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The Cannabis Effect on Crime: Time-Series Analysis of Crime in Colorado and Washington State

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ABSTRACT

Previous studies based on relatively weak analytical designs lacking contextualization and appropriate comparisons have reported that the legalization of marijuana has either increased or decreased crime. Recognizing the importance for public policy making of more robust research designs in this area during a period of continuing reform of state marijuana laws, this study uses a quasi-experimental, multi-group interrupted time-series design to determine if, and how, UCR crime rates in Colorado and Washington, the first two states to legalize marijuana, were influenced by it. Our results suggest that marijuana legalization and sales have had minimal to no effect on major crimes in Colorado or Washington. We observed no statistically significant long-term effects of recreational cannabis laws or the initiation of retail sales on violent or property crime rates in these states.

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Legalization of marijuana; Amendment 64; I-502; crime rates; interrupted time-series analysis

Introduction

In many ways the legalization of cannabis by ten states and the District of Columbia, as of March 2019, constitutes a grand ongoing experiment into how a major public policy initiative does or does not accomplish its expected outcomes. One of the principal expectations of the proponents of Initiative 502, the voter-initiated bill authorizing the recreational sale of marijuana in Washington, was that crime would decrease. Crimes generally were expected to decline in number, but particularly those crimes associated with the use of marijuana (e.g., possession, black market production, sales and distribution of cannabis, burglaries or thefts believed to be committed to secure funds to purchase marijuana). Some preliminary studies released shortly after legalization have intimated that crime rates have been going up rather dramatically in some of the states that have legalized recreational marijuana (Smart Approaches to Marijuana, 2018). In Washington State, early reports suggested that the number of marijuana-related offenses such as assault, theft, harassment, and vehicular offenses

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increased in Washington after the legalization (Northwest High Intensity Drug Trafficking Area [NHIDTA], 2016), but that "violent crime is down since Washington legalized marijuana" (Santos, 2017). Or, paradoxically, the article by Malcolm Gladwell in *The New Yorker,* claiming (based on a book by Berenson, [2019]) that violent crime had increased in Washington state post legalization.

As Garland (2001) has noted, there is a strong political demand for immediate answers to often quite complicated questions of public policy. In short, many politicians are inclined to make use of the earliest available data, and unfortunately too often what is available for public consumption at the outset of change in policy represents research employing limited pre/post analyses or misrepresentation of facts. Too often the results reported from such analyses fail to take into consideration the context of practice. For example, consider headlines associated with increasing citations for public marijuana consumption, in and around major cities. In many ways, these headlines are interpreted to suggest that marijuana users are increasingly consuming in public, a practice which was explicitly banned in Washington law. However, to some extent, these increases may in fact relate to property ordinances and rental agreements banning smoking, where violation is an automatic qualification for termination of the lease. Such policy conundrums create an environment where it is illegal to smoke in public and essentially illegal for marijuana users to smoke in their residence. Additionally, pressure from retail establishments and other members of the public can create pressure on police officers to issue citations.

In the absence of more rigorous and robust types of analyses, policy discussions and decisions in those states considering the liberalization of their own cannabis laws are prone to believe the misleading conclusions disseminated about likely outcomes. A variety of claims regarding the deleterious effects of legalization have already been made in a number of instances such as in Berenson's widely cited book (2019) about the purported dangers of marijuana and Vestal (2019)'s column for the *Spokesman Review*. Some politicians have also linked the legalization of marijuana with increases in violence, often without the support of empirical data (Adams, 2018). Advocacy groups, both for and against marijuana legalization might also contribute to this problem. For example, the group Smart Approaches to Marijuana (2018), frequently presents anecdotal or single-site evidence about potential increases in crime, without a robust analysis to support assertions.

Recognizing the importance for public policy making of more robust research designs in this area, this study uses a quasi-experimental, multi-group interrupted time-series design to determine if, and how, crime rates in Colorado and Washington State were influenced by the legalization of recreational marijuana in 2012 and the start of retail sales in 2014. The objective of the current study is to evaluate whether cannabis legalization would lead to changes in crime rates. This multi-group interrupted time-series study is more rigorous than the limited pre/post analysis frequently used to resolve political discussions because its quasi-experimental design has greater ability to assess causality than correlational studies (Cook & Campbell, 1979). As such, this research is timely in that these were the two earliest states to legalize the growing, processing, and commercial sale of cannabis for recreational use. Notably, we observed no statistically significant long-term effects of recreational cannabis laws or

the initiation of retail sales on violent or property crime rates in either Colorado or Washington.

As the nationwide debate about legalization, the federal classification of cannabis under the Controlled Substances Act, and the consequences for crime – from legalization – continues, it is essential to center that discussion on studies employing contextualized and robust research designs with as few limitations as possible.

Literature review

Background of cannabis laws in Colorado and Washington

In 1998 Washington State voters emulated action taken by voters in California in 1996 to pass Initiative 692, a law which legalized the use of cannabis for qualified patients with certain medical conditions (NHIDTA, 2016). Voters in Colorado continued this trend in 2000 with Amendment 20 which allowed physicians to recommend marijuana to patients and allowed patients to grow up to six plants with a registry identification card. Under Amendment 21, caregivers in Colorado were legally allowed to have minor grow operations for up to five patients (Salomonsen-Sautel, Sakai, Thurstone, Corley, & Hopfer, 2012).

