high school and university campuses. Currently, federal law prohibits the sale and delivery of firearms by licensed dealers to individuals below 21 years of age for handguns and 18 years of age for long guns. However, the law only applies to the sale and delivery of firearms. It does not make any explicit reference to the possession of firearms by individuals under certain ages.

There appears to be no prior research that examines the relationship between minimum age restrictions and the number of mass shootings. In this study, states were designated as treatment states if they had established a minimum age requirement to possess handguns.

Universal Background Check

Most federal gun laws have significant loopholes. Perhaps the most important loophole pertains to federal background checks. These checks are intended to keep guns out the hands of potentially dangerous individuals. Yet federal law only requires licensed firearm dealers to perform background checks; unlicensed dealers and private sellers are exempt. A study by ‘Everytown for Gun Safety’ (2015) found that states with universal background checks had 63% fewer mass shootings committed by individuals who were prohibited from possessing guns.

Miller et al. (2017) estimated that 42% of US gun owners acquired their most recent firearm without a background check. The authors obtained the data from a nationally representative, web-based survey. It was conducted in April 2015 by the survey firm Growth for Knowledge. Respondents were drawn from the firm’s KnowledgePanel (KP). The KP consisted of 55,000 nationally representative adults in the United States. The initial gun survey was shared with a subset of 7,318 KP members, 3,997 of whom completed the survey. (Active-duty military personnel were excluded.) Of those who finished the survey, 2,072 owned a firearm. A second survey was sent to these gun-owning participants, 1,613 of whom completed it. Results indicated that 22% of these individuals who obtained their most recent firearm within the previous 2 years did so without a background check. This includes those who purchased the new gun from a private seller, which meant no background check was conducted.

Implementing state-level background checks on every gun purchase may effectively close the federal law loophole. This is an especially important policy consideration as individuals are now allowed to purchase firearms at popular gun shows without undergoing such a check. Only nine states currently require universal background checks. Only two new states have enacted this policy since the start of 2013.

Lost or Stolen Report

State laws that mandate reporting lost or stolen firearms are a potentially important tool for holding gun owners accountable for their weapons. Currently, some states have mandatory loss/theft reporting laws, while others impose civil liability for stolen firearms. Despite the fact that several news outlets have discussed such laws as a means to reduce the number of mass shootings, there appears to be no research examining whether this dynamic might be true. This study aims to address this research gap by comparing states with mandatory loss/theft reporting laws—designated as treatment states—with those lacking such policies.

Controls

To isolate the impact of these firearm regulations on mass shootings from the influence of other factors, the models used in this study also adjusted for macroeconomic factors potentially associated with mass shootings. Unemployment rate and per capita income are included as control variables. A higher unemployment rate increases the probability of job loss, which in turn increases the probability of mass shootings. In fact, Webster et al. (2017) argued that job loss is one of the strongest predictive risk factors for gun violence. They note that job loss can adversely affect an individual's mental health, and poor mental health status is associated with a higher likelihood of perpetuating a mass shooting. Assessing the association between the unemployment rate and mass shootings, Pah et al. (2017) determined that the frequency of shootings at K-12 and post-secondary schools significantly correlated with higher unemployment rates across different geographic aggregation levels (national, regional, and state). Gathering data from 1990-2013, their analysis revealed a significant increase in school-based gun violence from 2007 to 2013, a time of major economic uncertainty for many Americans. The researchers concluded that school shootings are significantly correlated with multiple indicators of economic distress.

Methods

Hypotheses

This study anticipated that changes in any gun policy variable included in the study (see Table 13) would impact the number of mass shootings, along with related fatalities and injuries.

Data

Data on gun laws that became effective between January 2013 and June 2017 were obtained from the Giffords Law Center to Prevent Gun Violence. The center collects and summarizes data on gun laws throughout the nation. They also provide state legislative bill numbers and, when available, enactment dates. Each gun law included in this research was verified to make sure it became active within the study period. These bills were also reviewed using the online LegiScan database. Bills that did not mention an implementation date were assigned the default date for newly signed bills. Default dates were obtained from the StateScape database.

Data on unemployment rates were obtained from the Bureau of Labor Statistics (BLS). Per capita income data were collected from the Bureau of Economic Analysis (BEA). Population data were obtained from the US Census Bureau. The number of active concealed carry permits was obtained from GunsToCarry, the Crime Prevention Research Center, and the United States Government Accountability Office. Finally, data on dependent variables (number of mass shootings and associated fatalities and injuries) were obtained from the Mass Shooting Tracker database. Any incident where four or more people were shot and/or killed—which could include the shooter—at the same general time and location was defined as a mass shooting. Table 10 provides links to all the sources.

Table 10: Data Sources

Variable	**Data Source**
Mass Shootings	Mass Shooting Tracker - massshootingtracker.org
Gun Laws	Giffords Law Center to Prevent Gun Violence – lawcenter.giffords.org LegiScan – legiscan.com StateScape – statescape.com
Number of Active Concealed Carry Permits (Alternative Exposure)	GunsToCarry – gunstocarry.com Crime Prevention Research Center (CPRC) – crimeresearch.org United States Government Accountability Office (GAO) – gao.gov
Unemployment Rate	Bureau of Labor Statistics (BLS) – bls.gov
Per Capita Income	Bureau of Economic Analysis (BEA) – bea.gov
Population (Exposure)	US Census Bureau – census.gov

Table 11: Direct Links

Variable	**URLs**
Mass Shootings	https://www.massshootingtracker.org/data (Mass Shooting Tracker)
Gun Laws	https://lawcenter.giffords.org/gun-laws/policy-areas/background-checks/universal-background-checks/ (Giffords Law Center to Prevent Gun Violence) https://lawcenter.giffords.org/gun-laws/policy-areas/background-checks/mental-health-reporting/ (Giffords Law Center to Prevent Gun Violence) https://lawcenter.giffords.org/gun-laws/policy-areas/who-can-have-a-gun/domestic-violence-firearms/ (Giffords Law Center to Prevent Gun Violence) https://lawcenter.giffords.org/gun-laws/policy-areas/who-can-have-a-gun/minimum-age/ (Giffords Law Center to Prevent Gun Violence) https://lawcenter.giffords.org/gun-laws/policy-areas/gun-sales/gun-shows/ (Giffords Law Center to Prevent Gun Violence)

Table 11 Continued

Variable	**URLs**
Gun Laws	https://lawcenter.giffords.org/gun-laws/policy-areas/gun-owner-responsibilities/reporting-lost-stolen-firearms/ (Giffords Law Center to Prevent Gun Violence) https://lawcenter.giffords.org/gun-laws/policy-areas/child-consumer-safety/child-access-prevention/ (Giffords Law Center to Prevent Gun Violence) https://lawcenter.giffords.org/gun-laws/policy-areas/hardware-ammunition/assault-weapons/ (Giffords Law Center to Prevent Gun Violence) https://legiscan.com/ (LegiScan) http://www.statescape.com/resources/legislative/bill-effective-dates.aspx (StateScape: Legislative and Regulatory Tracking)

Table 11 Continued

Variable	**URLs**
Number of Active Concealed Carry Permits (Alternative Exposure)	https://www.gunstocarry.com/concealed-carry-statistics/ (GunsToCarry) https://www.gao.gov/assets/600/592552.pdf (United State Government Accountability Office, 2012)
Unemployment Rate	https://data.bls.gov/cgi-bin/dsrv?la (Bureau of Labor Statistics, United States Department of Labor)
Per Capita Income	https://apps.bea.gov/iTable/iTable.cfm?acrdn=7&isuri=1&reqid=70&step=1#acrdn=7&isuri=1&reqid=70&step=1 (Bureau of Economic Analysis, U.S. Department of Commerce)
Population (Exposure)	https://www.census.gov/content/census/en/data/tables/2017/demo/popest/state-detail.html (United State Census Bureau, 2017)

Table 12: States that Enacted Relevant Gun Laws (Jan'13 - Jun'17)

State	Law	Year	Month
Connecticut	Assault Weapon Ban	2013	7
Maryland	Assault Weapon Ban	2013	10
North Carolina	Child Access Prevention	2013	10
Louisiana	Domestic Violence	2014	8
Massachusetts	Domestic Violence	2014	11
Minnesota	Domestic Violence	2014	8
Oregon	Domestic Violence	2016	1
South Carolina	Domestic Violence	2015	6
Washington	Domestic Violence	2014	6
Rhode Island	Domestic Violence	2017	1
Vermont	Domestic Violence	2015	7
Virginia	Gun Shows	2016	7
Delaware	Lost or Stolen report	2013	6
Illinois	Lost or Stolen report	2014	6

Table 12 Continued

State	Law	Year	Month
Maryland	Lost or Stolen report	2013	10
Arizona	Mental Health	2014	8
Nevada	Mental Health	2015	6
Oklahoma	Mental Health	2015	7
South Carolina	Mental Health	2013	6
New York	Minimum Age	2013	2
Nevada	Universal Background Check	2017	1
Washington	Universal Background Check	2014	12

Data from the Mass Shooting Tracker database were aggregated to state-year-month level from January 2013 to June 2017. The study included all states in the contiguous US. Table 12 displays all gun laws that changed within the study period.