Over the course of a decade legislation was enacted loosening the restrictions on prescribing medical marijuana licenses and expanding qualifying conditions. In 2010, Colorado allowed for large scale licensed medical marijuana dispensaries (Reed, Hilkey, Thome, & English, 2018). In the following year in Washington, Senate Bill 5073 authorized the use of "collective gardens" that allowed up to ten patients or providers to grow up to 45 plants and produce up to 72 ounces of useable marijuana. It is believed that this collective garden provision in the state's medical marijuana laws substantially expanded the state's black market for cannabis whereby largely unregulated marijuana "dispensary" storefronts were able to sell substantial amounts of cannabis both to properly qualified and to unauthorized consumers alike (NHIDTA, 2016).

During this period after the passage of Initiative 692 voters in Seattle and Tacoma, two of Washington's most populous cities, passed local ordinances by the initiative process that required that police officers regard the possession of marijuana as a low priority for enforcement (a policy known as *deprioritization*). The first such ordinance was passed in 2002 ("Seattle Municipal Code," 2003, 12 A.20.060, Sect. A), and the second was passed in 2011 (ReformAct. Org., 2017, p. 1). Citizens of the consolidated City/County government of Denver, Colorado passed comparable legislation in the form of Question 100 in 2007. This measure made marijuana possession offenses the lowest priority for law enforcement officers. Although the initiative passed by a comfortable margin, Denver officials reiterated their right to enforce state and federal marijuana laws should public health and public safety require their action. Columnist Dick Kreck likened this action of the citizens of Denver to that taken to end prohibition (Amendment Seven) in 1934 by a vote of 2-to-one once the federal government turned over alcohol regulation to the states and their local governments (Kreck, 2009).

The growing movement to decriminalize cannabis use led to the eventual legalization of recreational marijuana in both Colorado and Washington. In November 2012, Washington state voters passed Initiative 502 by a 56% to 44% margin and Colorado

voters passed Amendment 64 by a similar 55% to 45% margin; both pieces of legislation legalized the possession, consumption and purchase of cannabis by individuals 21 years and older for recreational purposes, and allowed residents to start regulated licensed businesses that produce, process, and sell cannabis legally (NHIDTA, 2016; Washington State Liquor and Cannabis Board [WSLCB], 2014; Colorado Department of Revenue, 2019).

One of the core issues of concern for proponents and opponents of cannabis legalization was its likely effects on crime. Proponents believed that crime would decrease just by redefinition (possession of up to one ounce by adults would be legal), and that ancillary crimes attributed to black market drug dealing and acquisition, such as thefts and burglaries, would also decrease (Aalen, 2013; Contreras, 2017; Kepple & Freisthler, 2012). Those who opposed legalization were concerned that the prevalence of cannabis would lead to problematic consequences, including an increased crime rate as intoxicated and less inhibited adult and juvenile users engaged in index and traffic offenses and as adolescents found it easier to access cannabis for illegal use (Doherty, Tyson, & Weisel, 2015). In accord with these beliefs by both proponents and opponents, there is some research that indicates marijuana legalization and/or decriminalization can lead to: (1) increased marijuana use; (2) increased cash-based marijuana businesses; and, (3) diminished black marijuana market and cannabis-related charges.

Cannabis use

Perhaps the least debated direct consequence of permitting the sale and possession of marijuana for recreational purposes is increased marijuana use. While some researchers claim medical marijuana laws do not affect drug use (Harper, Strumpf, & Kaufman, 2012), most studies consistently demonstrate that after the passage of medical marijuana laws, marijuana use became more widespread in states which allowed its legal use (Cerdá, Wall, Keyes, Galea, & Hasin, 2012; Chu, 2015; Schuermeyer et al., 2014; Wall et al., 2011). For example, Cerdá et al. (2012) examined the relationship between state-level legalization of marijuana and state-level and individual-level cannabis use in the United States by employing the second wave of the *National Epidemiologic Survey on Alcohol and Related Conditions* data (NESARC) and the *National Survey on Drug Use and Health* (NSDUH) data. More specifically, they compared the level of cannabis use in 2004-2005 between states that had legalized medical marijuana by 2004 and states that had not. This investigation demonstrated that those who lived in states that legalized cannabis use for medical purposes by 2004 were more likely to use marijuana than residents of states that prohibited medical marijuana. Chu (2015) found similar evidence via different measurements of cannabis use. He used two indirect measurements, marijuana possession arrests and substance abuse treatment admissions, data collected from the *Uniform Crime Reporting* (UCR) program and *Treatment Episode Data Set*, respectively, between 1992 and 2011 and was able to indirectly assess the trend of cannabis use across time. This investigation indicates marijuana use increased by about 10 to 15 percent after the passage of medical marijuana laws.

The passage of marijuana laws may also induce more cannabis use by altering people's perceptions about it (Schuermeyer, et al., 2014; Wall et al., 2011). For example, Schuermeyer et al. (2014) compared the perceived risk of marijuana use by adults and adolescents living in Colorado with those who live in states without medical marijuana laws, using the *National Survey on Drug Use and Health* (NSDUH) statistics on self-reported attitudes toward cannabis use. They used 2010 to 2011 as the observation period because there was a series of policy changes in Colorado in 2009 that resulted in the rapid increase in the number of medical marijuana cardholders in Colorado. Their results indicated that compared to residents of non-medical marijuana states, Coloradans were less likely to disapprove of marijuana use and were less likely to perceive its use as a risky behavior in the time leading up to the legalization of recreational marijuana in Colorado in 2012. Consequently, consuming cannabis for medical and/or recreational purposes may become a more popular choice if people perceive the legalization of this substance as indicating its use is acceptable conduct.

Crime and cannabis use

Whether increased cannabis use will ultimately affect crime rates, however, is far from a settled matter. Prior research provides mixed and inconclusive evidence on the effect of marijuana use on crime. On the one hand, a number of empirical studies find that marijuana use enhances the likelihood of engaging in violent and property crimes and other forms of serious delinquent behavior (Brook et al., 2003; Pacula & Kilmer, 2003; Phillips, 2012; Reingle, Staras, Jennings, Branchini, & Maldonado-Molina, 2012; Reynolds, Tarter, Kirisci, & Clark, 2011). A longitudinal multi-level study of high-risk youth in the New York public school system over 5 years of observation demonstrates that the self-reported frequency of drug use predicts the self-reported frequency of engaging in general violence and hitting someone to hurt them (Phillips, 2012). Additionally, another longitudinal study using a national sample of adolescents and young adults found that being a consistent marijuana user increased one's odds of assaulting an intimate partner in later years of his/her early adulthood, compared with comparable adolescents who have not used cannabis (Reingle et al., 2012). Expanding the focus beyond crime to problematic conduct such as rebelliousness, juvenile delinquency, poor school achievement, and association with delinquent peers, researchers find earlier adolescent marijuana use is associated with a broad range of problematic conduct later on (Brook, et al., 2003). Although these studies were conducted based on self-reported data of adolescents and young adults, they demonstrate a plausible association between early onset of cannabis use and one's risk of engaging in violent and delinquent behavior during the transition to adulthood.

Cannabis users' risk of offending is also confirmed by a meta-analysis that investigated the connection between drug use and crime (Bennett, Holloway, & Farrington, 2008). This meta-analysis reviewed 30 studies examining the effect of drug use on a broad range of violent and property crimes across the globe. Among these studies, 18 were conducted in the United States, and ten investigated the relationship between marijuana use and offending. The average effect size of the meta-analysis suggested that the odds of marijuana users offending are about 1.5 times higher than the odds

of non-marijuana users offending. Overall, based on these empirical studies, one would expect crime rates to increase after legalizing medical and recreational cannabis use because there would be more marijuana abusers. One important caveat here is that this line of argument assumes that the relationship between marijuana and crime is the same for individuals who chose to use it when illegal as for those who choose to use it once it is legal.

Importantly, some evidence suggests cannabis use either will not affect or it may even ameliorate drug user's violent tendencies (Miller, 1990). In a study of spousal violence using a sample of parolees, Miller (1990) found that when parolees report having an alcohol problem, but not a drug problem, their level of violence increased; whereas, individuals who report having both alcohol and drug problems have a relatively steady violence level. Miller (1990) interpreted these results as possibly indicating drug use may suppress the violence induced by alcohol consumption. Another study examining the relationship between drug use and violent delinquency among adolescent Mexican-Americans found that when this group incrementally increased their use of cannabis, their commission of violent crimes decreased, possibly because marijuana is often used as a substitute for other controlled substances more consistently related to violent behaviors, such as alcohol, cocaine and amphetamines (Aalen, 2013). Hence, in light of this contradictory evidence, it is difficult to predict if, and to what extent, more frequent cannabis use is related to violent crimes.

Cash-based cannabis business and crime

There is also the concern that permitting state-licensed recreational cannabis production and sale will inevitably create booming businesses, inclusive of dispensaries, growers, and production facilities, in communities that by association may become attractive targets for crimes. This is due to commercial enterprises relying heavily on cash transactions and stolen products that can be readily sold and consumed (Contreras, 2017; Kepple & Freisthler, 2012). As cannabis remains a Schedule One drug that is prohibited at the federal level, banks have been unwilling to engage in transactions associated with marijuana businesses as they fear the risk of money laundering prosecution by federal authorities (Chemerinsky, Forman, Hopper, & Kamin, 2015). Therefore, cannabis business owners, especially in the early years of legalization, were forced to make cash transactions and to keep large quantities of cash on hand. Notably, in some communities there are now state-chartered savings and loan establishments that will handle cannabis business monies with a substantial surcharge fee.

Routine activity theory holds there are three elements necessary for a crime to occur, including motivated offenders, suitable targets, and capable guardians (Cohen & Felson, 1979). Based on this theory, cannabis businesses and customers are suitable targets for motivated offenders seeking cash and/or drugs. They are at risk of property crimes such as burglary, shoplifting, and economically oriented violent crimes such as robbery. More property and violent crimes may also occur in the neighborhoods where marijuana businesses are located because offenders are targeting customers who are forced to carry large amounts of cash. The increased presence of offenders may lead to additional crimes against other persons or businesses not related to

marijuana, simply because offender presence may equate with opportunity. Of course, potential offenders' final decision to engage in crime might be influenced by the protective measures taken at the dispensaries and in the communities. If strong guardianship technology, such as security and monitoring systems, are present then the businesses may not necessarily attract more motivated offenders because they are less accessible (Kepple & Freisthler, 2012).

The marijuana market and crime

Scholars also argue that it is the systematic nature of illicit marijuana markets that causes violent crimes (Aalen, 2013; Goldstein, 1985). Because there are ample demands for marijuana and abundant profitable opportunities associated with marijuana businesses, the prohibition of this substance gives rise to black markets. However, those involved in marijuana businesses cannot resolve disputes through legal channels without risking incriminating themselves. They have to rely on alternative means, which usually involves corruption (payoffs) or violence, to address disputes (Aalen, 2013). By having a legalized market for cannabis transactions, growers, producers, sellers, and customers can operate in a safer and more predictable environment where transactions are transparent, open to scrutiny, and free from corruption. These newly lawful circumstances will necessarily depress the systematic violence inherent in an underground cannabis market (Aalen, 2013).