Table 13: Defining Each Gun Law

Gun Laws Variables	Value = 1 if
Domestic Violence	Laws prohibit individuals convicted of misdemeanor domestic violence from possessing or buying any kind of firearms
Lost or stolen Report	States that require mandatory reporting for lost or stolen firearms
Mental Health	States that require reporting to the National Instant Criminal Background Check System (NICS) database of individuals with mental health issues
Universal Background Check	States with universal background check
Child Access Prevention (CAP)	Laws with any degree of CAP laws; these vary from criminal liability for negligent storage to actual use
Assault Weapon Ban	States that have the law in place
Gun Shows	Laws with any kind of regulations attempting to close the gun show loophole
Minimum Age	States that establish minimum age to possess handguns

Model Design

$$Y_{imt} = f(L_{imt}, U_{imt}, C_{imt}, S_i, M_m, T_t)$$

Where Y_{imt} represents the total number of mass shootings, or mass shooting related deaths and injuries in state 'i' at month 'm' and time 't'; L_{imt} represents a vector of gun policy variables (universal background check, child access prevention laws, domestic violence law, mental health, lost/stolen reporting, gun shows, and assault weapon ban) ; C_{imt} refers to controls variables (unemployment rate and income per capita); S_i controls for state-fixed effects (hence it only changes with state 'i'); M_m is a vector of month dummy variables, controlling for month effect; and T_t controls for year effects.

$$Y_{imt} = \alpha + \beta_l . L_{imt} + \delta_c . C_{imt} + \varphi . S_i + \sigma . M_m + \mu . T_t + \varepsilon_{imt}$$

Where β_l and δ_c represent estimates for their respective independent variables based on the subscripts. Models were estimated in terms of Incidence Rate Ratio (IRR).

Models

1. Each gun policy variable separately as an independent variable
2. All gun policy variables combined in a single regression
3. All variables (gun policy variables and controls)

The study utilized a quasi-experimental difference-in-difference design with negative binomial specification and state-fixed effects. The following results are based on population as the exposure variable. The appendix includes results using an alternative exposure variable (number of active concealed carry permits). Ideally, in a count data model like this, an exposure variable would accurately capture the number of people in a given state with access to a firearm. Unfortunately, precise state-level data is not available for researchers and policymakers.

Given this reality, a close proxy variable is the number of people with active concealed carry permits. Such data use, however, presents two measurement limitations. First, no state has concealed carry data for all the years in the study period. In cases of missing data for particular years, data from the most recent years available prior to the study period was used instead. A second limitation is the study data does not accurately represent the number of people with access to firearms. Instead, it only reveals how many individuals have active concealed carry permits. This is problematic given that previous research indicates most crimes are committed with illegally obtained firearms (Braga et al, 2012). Estimates reveal that only about one in six firearms used to commit a crime was obtained legally (Reiss et al, 1993).

There is no research consensus regarding the exposure variable in gun policy research. This study therefore used the inclusive variable of population. This had several research benefits. Statewide population totals were available for the entire study period. These numbers include all individuals within a particular state who have access to firearms. This means even people who illegally obtained a gun are fully captured by this variable. (Note that results from using active permits as the exposure variable are also presented in the appendix section.)

Results

Table 14: Basic Descriptive Statistics for State Panel Data: 48 US States, January 2013 – June 2017

Variable	Obs[1]	Mean[2]	Std. Dev.	Min	Max
Killed	2592	0.84	2.10	0.00	53.00
Injured	2592	2.39	4.77	0.00	60.00
Number of Mass Shootings	2592	0.66	1.14	0.00	9.00
Unemployment	2592	5.41	1.55	2.00	10.80
Population (in 100k)	2592	66.17	71.86	5.83	398.50
Income Per Capita (in $10k)	2592	8.69	4.19	3.55	20.50
Children	2592	0.54	0.50	0.00	1.00
Domestic	2592	0.46	0.50	0.00	1.00
Mental	2592	0.78	0.41	0.00	1.00
Background	2592	0.16	0.37	0.00	1.00
Stolen	2592	0.22	0.41	0.00	1.00
Minimum Age	2592	0.15	0.35	0.00	1.00
Gun shows	2592	0.23	0.42	0.00	1.00
Assault	2592	0.12	0.32	0.00	1.00

[1] 54 months of data for 48 contiguous US states: 54x48 = 2,592.

[2] The mean values for policy variables are interpreted as the proportion of the 2592 state–month–year observations in which the specified law was in effect.

The study period included data from January 2013 to June 2017, resulting in 54 months of available state data. Because all 48 states in the contiguous US were studied, this resulted in a total of 2,592 observations. (54 months times 48 states.) Initial descriptive statistics show that prohibiting individuals with a documented history of mental illness from purchasing a firearm is the most widely used gun control policy in the contiguous United States; almost 78% of the data has value 1 for mental health policy. By contrast, a ban on purchasing assault weapons was the least implemented gun policy during this study period, only 12% of the data has value 1.

Table 24 shows how the average number of mass shooting deaths varied between the states that did and did not have laws restricting gun ownership. Except for minimum age, all the policy variables saw an increase in deaths after law implementation. Based on the descriptive statistics, one might conclude that deaths related to mass shootings increased after restrictive gun policies were implemented, but these analyses did not control for time trend or fixed effects. It is possible that mass shooting fatalities were already increasing before any particular policy was enacted. As a result, it is impossible to conclude that these laws impacted the number of deaths caused by mass shootings.

Table 25, documenting the number of people injured in mass shootings, indicates a similar trend. States with legal gun restrictions in place recorded more injuries related to mass shootings than states without such laws. Table 26 also shows an increase in the total number of mass shootings after gun control laws were implemented. All these statistics indicate that restrictive gun policies did not curtail either the number of mass shootings or the related fatalities and injuries. However, difference-in-difference analyses were conducted to determine the actual effect of policy changes while controlling for other possible factors. This was necessary because descriptive analysis did not account for other factors that might have impacted the rate of mass shootings and their destructive consequences.

Table 27 shows the impact of state-level gun control laws passed during the study period. Domestic violence laws, implemented in 8 states, displayed the most variation. In almost all cases, after a state enacted such a law, the number of mass shootings increased, as did the related deaths and injuries.

In some cases, states lacked enough pre-implementation data to accurately determine the impact of gun control policies. For example, New York was the only state that implemented a minimum age requirement to possess a firearm during the study time period. All the other states had either already enacted such a measure or never did so. Since New York imposed the minimum age requirement in February 2013, there was only one month within the study period prior to this policy change (Table 28). In that month (January 2013) there were no mass shootings in New York state, while there was an average of more than one mass shooting per month during the study period after the law's implementation. Since this fact would lead to misleading estimates, the minimum age law was dropped from the analyses.

All the difference-in-difference analyses were conducted using three different models, as previously defined in the methodology section.

Table 15 to Table 17 present results from regressions that examine each policy variable separately. This means each table reports estimates from 7 regressions, for a total of 21 regressions in the 3 tables.