Some scholars argue that the association between crime and marijuana is due to its illegality, which would not exist, or at a minimum, diminish significantly, in an environment where cannabis is legalized. Pedersen and Skardhamar (2010) followed 1,353 Norwegian adolescents over the span of 13 years and found that early cannabis use can only predict adolescents' future involvement in drug-specific crimes such as use and possession of drugs. They found little evidence indicating cannabis use is a stepping-stone to more general criminal involvement. Even though there was a robust association between cannabis use and subsequent criminal involvement in their study, Pedersen and Skardhamar (2010) report this relationship disappears when drug-specific charges are excluded. Their research indicates that if use and possession of recreational cannabis were legal, then adolescent abusers would not have been labeled as more prone to commit crimes.

At the same time, prior research on the effect of enacting medical marijuana laws on crime also provides mixed and inconclusive evidence about what could happen if recreational marijuana use is further permitted. Analyzing *National Crime Victimization Survey* (NCVS) data between 1992 and 1994, Markowitz (2005) finds violent crime rates are higher in states where marijuana use is decriminalized. In contrast, other empirical findings suggest permitting medical marijuana is associated with a significant drop in violent crime rates, especially homicide and assault rates (Aalen, 2013; Morris, TenEyck, Barnes, & Kovandzic, 2014; Shepard & Blackley, 2016), and a non-significant change in property crime rates (Morris et al., 2014; Shepard & Blackley, 2016). For example, a recent study conducted on the violent and property crime rates of 11 states in the Western U.S. shows after controlling for state-level factors, states that adopted medical

marijuana laws experienced a significant drop in the violent crime rate and a non-significant change in the property crime rate (Morris et al., 2014).

Prior studies which have focused specifically on local crime changes after the establishment of medical marijuana dispensaries also provide inconclusive evidence. Contreras (2017) reports that opening medical marijuana dispensaries is related to an increase of violent crime rates in socially organized neighborhoods, especially robbery and homicide rates in Los Angeles, California. However, a similar study exploring the spatial relationship between density of medical marijuana dispensaries and violent and property crimes in Sacramento, California did not find a significant relationship between placement of medical marijuana dispensaries and crime rates. Rather, important contextual factors such as the percentage of commercially zoned areas, the percentage of one-person households, unemployment rates, concentrated disadvantage, and population age are found to be more salient predictors of the crime rates of a neighborhood (Kepple & Freisthler, 2012). Lastly, another study examining marijuana outlets in a jurisdiction with legal recreational marijuana (Denver, CO) found that that the density of marijuana outlets was unrelated to crime in the immediate area, but instead resulted in increased crime in adjacent areas (Freisthler, Gaidus, Tam, Ponicki, & Gruenewald, 2017). This study is noteworthy in that it is the only published study to examine recreational marijuana outlets and crime, though it only compares neighborhoods with and without dispensaries and does not examine crime trends pre-legalization.

Summary of research findings and limitations

In sum, the literature on cannabis use and legalization/decriminalization evinces two conflicting paradigms of how they affect use, abuse and crime. Under the first paradigm with research that supports a more malevolent view of legalization, loosening marijuana laws will motivate more cannabis use and alter people's attitudes toward this substance (Cerdá et al., 2012; Chu, 2015; Schuermeyer et al., 2014; Wall et al., 2011). The prevalence of cannabis use, particularly the early onset of youth cannabis use, will increase youth's risk of engaging in violence and delinquency (Brook et al., 2003; Phillips, 2012; Reingle et al., 2012). The growth in the number of marijuana abusers as a result of the legalization may also lead to more crimes because some research suggests marijuana users are more likely to commit violent and property crimes (Bennett et al., 2008). The vulnerability of cannabis businesses (i.e., cash-based businesses, with easily sold and consumed merchandises) may also incentivize crimes such as burglary, shoplifting, and robbery as these businesses are attractive targets for crimes. Hence, under the first paradigm with a more malevolent view of the effects of legalization, there is theoretical support for an increase of violent and property crime rates post cannabis legalization.

An alternate paradigm, however, with research that supports a more benign view of the effects of legalization, suggests that cannabis legalization will not affect, or even lead to an increase in crime rates. Violent crime rates may decrease because some research suggests an individual's violent tendencies may be suppressed by the consumption of cannabis (Miller, 1990). There is also evidence that cannabis users are

not more prone to commit general crimes than others; they are not more likely to violate the law if drug-specific conduct, such as use and possession of drugs, are legal (Pedersen & Skardhamar, 2010). Meanwhile, the systematic violence inherent in an underground cannabis market is expected to diminish as the marijuana market is legalized (Aalen, 2013).

Despite researchers' ample interest in studying the consequences of legalizing marijuana use it is difficult to draw firm conclusions about the effect of legalization on crime rates; there is conflicting evidence at every level. At the individual-level, there is both evidence that marijuana use is linked to other crimes and evidence that it is not. However, no research considers whether individuals who choose to use after legalization differ in their criminality from individuals who were willing to use marijuana pre-legalization. Similarly, while most of the research on medical marijuana laws indicates that increases in the availability of marijuana are associated with crime reductions, there are some studies which show increases associated with medical marijuana laws. Moreover, to date studies have yet to examine the link between recreational marijuana laws and crime, and those that have done so have failed to account for pre-legalization trends (Freisthler et al., 2017). Given that the United States appears to be on the precipice of a "legalization bandwagon" (Hall & Weier, 2017) and the added energy of Canada's decision to legalize recreational marijuana, robust empirical research is desperately needed to parse out the effects of marijuana legalization on crime in the first few years post-legalization. Therefore, our study seeks to answer if crime rates increased in Washington state and Colorado as compared to states do not have broad marijuana laws.

Methods

This study aims to overcome the limitations of previous studies and address the conflicting malevolent and benign views about how cannabis legalization would affect crime rates. We conducted a series of multi-group interrupted time series of monthly crime rates comparing Colorado and Washington to states which have yet to legalize marijuana.[1] Interrupted time-series analysis has long been viewed as one of the strongest quasi-experimental approaches for understanding the short- and long-term effects of interventions (Bernal, Cummins, & Gasparrini, 2017; Cook & Campbell, 1979; Wagner, Soumerai, Zhang, & Ross-Degnan, 2002). The basic principle behind an interrupted time series approach is to estimate the trend of some particular outcome before and after an intervention, with a focus on determining if there are immediate intervention and/or intervention effects over time (Linden, 2015). In a traditional interrupted time-series design, the period prior to the intervention serves as a counterfactual, and by controlling for this pre-intervention trend interrupted time-series analysis is able to estimate the impact of interventions on a given outcome.

[1]As of March 30, 2018, 21 states in the U.S. have not legalized recreational and/or medical marijuana use on a broad scale. These states include Alabama, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Mississippi, Missouri, Nebraska, North Carolina, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, West Virginia, Wisconsin, and Wyoming. Even though West Virginia has passed a medical marijuana law, it is still categorized as not legalized on a broad scale because only consuming cannabis-infused products for medical purposes is permitted (Governing Magazine, 2018).

Table 1. Major marijuana laws in Washington State.

Intervention Date	Description
December, 2012	Legalization of recreational marijuana in Washington State(I-502) and Colorado (Amendment 64)
January, 2014	Date of legalized retail sales of recreational marijuana in Colorado
July, 2014	Date of legalized retail sales of recreational marijuana in Washington State

For our purposes, we are interested in the degree to which crime rates changed following the legalization of recreational marijuana and the start of recreational sales in Colorado and Washington State. Instead of examining each state in a single-group interrupted time-series approach, which is known to have limited ability to determine causality, we compare crime trends in these states to those with no marijuana laws on the books using a multi-group approach. Linden (2017) demonstrates that a multi-group interrupted time series design can better detect immediate and over-time intervention effects. As such, for our models, we compare monthly crime rates in Colorado and Washington State to the 21 states that have not legalized marijuana use for recreational or medical purposes on a large scale.

Crime data for this project were obtained from the FBI's *Uniform Crime Report* for the period 1999 to 2016 for agencies which reported complete data over this time period. Specifically, yearly *Uniform Crime Reporting Program Data: Offenses Known and Clearances by Arrest* data from 1999 to 2016 were obtained from the Institute for Social Research at the University of Michigan (ICPSR) website. We calculated monthly violent, property, aggravated assault, auto theft, burglary, larceny, and robbery rates for Colorado and Washington and the monthly average of each of these crime rates for the control group. For aggravated assault, auto theft, burglary, larceny, and robbery, monthly crime rates are calculated by firstly summing up the total number of the corresponding type of crime cleared by the law enforcement agencies in a state each month. Next, the monthly crime rates per capita is calculated by dividing the total number of crimes by the state's population and then multiple it by 100,000. Monthly violent and property crime rates are calculated in the same procedures but include more types of offenses. Violent crime includes murder, manslaughter, aggravated assault, rape, and robbery. Property crime includes auto theft, burglary and larceny. Though our primary focus is on examining the effects of legalized recreational marijuana, we include a longer time-series to better account for trends in violent and property crime prior to the legalization in both states in 2012. Table 1 displays each of the potential intervention points, and the date of each intervention.

Because Washington and Colorado began sales at different dates, we estimate separate multi-group interrupted time series models for each state. We estimate our models using the segmented regression approach, which is recommended by a variety of experts on examining the longitudinal effects of policy changes (Bernal et al., 2017; Linden, 2015; Wagner et al., 2002). Jandoc, Burden, Mamdani, Lévesque, and Cadarette (2015) note that there are three broad concerns with interrupted time-series models: 1) serial autocorrelation; 2) stationarity, and 3) seasonality. To address autocorrelation, we estimate our models using the Prais-Winsten estimator, which recursively estimates coefficients and error autocorrelation until a model with AR(1) coefficients and error terms are obtained (Prais & Winsten, 1954). These models are recommended when

Table 2. Colorado ITSA results on specific crime rates per month.

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between CO and control prior to interventions	−3.70** (.493)	−45.477** (3.978)	−2.825** (.350)	7.936** (.919)	−19.993** (1.002)	−33.419** (2.595)	−1.492** (.229)
Trend prior to legalization (Control)	−.051** (.004)	−.632** (.037)	−.030** (.003)	−.078** (.009)	−.050** (.008)	−.503** (.023)	−.018** (.002)
Trend prior to legalization (CO)	.049** (.005)	−.115** (.041)	−.030** (.003)	−.049** (.009)	−.061** (.010)	−.006 (.027)	.009** (.002)
Immediate effect after recreational legalization (Control)	−2.315 (1.414)	−9.490 (12.565)	−1.835^{+} (1.021)	−.363 (3.087)	−6.707* (2.812)	−2.348 (7.947)	−.685 (.542)
Immediate effect difference between control and CO after recreational legalization	.050 (1.750)	28.069* (14.178)	−1.364 (1.243)	1.656 (3.284)	6.016^{+} (3.552)	20.382* (9.238)	.827 (.800)
Trend after recreational legalization (Control)	.080 (.192)	.436 (1.702)	.074 (.139)	.111 (.418)	−.261 (.382)	.589 (1.077)	−.026 (.074)
Trend after recreational legalization (CO)	−.170 (.238)	−1.639 (1.928)	−.020 (.169)	−.065 (.447)	−.224 (.482)	−1.358 (1.256)	−.132 (.108)
Immediate effect after retail (Control)	−3.136^{+} (1.897)	−11.245 (16.936)	−2.322+ (1.371)	−.485 (4.179)	−6.250^{+} (3.770)	−4.674 (10.693)	−.603 (.726)
Immediate effect difference between control and CO after retail	.001 (2.345)	−23.055 (18.959)	1.129 (1.665)	−7.617^{+} (4.386)	.605 (4.762)	−15.911 (12.360)	−1.048 (1.082)
Trend after retail (Control)	.156 (.196)	−.037 (1.741)	.090 (.142)	.041 (.428)	.148 (.390)	−.227 (1.101)	.064 (.075)
Trend after retail (CO)	.091 (.243)	2.503 (1.968)	−.049 (.172)	.426 (.456)	.322 (.493)	1.759 (1.282)	.128 (.111)
Constant	35.367** (.593)	271.945** (5.307)	22.055** (.429)	16.157** (1.307)	67.565** (1.176)	188.820** (3.350)	9.619** (.219)
LRT	744.447**	577.188**	773.226**	555.870**	857.504**	744.991**	611.124**
AR(1) rho	.125	.202	.139	.246	.106	.179	−.059
Corrected Durbin-Watson	2.156	2.336	2.157	2.428	2.153	2.272	1.933