Table 15: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Each Gun Policy (Single Independent Variable)[1] on the Mass Shooting related Deaths: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.54	0.38 – 0.76	0.001
Children	1.10	0.85 – 1.44	0.46
Domestic	1.00	0.78 – 1.27	0.98
Mental	0.92	0.66 – 1.29	0.64
Stolen	1.26	0.93 – 1.69	0.13
Gun Shows	0.97	0.73 – 1.28	0.81
Assault Rifle Ban	1.12	0.76 – 1.65	0.56

IRR: Incidence Rate Ratio

[1]Each row represents a separate model with only one policy variable in a negative binomial regression with year, month, and state fixed effects.

The first model, shown in Table 15, regressed the number of deaths in mass shootings in state-year-month on each gun policy variable separately. At the 5% significance level, only the policy of universal background checks for gun purchases impacted the number of people killed in mass shootings. Enactment of universal background checks was associated with a 46% decrease in number of deaths related to mass shootings.

Table 16: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Each Gun Policy (Single Independent Variable)[1] on the Mass Shooting related Injuries: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.70	0.54 – 0.92	0.01
Children	0.98	0.80 – 1.22	0.89
Domestic	1.06	0.87 – 1.28	0.58
Mental	0.93	0.72 – 1.21	0.60
Stolen	1.11	0.89 – 1.37	0.36
Gun Shows	1.10	0.88 – 1.36	0.41
Assault Rifle Ban	0.93	0.71 – 1.21	0.58

IRR: Incidence Rate Ratio

[1] Each row represents a separate model with only one policy variable in a negative binomial regression with year, month, and state fixed effects.

Table 16 shows estimates for the association between the number of injuries in mass shootings and the state gun laws. As previously seen with shooting-related deaths, only a policy of universal background checks had an impact on injuries at the 5% significance level.

Enactment of universal background checks was associated with a 30% decrease in the number of injuries related to mass shootings.

Table 17: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Each Gun Policy (Single Independent Variable)[1] on the Number of Mass Shootings: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.83	0.39 – 1.77	0.63
Children	0.53	0.28 – 0.99	0.05
Domestic	1.39	0.97 – 1.98	0.07
Mental	0.55	0.34 – 0.88	0.01
Stolen	1.18	0.81 – 1.72	0.39
Gun Shows	0.73	0.36 – 1.49	0.39
Assault Rifle Ban	1.88	0.67 – 5.31	0.23

IRR: Incidence Rate Ratio

[1] Each row represents a separate model with only one policy variable in a negative binomial regression with year, month, and state fixed effects.

Table 17 shows estimates for the association between the number of mass shootings and state-level gun laws. States that required reporting of individuals with a history of mental illness to NICS had 45% fewer mass shootings compared to states that did not mandate NICS reporting. No other variable impacted the number of mass shootings.

Table 18 to Table 20 report estimates from regression models that included all the gun laws in a single model. Each table presents estimates from a single model, for a total of 3 regressions in 3 tables.

Table 18: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Deaths: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.33	0.20 – 0.55	<0.001
Children	1.06	0.80 – 1.39	0.70
Domestic	1.14	0.87 – 1.51	0.34
Mental	0.99	0.68 – 1.45	0.97
Stolen	1.32	0.86 – 2.01	0.20
Gun shows	1.10	0.78 – 1.56	0.60
Assault rifle ban	1.48	0.79 – 2.78	0.22

IRR: Incidence Rate Ratio

[1]Results are from a negative binomial regression including all the policy variables with year, month, and state fixed effects

As with previous estimates, Table 18 indicates that only a policy of universal background checks had a statistically significant association with the number of casualties in mass shootings. States with universal background checks had 67% fewer deaths related to mass shooting incidents.

Table 19: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Injuries: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.53	0.38 – 0.75	<0.001
Children	0.98	0.79 – 1.23	0.88
Domestic	1.15	0.92 – 1.43	0.21
Mental	1.01	0.74 – 1.39	0.93
Stolen	1.37	1.00 – 1.87	0.05
Gun shows	1.30	1.00 – 1.69	0.05
Assault rifle ban	0.81	0.54 – 1.23	0.32

IRR: Incidence Rate Ratio

[1] Results are from a negative binomial regression including all the policy variables with year, month, and state fixed effects

Table 19 displays estimates for the association between the number of injuries in mass shootings and firearm policy variables. Enactment of universal background checks was associated with a 47% decrease in number of injuries in mass shootings.

Table 20: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (single multivariate model)[1] on the Number of Mass Shootings: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.75	0.34 – 1.69	0.49
Children	0.53	0.28 – 1.00	0.05
Domestic	1.42	0.99 – 2.04	0.06
Mental	0.55	0.34 – 0.88	0.01
Stolen	1.10	0.74 – 1.63	0.65
Gun shows	0.74	0.36 – 1.52	0.42
Assault rifle ban	1.72	0.59 – 5.03	0.33

IRR: Incidence Rate Ratio

[1] Results are from a negative binomial regression including all the policy variables with year, month, and state fixed effects

Table 20 presents estimates for the association between gun policy variables and the frequency of mass shootings. None of the variables had a p-value of less than 0.05 except mental health variable.

Table 21 to Table 23 include macroeconomic controls not included among the policy variables in the three previous tables. Unemployment rate and per capita income are included as control variables. The following three tables represent estimates for final models.

Table 21: Negative Binomial Regression (with State Fixed Effects and Control Variables) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Deaths: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.34	0.21 – 0.56	<0.001
Children	1.07	0.81 – 1.41	0.62
Domestic	1.13	0.85 – 1.49	0.40
Mental	0.99	0.68 – 1.44	0.94
Stolen	1.32	0.86 – 2.02	0.20
Gun shows	1.09	0.77 – 1.54	0.62
Assault rifle ban	1.45	0.77 – 2.75	0.25
Unemployment	1.13	1.01 – 1.26	0.03
Income Per Capita	0.99	0.90 – 1.10	0.80

IRR: Incidence Rate Ratio

[1]Results are from a negative binomial regression including all the policy variables and control variables with year, month, and state fixed effects

Estimates from Table 21 show that the unemployment rate and universal background checks had statistically significant impacts on the number of casualties in mass shooting events. States that enacted universal background checks had a 76% decrease in deaths related to mass shootings. Unemployment rate was included as a control, but estimates show that a 1% increase in the unemployment rate was associated with a 13% increase in mass shooting deaths.

Table 22: Negative Binomial Regression (with State Fixed Effects and Control Variables) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Injuries: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.54	0.38 – 0.77	0.001
Children	1.07	0.85 – 1.33	0.58
Domestic	1.15	0.92 – 1.43	0.22
Mental	1.03	0.75 – 1.42	0.84
Stolen	1.41	1.03 – 1.92	0.03
Gun shows	1.24	0.95 – 1.61	0.11
Assault rifle ban	0.85	0.55 – 1.30	0.45
Unemployment	1.25	1.14 – 1.37	<0.001
Income Per Capita	0.95	0.88 – 1.03	0.25

IRR: Incidence Rate Ratio

[1] Results are from a negative binomial regression including all the policy variables and control variables with year, month, and state fixed effects

Table 22 presents results for the association between all study variables and the number of injuries in mass shootings. Universal background checks were associated with a 46% decrease in injuries. Laws requiring reporting of lost or stolen firearms were associated with a 41% increase in injuries related to mass shooting incidents. Among the macroeconomic variables, a

1% increase in the unemployment rate was associated with a 25% increase in mass shooting injuries. None of the other variables had a significant impact.

Table 23: Negative Binomial Regression (with State Fixed Effects and Control Variables) Results for the Effects of Gun Policy (single multivariate model)[1] on the Number of Mass Shootings: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.76	0.33 – 1.71	0.50
Children	0.55	0.29 – 1.03	0.06
Domestic	1.37	0.95 – 1.98	0.09
Mental	0.54	0.33 – 0.87	0.01
Stolen	1.16	0.77 – 1.74	0.48
Gun shows	0.72	0.35 – 1.47	0.37
Assault rifle ban	1.64	0.56 – 4.81	0.37
Unemployment	1.06	0.96 – 1.17	0.22
Income Per Capita	0.99	0.90 – 1.08	0.77

IRR: Incidence Rate Ratio

[1] Results are from a negative binomial regression including all the policy variables and control variables with year, month, and state fixed effects

Table 23 provides estimates for the association between the frequency of mass shootings and the gun policy variables and macroeconomic controls. In the final model, only one variable had a statistically significant association. States that required reporting of individuals with a history of mental illnesses to NICS had 46% fewer mass shootings than states that did not require reporting.

Discussion

The study variables of universal background checks, mandatory reporting to NICS, mandatory reporting of lost or stolen firearms, and unemployment rate all had a significant impact. Universal background checks were associated with decreased deaths and injuries related to mass shooting incidents (but had no impact on the number of mass shooting events). States that required the reporting of individuals with mental illnesses to the NICS database also experienced a decrease in mass shooting incidents. A lower unemployment rate was associated with a decrease in mass shooting-related injuries and fatalities (but did not impact the number of mass shootings.) Mandatory reporting of lost or stolen firearms decreased the number of shooting injuries, but had no impact on either the number of people killed in mass shootings or the number of mass shootings themselves.

Most other estimates did not have a significant impact on the number of mass shootings, fatalities, and injuries. These policies included: laws prohibiting individuals with a history of domestic violence from purchasing firearms; gun show loophole; child access prevention laws related to the safe storage of guns; and assault weapons bans. This finding of a lack of significance echoes previous research suggesting that policy arguments about background checks for legal gun purchases are largely misguided as most criminals—including those who perpetuate mass shootings—do not obtain their firearms through legal means (Cook, 2018). To reduce mass shootings, more policies should probably focus on the illegal supply side of firearms rather than regulating legal access to guns.

The current study has some limitations. First, its design did not account for the improper implementation of state gun policies. This is important because in many cases these laws were not implemented as strictly by the state as legislators originally intended. For example, in the case of the Texas church shooting in November 2017, the perpetrator had a history of domestic abuse yet was not in the state database of offenders. Second, the study included only 3.5 years of data, and data before 2013 were unavailable. As a result, analysis could have been affected due to a smaller sample size. Third, unemployment rate was used as an imprecise proxy for the variable of job loss. Future research needs to find a more accurate proxy. Finally, past gun policy research is inconsistent in its choice of an exposure variable. For the current study, state population per month-year was used as an exposure variable. Since it is not clear how well this predicts the occurrence of the dependent variable (number of mass shootings, number of mass shootings related fatalities, and number of mass shooting related injuries) due to a lack of comparable analyses, it could result in imprecise estimates with wide confidence intervals.

Conclusions

This study points out the need for more research focused specifically on mass shootings. Most policy variables in this study lacked any association with mass shooting-related deaths and injuries. It is essential that future research explores why past gun policies have not had the intended impact, and whether policymakers need to focus more on restricting the supply of illegal firearms rather than erecting barriers to legal purchases.

Appendix

Changes and Corrections to Gun Data

A previous version of this study employed Poisson distribution with fixed effects to examine gun data. The exposure variable was the number of concealed carry permits per state-year. However, there were two significant problems with the model design and use of that exposure variable. First, a Poison distribution is the preferred approach if the data mean and variance are the same for dependent variables, but that was not the case in this study. Thus, results from the previous model were not reliable. In the data, all the dependent variables had mean values significantly different from the variance values. The mean value for the variable number of deaths in mass shootings was 0.84, meaning on average 0.84 deaths occurred per state-year-month, while variance for the same variable was 4.41. Similarly, on average 2.39 people were injured in mass shootings, while variance for the same variable was 22.75. Finally, there were 0.66 mass shootings on average per state-year-month, while variance was 1.30. Given these large discrepancies for the dependent variables, a Poison distribution was not appropriate for this study. Instead, a negative binomial model with state fixed effects was used.

A second problem was that study previously used number of concealed carry permits as the exposure variable in the model. The exposure variable in this research is intended to help define which individuals are most likely to be involved in mass shooting incidents. However, there is no scholarly consensus about the best exposure variable in gun policy research. In the current study, there was not complete data for the number of concealed carry permits issued during the research timeframe. For example, some states had only 1 year of data available. Such incomplete data can produce misleading findings. More importantly, using concealed carry permit data restricts the study population. It assumes that the number of people holding permits accurately reflects the distribution of the dependent variables (i.e., number of deaths in mass shootings, number of injuries in mass shootings, and number of mass shooting incidents). The study instead now uses population as the exposure variable. It is a less restrictive variable which allows the model to include the whole population to define the dependent variable. In addition, accurate population data is available for all states and years included in the study. As a result, the previous problem of missing data is eliminated.

(Note: These are the only two changes made to the model to accommodate the issues resulting from missing data and Poison distribution.)

Constructing Mass Shootings Data

Data from the Mass Shooting Tracker was utilized for the duration January 2013 – June 2017. Following is the link for downloading the data and replicating the results: -

https://www.massshootingtracker.org/data

Above link takes to page for all the data available from MST, and from there years 2013 – 2017 can be selected from the drop-down menu to download the raw data.

Following screenshots show the steps: -

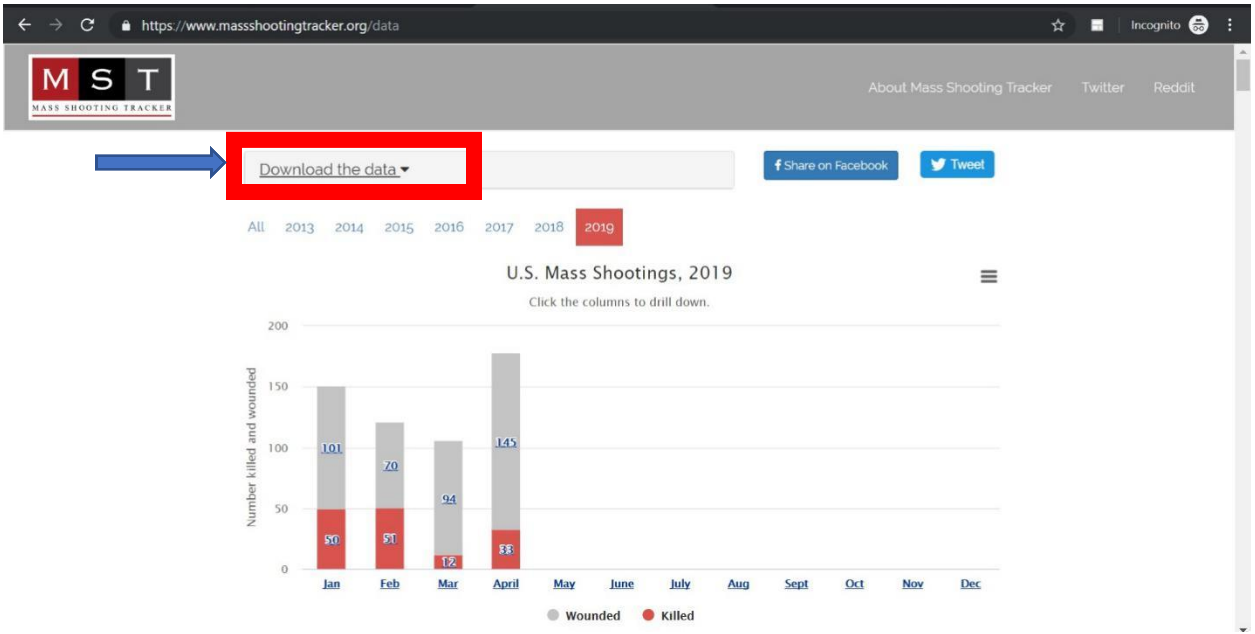


Figure 3: Downloading and Constructing Data from Mass Shooting Tracker: Step 1

After clicking on the "Download the data" we will see a drop-down list of years.

Following screenshot shows the years, and each year file can be downloaded separately.