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

serial autocorrelation (especially such that exists for multiple lags) exist (Linden, 2015). Moreover, the Prais-Winsten estimators are also recommended to address issues of heteroskedasticity (Bernal et al., 2017; Linden, 2015), though there were no obvious funnel patterns in the residuals for the models presented below. On the issue of autocorrelation, we also report iteratively generated AR(1) coefficients (rho) for each model. Generally speaking, the rho values are fairly small after the Prais-Winsten estimator converges, though some larger values exist for the auto-theft models. As a matter of checking the robustness of our results for potential heteroskedasiticy issues, we applied the natural logarithmic transformation to our monthly crime rates and re-estimated the models presented in Tables 2 through 5 (these are available in the appendix). We also report the adjusted Durbin Watson statistics for each model as well. Most models produce values close to 2 (indicating no autocorrelation), though again, the auto-theft models continue to exhibit some level of autocorrelation. In terms of stationarity, we estimated the augmented Dickey-Fuller statistic for each of our outcome variables, as recommended by Jandoc et al. (2015). These results (available upon request) indicate that each outcome variable's time series meet stationarity condition, except for Colorado and Washington time series for auto-theft. Lastly, Bernal et al. (2017) suggest that regular seasonal variation can bias interrupted time-series results. Preliminary analysis suggested somewhat regular monthly variation, and so we add a dummy variable to account for monthly variation to these models (as recommended by Jandoc et al. (2015). In summary, we estimated 14 interrupted times-series models (one for each crime type for each state) in the following form:

$$Y_t = \alpha + \ \beta_0 + \beta_1 L + \ \beta_2 T_t + \beta_3 T_t L + \beta_4 X_{1t} + \ \beta_5 X_{1t} L + \beta_6 T_t L_{1t} + \beta_7 T_t X_{1t} L + \beta_8 X_{2t} + \beta_9 X_{2t} L + \beta_{10} T_t X_{2t} + \beta_{11} T_t X_{2t} L$$

Where Y_t is the monthly crime rate, L is a dummy variable indicating one of the legalized states (0 = control), T_t is the month (centered at the point of the first interruption, December, 2012, to facilitate the correct interpretation of the effect of this interruption), X_{1t} and X_{2t} are dummy variables for the three interruptions (X_{1t} equals 1 from December 2012 onward and X_{2t} equals 1 from January 2014/July 2014 (CO and WA started sales at different time points onward), and α is a matrix of 11 fixed-effects dummy variables to control for monthly variation. Therefore, β_0 represents the average crime rate for control states in January 1999, β_1 is the expected difference between the crime rate in one of the legalized and the control states in January of 1999, β_2 is the initial trend in crime rates for the control group, and β_3 is the difference in crime rate trends between a legalized state and the control average prior to legalization. β_4 and β_8 represent the immediate treatment effects of recreational legalization and sales for the control group, while β_5 and β_9 represent the differences in the treatment effects for legalized states and the control group average. β_6 and β_{10} represent the treatment effects over-time of recreational legalization and the start of sales for the control group, while β_7 and β_{11} represent the difference in the treatment effects over-time between legalized states and the control group. In summary, statistically significant coefficients for β_5 and β_9 would indicate a significantly larger immediate change in crime rates in states that legalized than in the control states, while statistically significant coefficients for β_7 and β_{11} would indicate that trends in a legalized state were significantly different than the control group and would be indicative of treatment

effects over-time. These coefficients are ultimately the most important ones in the Colorado and Washington models, as they would indicate the extent to which legalization and the start of sales have resulted in a shift in crime rates over-time.

It is important to note that there are several other laws related to marijuana that have passed in these states over time (for example, in 2003 Seattle voters passed an initiative to make marijuana a low priority for law enforcement). Fortunately, the interrupted time-series approach is readily adaptable to multiple interventions (Linden, 2015). We focus on recreational legalization and sales as these interventions most directly affected the ease with which individuals could obtain marijuana. As a check on robustness, we also estimated interrupted time-series models only examining legalization and these results were substantively similar.

Results

To better illustrate the trends of different types of crimes in Colorado and Washington and states that do not have broad laws legalizing marijuana, we present our results both visually and in table form. Table 2 displays the interrupted time series results for Colorado for violent and property crime, as well as results disaggregated by crime type. Each of the models presented in Table 2 also included a set of monthly dummy variables to account for month-to-month variation, but these results are not presented to improve the presentation of results. Table 3 presents the same set of models for Washington.