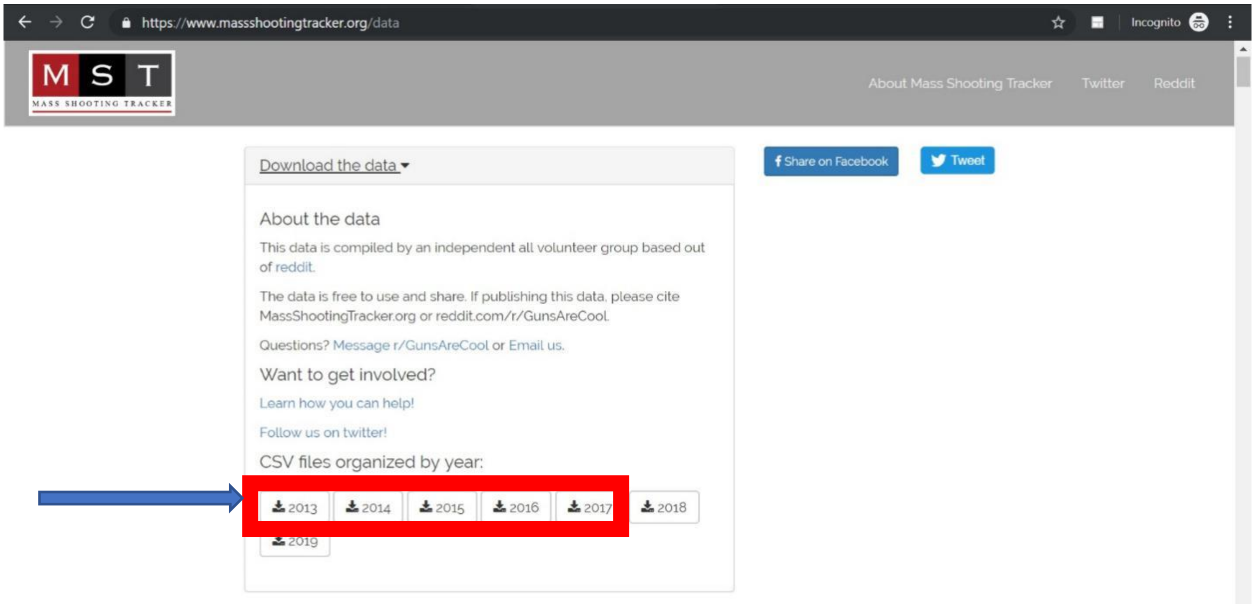
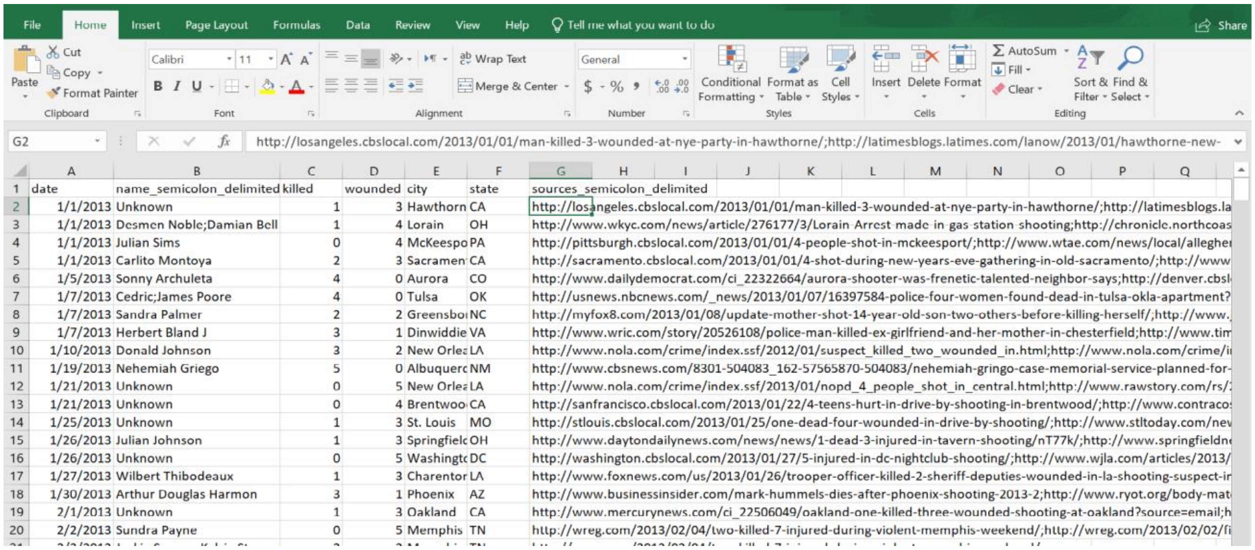


Figure 4: Downloading and Constructing Data from Mass Shooting Tracker: Step 2

Once the files are downloaded, raw data from each file is usually in the following form: -



	date	name_semicolon_delimited	killed	wounded	city	state	sources_semicolon_delimited
2	1/1/2013	Unknown	1	3	Hawthorn	CA	http://losangeles.cbslocal.com/2013/01/01/man-killed-3-wounded-at-nye-party-in-hawthorne/;http://latimesblogs.la
3	1/1/2013	Desmen Noble;Damian Bell	1	4	Lorain	OH	http://www.wkyc.com/news/article/276177/3/Lorain-Arrest-made-in-gas-station-shooting;http://chronicle.northcoas
4	1/1/2013	Julian Sims	0	4	McKeespo	PA	http://pittsburgh.cbslocal.com/2013/01/01/4-people-shot-in-mckeesport/;http://www.wtae.com/news/local/allegher
5	1/1/2013	Carlito Montoya	2	3	Sacramen	CA	http://sacramento.cbslocal.com/2013/01/01/4-shot-during-new-years-eve-gathering-in-old-sacramento/;http://www
6	1/5/2013	Sonny Archuleta	4	0	Aurora	CO	http://www.dailydemocrat.com/ci_22322664/aurora-shooter-was-frenetic-talented-neighbor-says;http://denver.cbsl
7	1/7/2013	Cedric;James Poore	4	0	Tulsa	OK	http://usnews.nbcnews.com/_news/2013/01/07/16397584-police-four-women-found-dead-in-tulsa-okla-apartment?
8	1/7/2013	Sandra Palmer	2	2	Greensbo	NC	http://myfox8.com/2013/01/08/update-mother-shot-14-year-old-son-two-others-before-killing-herself/;http://www.
9	1/7/2013	Herbert Bland J	3	1	Dinwiddie	VA	http://www.wric.com/story/20526108/police-man-killed-ex-girlfriend-and-her-mother-in-chesterfield;http://www.tim
10	1/10/2013	Donald Johnson	3	2	New Orlea	LA	http://www.nola.com/crime/index.ssf/2012/01/suspect_killed_two_wounded_in.html;http://www.nola.com/crime/i
11	1/19/2013	Nehemiah Griego	5	0	Albuquerc	NM	http://www.cbsnews.com/8301-504083_162-57565870-504083/nehemiah-gringo-case-memorial-service-planned-for-
12	1/21/2013	Unknown	0	5	New Orlea	LA	http://www.nola.com/crime/index.ssf/2013/01/nopd_4_people_shot_in_central.html;http://www.rawstory.com/rs/
13	1/21/2013	Unknown	0	4	Brentwoo	CA	http://sanfrancisco.cbslocal.com/2013/01/22/4-teens-hurt-in-drive-by-shooting-in-brentwood/;http://www.contraco
14	1/25/2013	Unknown	1	3	St. Louis	MO	http://stlouis.cbslocal.com/2013/01/25/one-dead-four-wounded-in-drive-by-shooting/;http://www.stltoday.com/nev
15	1/26/2013	Julian Johnson	1	3	Springfielc	OH	http://www.daytondailynews.com/news/news/1-dead-3-injured-in-tavern-shooting/nT77k/;http://www.springfieldn
16	1/26/2013	Unknown	0	5	Washingtc	DC	http://washington.cbslocal.com/2013/01/27/5-injured-in-dc-nightclub-shooting/;http://www.wjla.com/articles/2013/
17	1/27/2013	Wilbert Thibodeaux	1	3	Charentor	LA	http://www.foxnews.com/us/2013/01/26/trooper-officer-killed-2-sheriff-deputies-wounded-in-la-shooting-suspect-ir
18	1/30/2013	Arthur Douglas Harmon	3	1	Phoenix	AZ	http://www.businessinsider.com/mark-hummels-dies-after-phoenix-shooting-2013-2;http://www.ryot.org/body-mat
19	2/1/2013	Unknown	1	3	Oakland	CA	http://www.mercurynews.com/ci_22506049/oakland-one-killed-three-wounded-shooting-at-oakland?source=email;h
20	2/2/2013	Sundra Payne	0	5	Memphis	TN	http://wreg.com/2013/02/04/two-killed-7-injured-during-violent-memphis-weekend/;http://wreg.com/2013/02/02/f

Figure 5: Downloading and Constructing Data from Mass Shooting Tracker: Step 3

Each file provides information on 7 variables, displayed in the first row in the above Excel screenshot. These variables include: date, name, killed, wounded (injured), city, state, and sources.

Date provides the date of a mass shooting incident; *name* provides the name of the shooter; *killed* refers to the number of deaths related to the incident; *wounded* (injured) refers to the number of people injured in the incident; *city* and *state* provide the location of the incident; and *source* provides the link to news report of the incident.

Using the date variable, two new variables ("year" and "month") were created in each file to indicate the year and month of the mass shooting. Each file from 2013 – 2017 was then appended into a single file. Only data from January 2013 – June 2017 was included. Then the data was sorted by the state-year-month. Finally, the data were aggregated to state-year-month level. This data in its final form provided state-year-month observations for January 2013 – June 2017. This dataset was merged with the data on gun policy for the same period, which produced the final form of the data used to conduct the analysis.

Data on state-level gun policies were gathered from LegiScan by searching the bill numbers for each firearm-related law implemented during the study period. If the implementation date was mentioned in a particular bill, this date was used in the data. Otherwise, effective dates were obtained from StateScape, which provides a list of default effective dates for each state if this information is not specified in a particular bill.

LegiScan: https://legiscan.com

StateScape: http://statescape.com/resources/legislative/bill-effective-dates.aspx

Following is the screenshot from StateScape: -

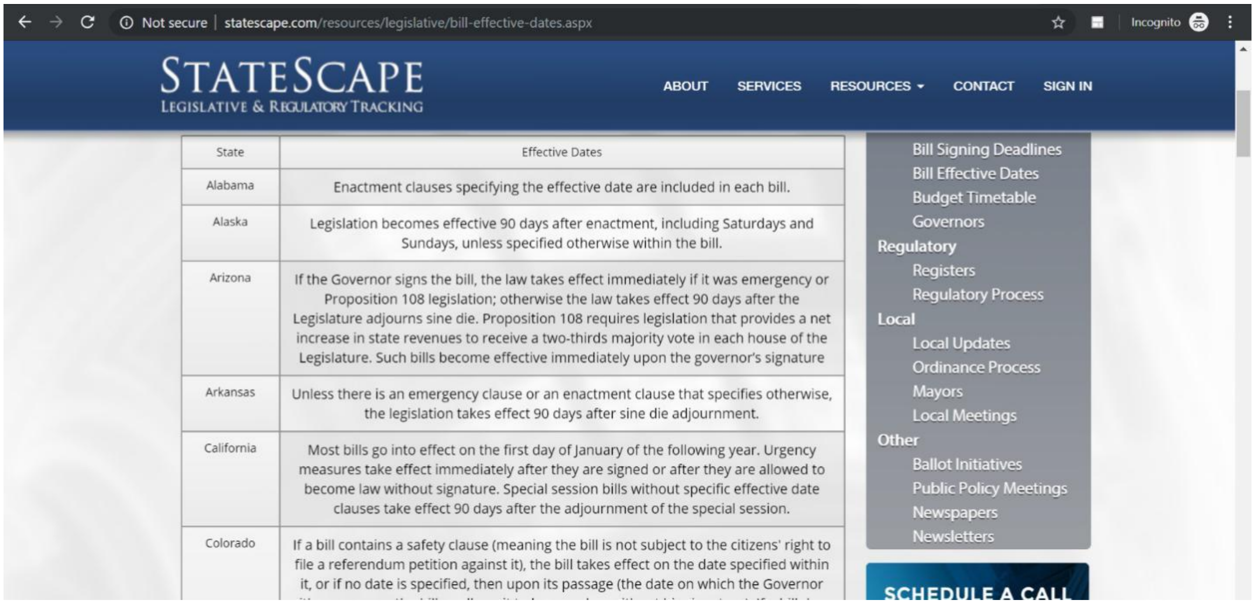


Figure 6: Data Source: StateScape

And, following is the screenshot from LegiScan (showing an example of Louisiana House Bill for prohibiting domestic violence convicts from having access to firearms): -

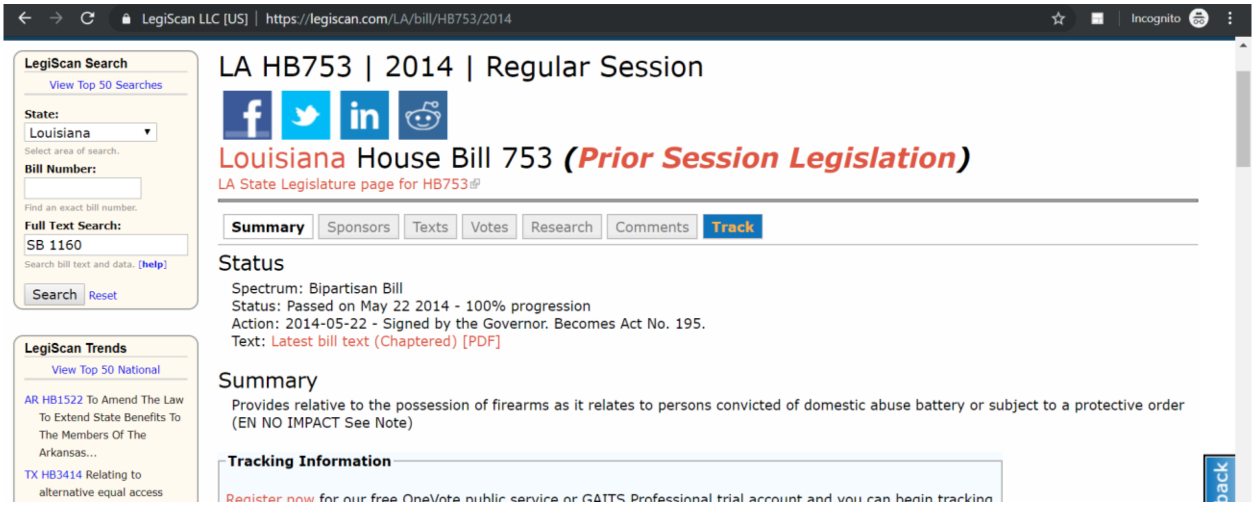


Figure 7: Data Source: LegiScan

Each bill was first checked on LegiScan, and dates from StateScape were only included as effective dates if they were not available in the bill.

Final data included data on mass shooting numbers, gun policy variables, exposure variable (population) and control variables (per capita income and unemployment rate).