Overall, each of the fitted multiple group interrupted time-series models fits well (all of the likelihood ratio tests indicate that the models are superior to null models). For both of the interruption points (the legalization of recreational marijuana and the start of recreational sales), multiple group ITSA regressions produce coefficients for trends prior to the intervention, immediately after the intervention, and post-intervention effects over time. It also produces coefficients describing the differences in crime rates between treatment group (Colorado or Washington) and control group (states have no broad laws legalizing marijuana) for immediate changes associated with each intervention, and for changes in trends between the treatment and control group following each intervention.

In general, the results suggest that marijuana policies and laws have had *little effect on crime* in Colorado or Washington State. The most important rows in this chart are those that describe the difference in immediate crime rate changes between the control states and Colorado/Washington, and those that describe the difference in trends between the control states and Colorado/Washington after a specific intervention. For example, for violent crime, there were no statistically significant immediate treatment effects of legalization in Washington ($b = 2.132$, $p > .05$) or Colorado ($b = .050$, $p > .10$). This trend of non-significant results held true for most models for both states.

There were, however, some statistically significant results suggesting that legalization may have had an immediate effect on crime. In Colorado, there was a statistically significant increase in the property crime rate ($b = 28.069$) at the point of legalization, which appears to be largely driven by a statistically significant increase in larceny ($b = 20.382$). In Washington, there, there was a statistically significant increase in property

Table 3. Washington ITSA results on specific crime rates per month.

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between WA and control prior to interventions	−11.021** (.425)	12.396** (3.496)	−9.132** (.330)	14.354** (.705)	−1.267 (1.038)	−.717 (2.314)	−1.345** (.138)
Trend prior to legalization (Control)	−.051** (.003)	−.634** (.028)	−.030** (.002)	−.079** (.006)	−.050** (.007)	−.504** (.018)	−.018** (.001)
Trend prior to legalization (WA)	2.132^{+} (1.278)	−.152** (.036)	.002 (.003)	−.012 (.007)	14.117** (3.099)	−.112** (.024)	.011** (.001)
Immediate effect after recreational legalization (Control)	−2.654** (.894)	−7.238 (8.051)	−2.051** (.649)	−.412 (2.149)	−6.056** (2.009)	−.821 (5.338)	−.874* (.375)
Immediate effect difference between control and WA after recreational legalization	2.132^{+} (1.278)	24.299* (10.563)	2.034* (.987)	−1.374 (2.146)	14.112** (3.099)	11.565^{+} (6.992)	.498 (.418)
Trend after recreational legalization (Control)	.102 (.080)	−.123 (.721)	.076 (.058)	.143 (.192)	−.455* (.180)	.175 (.478)	.008 (.034)
Trend after recreational legalization (WA)	.008^{+} (.004)	1.184 (.947)	−.104 (.088)	.320^{+} (.193)	−.029** (.011)	1.075 (.627)	−.009 (.037)
Immediate effect after retail (Control)	−3.680* (1.627)	−16.577 (14.661)	−3.099** (1.183)	−1.681 (3.959)	−7.687* (3.664)	−6.892 (9.720)	−.396 (.687)
Immediate effect difference between control and WA after retail	.147 (2.331)	13.634 (19.217)	.410 (1.806)	−.695 (3.893)	3.627 (5.674)	10.865 (12.721)	−.100 (.758)
Trend after retail (Control)	.157^{+} (.089)	.596 (.806)	.114 (.065)	.044 (.217)	.360^{+} (.201)	.198 (.535)	.030 (.038)
Trend after retail (WA)	−.010 (.128)	−1.271 (1.058)	.018 (.099)	−.254 (.214)	−.003 (.311)	−1.014 (.700)	−.025 (.042)
Constant	35.628** (.427)	271.446** (3.915)	22.395** 9.303)	16.463** (1.057)	68.191** (.934)	187.365** (2.596)	9.356** (.185)
LRT	1132.253**	701.564**	1135.887**	727.398**	541.402**	559.434**	768.660**
AR(1) rho	−.015	.072	−.088	.286	−.106	.073	.209
Corrected Durbin-Watson	1.971	2.108	1.886	2.486	1.849	2.102	2.231

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

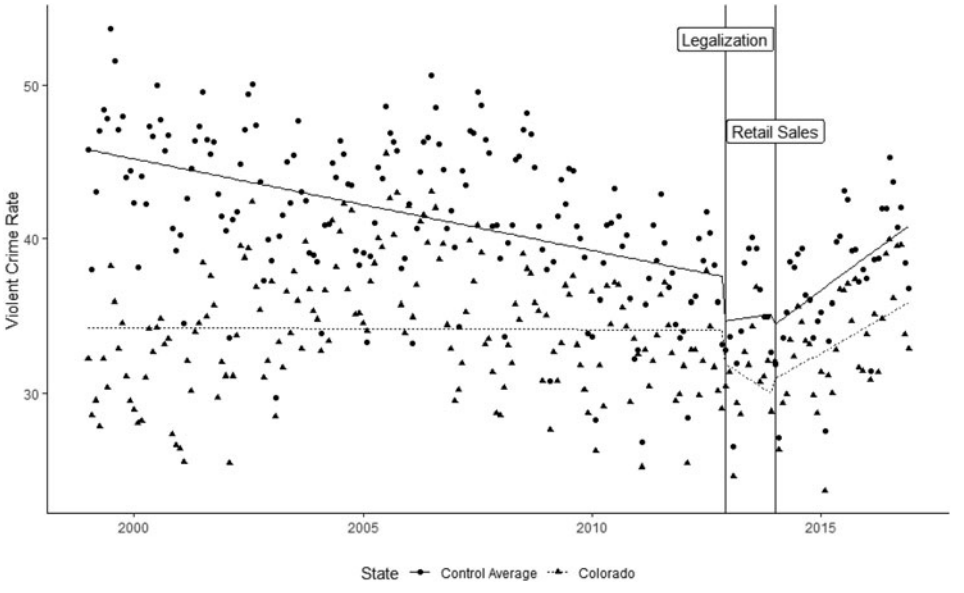

Figure 1. Violent Crime Rate per 100,000 in Colorado from 1999 to 2016.