Table 24: Average Number of Deaths in Mass Shootings by Each Law: 48 US States, January 2013 – June 2017

	No Law	Law Effective
Children	0.59	1.05
Domestic	0.73	0.96
Mental	0.51	0.93

Table 24 Continued

	No Law	Law Effective
Background	0.82	0.92
Stolen	0.77	1.09
Minimum Age	0.85	0.75
Gun shows	0.75	1.13
Assault	0.78	1.23

Table 25: Average Number of People Injured in Mass Shootings by Each Law: 48 US States, January 2013 – June 2017

	No Law	Law Effective
Children	1.60	3.07
Domestic	1.84	3.04
Mental	1.43	2.66
Background	2.26	3.04
Stolen	1.86	4.28
Minimum Age	2.18	3.59
Gun shows	1.93	0.54
Assault	2.08	4.70

Table 26: Average Number of Mass Shootings by Each Law: 48 US States, January 2013 – June 2017

	No Law	Law Effective
Children	0.44	0.84
Domestic	0.52	0.82
Mental	0.41	0.73
Background	0.63	0.80
Stolen	0.53	1.11
Minimum Age	0.61	0.91
Gun shows	0.54	1.03
Assault	0.58	1.22

Table 27: Averages Before and After the Law, by State per Year-Month: 2013 – June 2017

	State	Law	Killed	Injured	Mass Shootings
Children	North Carolina	0	1.00	5.11	1.44
	North Carolina	1	0.98	3.18	0.91

Table 27 Continued

	State	Law	Killed	Injured	Mass Shootings
Domestic Violence	Louisiana	0	0.84	4.32	0.84
	Louisiana	1	1.60	5.91	1.46
	Massachusetts	0	0.09	1.00	0.23
	Massachusetts	1	0.19	1.16	0.28
	Minnesota	0	0.32	0.53	0.21
	Minnesota	1	0.46	1.94	0.49
	Oregon	0	0.33	0.67	0.14
	Oregon	1	0.61	0.33	0.22
	Rhode Island	0	0.00	0.35	0.08
	Rhode Island	1	0.00	0.00	0.00
	South Carolina	0	0.72	1.41	0.45
	South Carolina	1	1.68	2.52	0.92
	Vermont	0	0.00	0.00	0.00
	Vermont	1	0.17	0.00	0.04
	Washington	0	0.53	1.00	0.29
	Washington	1	0.84	1.16	0.43

Table 27 Continued

	State	Law	Killed	Injured	Mass Shootings
Mental Health	Arizona	0	1.11	1.00	0.47
	Arizona	1	0.94	1.11	0.40
	Nevada	0	0.69	0.93	0.38
	Nevada	1	0.40	0.64	0.24
	Oklahoma	0	0.90	1.33	0.53
	Oklahoma	1	0.42	0.67	0.21
	South Carolina	0	0.20	0.80	0.20
	South Carolina	1	1.27	2.04	0.71
Universal Background Check	Nevada	0	0.60	0.81	0.33
	Nevada	1	0.17	0.67	0.17
	Washington	0	0.65	1.13	0.35
	Washington	1	0.81	1.10	0.42
Lost/Stolen Report	Delaware	0	0.60	0.40	0.20
	Delaware	1	0.02	0.55	0.12
	Illinois	0	1.76	8.94	2.06
	Illinois	1	2.62	11.68	3.03
	Maryland	0	0.44	1.78	0.44

Table 27 Continued

	State	Law	Killed	Injured	Mass Shootings
Lost/Stolen Report	Maryland	1	0.82	2.82	0.76
Minimum Age	New York	0	0.00	0.00	0.00
	New York	1	1.08	5.74	1.43
Gun Shows	Virginia	0	1.12	2.69	0.83
	Virginia	1	0.92	3.17	0.83
Assault Weapon Ban	Connecticut	0	0.00	0.00	0.00
	Connecticut	1	0.21	1.46	0.31
	Maryland	0	0.44	1.78	0.44
	Maryland	1	0.82	2.82	0.76

Table 28: State Minimum Age Laws: 48 US States, January 2013 – June 2017

	Minimum Age		
State	**Number of Months with No Law**	**Number of Months with Law in Place**	**Total Month-Year**
Alabama	54	0	54
Arizona	54	0	54
Arkansas	54	0	54
California	54	0	54
Colorado	54	0	54
Connecticut	0	54	54
Delaware	54	0	54
Florida	54	0	54
Georgia	54	0	54
Idaho	54	0	54
Illinois	0	54	54
Indiana	54	0	54
Iowa	0	54	54
Kansas	54	0	54
Kentucky	54	0	54
Louisiana	54	0	54

Table 28 Continued

Minimum Age			
State	**Number of Months with No Law**	**Number of Months with Law in Place**	**Total Month-Year**
Maine	54	0	54
Maryland	0	54	54
Massachusetts	0	54	54
Michigan	54	0	54
Minnesota	54	0	54
Mississippi	54	0	54
Missouri	54	0	54
Montana	54	0	54
Nebraska	54	0	54
Nevada	54	0	54
New Hampshire	54	0	54
New Jersey	0	54	54
New Mexico	54	0	54
New York	1	53	54
North Carolina	54	0	54
North Dakota	54	0	54

Table 28 Continued

Minimum Age			
State	**Number of Months with No Law**	**Number of Months with Law in Place**	**Total Month-Year**
Ohio	54	0	54
Oklahoma	54	0	54
Oregon	54	0	54
Pennsylvania	54	0	54
Rhode Island	54	0	54
South Carolina	54	0	54
South Dakota	54	0	54
Tennessee	54	0	54
Texas	54	0	54
Utah	54	0	54
Vermont	54	0	54
Virginia	54	0	54
Washington	54	0	54
West Virginia	54	0	54
Wisconsin	54	0	54
Wyoming	54	0	54

Results with Number of Active Concealed Carry Permits as Exposure Variable

Table 29: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (Single Independent Variable)[1] on the Mass Shooting related Deaths: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	2.42	1.63 – 3.59	<0.001
Children	1.92	1.42 – 2.60	<0.001
Domestic	2.13	1.61 – 2.81	<0.001
Mental	1.60	1.11 – 2.30	0.01
Stolen	14.16	9.81 – 20.44	<0.001
Gun Shows	3.44	2.49 – 4.75	<0.001
Assault Rifle Ban	37.02	23.11 – 59.32	<0.001

IRR: Incidence Rate Ratio

[1] Each row represents a separate model with only one policy variable in a negative binomial regression with year, month, and state fixed effects.

Table 30: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (Single Independent Variable)[1] on the Mass Shooting related Injuries: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	2.54	1.86 – 3.46	<0.001
Children	1.37	1.09 – 1.71	0.05
Domestic	1.54	1.25 – 1.89	<0.001

Table 30 Continued

Independent Variable	IRR	95% Confidence Interval	P-value
Mental	1.38	1.05 – 1.81	0.02
Stolen	6.39	4.90 – 8.33	<0.001
Gun Shows	2.62	2.05 – 3.35	<0.001
Assault Rifle Ban	18.92	13.47 – 26.58	<0.001

IRR: Incidence Rate Ratio

[1] Each row represents a separate model with only one policy variable in a negative binomial regression with year, month, and state fixed effects.

Table 31: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (Single Independent Variable)[1] on the Number of Mass Shootings: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.86	0.39 – 1.90	0.71
Children	0.71	0.38 – 1.34	0.29
Domestic	1.58	1.11 – 2.24	0.01
Mental	0.58	0.37 – 0.93	0.02
Stolen	0.41	0.28 – 0.59	<0.001
Gun Shows	0.73	0.23 – 2.28	0.59
Assault Rifle Ban	17.13	0.79 – 6.19	<0.001

IRR: Incidence Rate Ratio

[1] Each row represents a separate model with only one policy variable in a negative binomial regression with year, month, and state fixed effects.

Table 32: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Deaths: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.19	0.11 – 0.33	<0.001
Children	1.29	0.95 – 1.75	0.10
Domestic	1.44	1.07 – 1.95	0.02
Mental	1.31	0.86 – 1.97	0.21
Stolen	2.45	1.51 – 3.97	<0.001
Gun shows	0.90	0.61 – 1.33	0.60
Assault rifle ban	34.57	17.58 – 67.98	<0.001

IRR: Incidence Rate Ratio

[1]Results are from a negative binomial regression including all the policy variables with year, month, and state fixed effects

Table 33: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Injuries: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.34	0.23 – 0.51	<0.001
Children	1.38	1.09 – 1.75	0.05
Domestic	1.30	1.04 – 1.62	0.02
Mental	1.50	1.06 – 2.13	0.02

Table 33 Continued

Independent Variable	IRR	95% Confidence Interval	P-value
Stolen	3.35	2.31 – 4.85	<0.001
Gun shows	0.81	0.60 – 1.08	0.15
Assault rifle ban	13.50	8.04 – 22.67	<0.001

IRR: Incidence Rate Ratio

[1]Results are from a negative binomial regression including all the policy variables with year, month, and state fixed effects

Table 34: Negative Binomial Regression (with State Fixed Effects) Results for the Effects of Gun Policy (single multivariate model)[1] on the Number of Mass Shootings: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.57	0.24 – 1.33	0.20
Children	0.66	0.35 – 1.26	0.21
Domestic	1.50	1.05 – 2.14	0.03
Mental	0.53	0.33 – 0.86	0.01
Stolen	0.28	0.18 – 0.43	<0.001
Gun shows	0.45	0.19 – 1.03	0.06
Assault rifle ban	9.45	3.02 – 29.55	<0.001

IRR: Incidence Rate Ratio

[1]Results are from a negative binomial regression including all the policy variables with year, month, and state fixed effects

Table 35: Negative Binomial Regression (with State Fixed Effects and Control Variables) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Deaths: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.19	0.11 – 0.33	<0.001
Children	1.29	0.95 – 1.75	0.10
Domestic	1.38	1.03 – 1.86	0.03
Mental	1.23	0.82 – 1.86	0.31
Stolen	2.12	1.30 – 3.45	0.003
Gun shows	0.91	0.62 – 1.34	0.65
Assault rifle ban	32.34	16.34 – 64.03	<0.001
Unemployment	1.26	1.12 – 1.42	<0.001
Income Per Capita	1.05	0.95 – 1.17	0.34

IRR: Incidence Rate Ratio

[1]Results are from a negative binomial regression including all the policy variables and control variables with year, month, and state fixed effects

Table 36: Negative Binomial Regression (with State Fixed Effects and Control Variables) Results for the Effects of Gun Policy (single multivariate model)[1] on the Mass Shooting related Injuries: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.35	0.24 – 0.53	<0.001
Children	1.48	1.17 – 1.87	0.001
Domestic	1.28	1.02 – 1.60	0.03
Mental	1.43	1.01 – 2.02	0.04
Stolen	3.03	2.09 – 4.40	<0.001
Gun shows	0.79	0.59 – 1.06	0.12
Assault rifle ban	12.95	7.68 – 21.82	<0.001
Unemployment	1.39	1.25 – 1.53	<0.001
Income Per Capita	1.01	0.94 – 1.09	0.80

IRR: Incidence Rate Ratio

[1]Results are from a negative binomial regression including all the policy variables and control variables with year, month, and state fixed effects

Table 37: Negative Binomial Regression (with State Fixed Effects and Control Variables) Results for the Effects of Gun Policy (single multivariate model)[1] on the Number of Mass Shootings: 48 US States, January 2013 – June 2017

Independent Variable	IRR	95% Confidence Interval	P-value
Background	0.63	0.27 – 1.48	0.29
Children	0.71	0.37 – 1.35	0.29
Domestic	1.41	0.98 – 2.04	0.07
Mental	0.53	0.33 – 0.85	0.01
Stolen	0.30	0.19 – 0.47	<0.001
Gun shows	0.46	0.20 – 1.04	0.06
Assault rifle ban	10.16	2.97 – 34.81	<0.001
Unemployment	1.12	1.01 – 1.24	0.03
Income Per Capita	1.00	0.91 – 1.09	0.99

IRR: Incidence Rate Ratio

[1] Results are from a negative binomial regression including all the policy variables and control variables with year, month, and state fixed effects

CHAPTER 5

CONCLUSIONS

Public health policy is a crucial tool for bettering the everyday lives of a nation's citizens. This dissertation consists of three studies that measured the health impact of certain state laws (marijuana legalization, same-sex marriage legalization, and gun policy) on their outcome variables (number of pediatric poisoning related ED visits, number of STI-related ED visits, number of mass shootings, number of mass shootings related fatalities, and number of mass shootings related injuries). The consequences of marijuana legalization, same-sex marriage legalization, and gun policy were analyzed to determine their impact on pediatric poisoning, sexually transmitted infections, and mass shootings, respectively.

The three studies utilized a similar quasi-experimental design to estimate the effect of different state laws (marijuana legalization, same-sex marriage legalization, and gun policy) on the outcome variables (number of pediatric poisoning related ED visits, number of STI-related ED visits, number of mass shootings, number of mass shootings related fatalities, and number of mass shootings related injuries). Data were analyzed with a difference-in-difference model that compared treatment states to control states to estimate the average treatment effect of the laws. The first and second studies—investigating the impact of marijuana legalization on pediatric poisoning-related ED visits and same-sex marriage legalization on STI-related ED visits, respectively—obtained data from SID and SEDD. The third study, examining firearm policy and mass shootings, obtained data from the Mass Shooting Tracker and Giffords Law Center to Prevent Gun Violence. The unit of observation for all studies was state-year-month, and all the models included state-fixed effects to account for time-invariant state effects. In addition, the studies employed time dummies (month and year) to account for time effects. All three studies employed the negative binomial distribution. All the analyses were performed in STATA version 13 (StataCorp LP, College Station, TX).

The first study analyzed the impact of marijuana legalization on pediatric poisoning-related ED visits. States which had legalized recreational or medical marijuana were designated as treatment states. Two separate model specifications were utilized to estimate the effects of both types of legalization without any spillover/over lapse. Results indicated that both recreational and medical marijuana legalization resulted in a significant rise in pediatric poisoning ED visits.

The second study examined the impact of same-sex marriage legalization on sexually transmitted infections that resulted in ED visits. For comparison purposes, data prior to the 2015 Supreme Court legalization ruling was analyzed. States that had legalized same-sex marriages were designated as treatment states, while those which had not were included as control states. Results indicate legalization of same-sex marriage had a negative association with STI-related ED visits.

The third study estimated the impact of multiple gun policy variables on the number of mass shootings, and related fatalities and injuries. States with gun restriction laws in place were designated as treatment states, while those without such laws were designated as control states. While most gun policy variables did not produce a significant association, treatment states requiring universal background checks were associated with a decrease in fatalities and injuries related to mass shootings. Additionally, prohibiting individuals with a documented history of mental illness from purchasing firearms resulted in fewer mass shooting incidents. A lower unemployment rate was also associated with a decrease in the number of mass shootings and related injuries.

The health consequences of marijuana legalization, particularly regarding pediatric poisoning, also warrants further study. Despite the growing popularity of state measures that legalize medical or recreational marijuana use, such policies have had unpredictable and dangerous impacts on children aged 9 and younger. Research in states that have legalized marijuana is needed to determine how to reduce related cases of pediatric poisoning. This is particularly urgent, as several additional states have recently legalized medical or recreational marijuana use and others are considering doing so. In order to curb the negative impact of pediatric poisoning, a new federal policy may be required to ensure that states which legalize marijuana consumption also address the often-ignored public health risks of such laws.

Study results indicate a clear public health benefit associated with legalization of same-sex marriage. Data indicate a significant reduction in STI-related ED visits following the legalization of same-sex marriages. In addition to positively impacting the daily lives of those in the LGBTQ community, this policy shift has also reduced healthcare costs associated with STI-related cases, thus benefiting society as a whole as well.

Findings from the gun policy study indicate that state lawmakers must recognize that certain legal measures can significantly reduce both the frequency of and harm from mass shootings. They also need to acknowledge that certain gun-related laws may have unintended consequences regarding these tragic events. Further empirical research is needed to better understand how the details and implementation of different gun policies impact mass shootings. Research is also needed to understand why similar laws passed in different states do not always produce similar results.

While results from these three studies confirm the potential health benefits of state policies, they also highlight the need for more research to address unforeseen complications and consequences. The three policy areas under consideration—marijuana legalization, same-sex marriage legalization, and gun regulation—all have broad societal health impacts. Policymakers need to take great care, informed by rigorous research, to make sure well-meaning measures do not prove ineffective—or worse, do more harm than good. Without such well-informed caution on the part of state legislators, new laws can endanger children whose parents use legalized drugs (as in the first study), increase the horizontal transmission of certain infections or diseases (as in the second study), or new laws can be ineffective (as in third study).

Especially in a nation as large and diverse as the United States, with considerable political and policy differences between the states, it is imperative that health-related law development and implementation be regarded as only the first step in bringing about desired societal change. Equally important is the research that follows to make sure that maximum public benefit and minimum public risk is indeed the final real-world outcome.

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