crime overall ($b = 24.299$), burglary ($b = 14.112$), and aggravated assault ($b = 2.034$) at the point of intervention. These coefficients correspond to a one-time increase in the crime rate per 100,000 of the coefficient values listed. In the segmented regression approach utilized here, this is equivalent to shifting the intercept for the second segment of the regression model. It is important to note that none of the coefficients represented the trends or long-term effects were statistically significant, suggesting that if marijuana legalization influenced crime, it was short-lived. In fact, our models did not produce any statistically significant positive results regarding the long-term effects of legalization or retail sales on any of our measures of crime for either state. The only statistically significant result was a negative coefficient burglary in the Washington model, where burglary rates declined by .029 (per 100,000) per month following the legalization of Washington.

In summary, our results suggest that there may have been some immediate increases in crime at the point of legalization, yet there have been essentially no long-term shifts in crime rates because of legalization, aside from a decline in Burglary in Washington. Though the short-term increases might appear to suggest that marijuana increased crime, we caution against this interpretation as the increases do not reflect permanent shifts (that is, these are shifts in intercepts, not slopes) and could be artificially induced by the small number of time units between legalization and sales.

Finally, we also display our results visually. Figures 1 through 4 illustrate the interrupted time-series results for violent crime and property crime in Colorado and Washington. Figures for the disaggregated crime models are available upon request. Specifically, each plot contains dots for observed values for the control states, triangles for the observed values for Colorado/Washington, solid lines for the predicted values for the control states, and dashed lines for the predicted values for Colorado/Washington. It is important to note that these figures are not generated using the

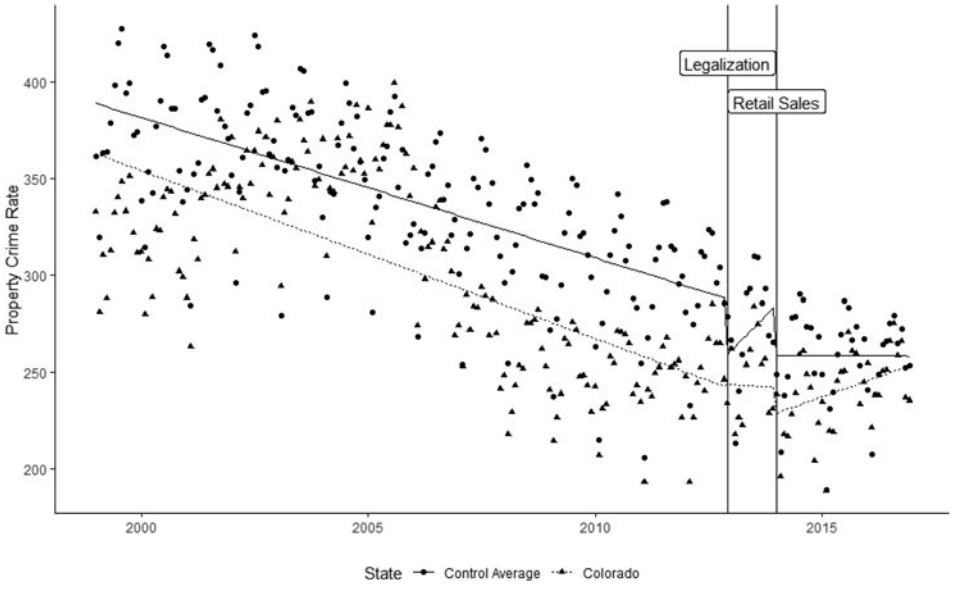

Figure 2. Property Crime Rate per 100,000 in Colorado from 1999 to 2016.

exact same models presented in Table 2. Specifically, we estimated these models without the monthly dummy variables. Though fitted lines with the monthly dummy variables show a pattern in which the predicted values track the observed values much more closely, these fitted values oscillate from month to month and make it difficult to visually track trends in crime rates. Figures accounting for monthly variation are available upon request.

These figures show an overall decline in crime for Colorado, Washington and the control states over time with a potential uptick in violent crime in later years. This is perhaps reflective of the continuation of the crime drop of the 90's (Blumstein & Wallman, 2006), which largely continued until somewhere around 2015 (Gravert & Cullen, 2016). When interpreting these curves, it is important to note that they do not match up precisely to the results in Table 2. As mentioned, the models used to generate these fitted curves do not include monthly dummy variables. But more importantly, these predicted values are mapped to observed trends in crime rates, while the coefficients in the interrupted time series models have to be interpreted in comparison to the prior time periods in the model and, for Washington, in comparison to the control state coefficients.

For violent crime, Figures 1 and 3 show that this type of crime decline most steadily for Washington and the control states from 1999 to 2012 (legalization), while violent crime was relatively flat for Colorado. Following legalization and the start of retail sales (2014), Colorado and Washington follow the same basic pattern as the control states, suggesting that legalization did not result in any major increases or decreases in crime. For property crime, the same general results are found, though there is some evidence that property crime in Colorado increased after the start of retail sales. Though this finding did not reach the traditional cutoff for statistical significance, it is important to continue to track this trend in the future, as it is possible that with more

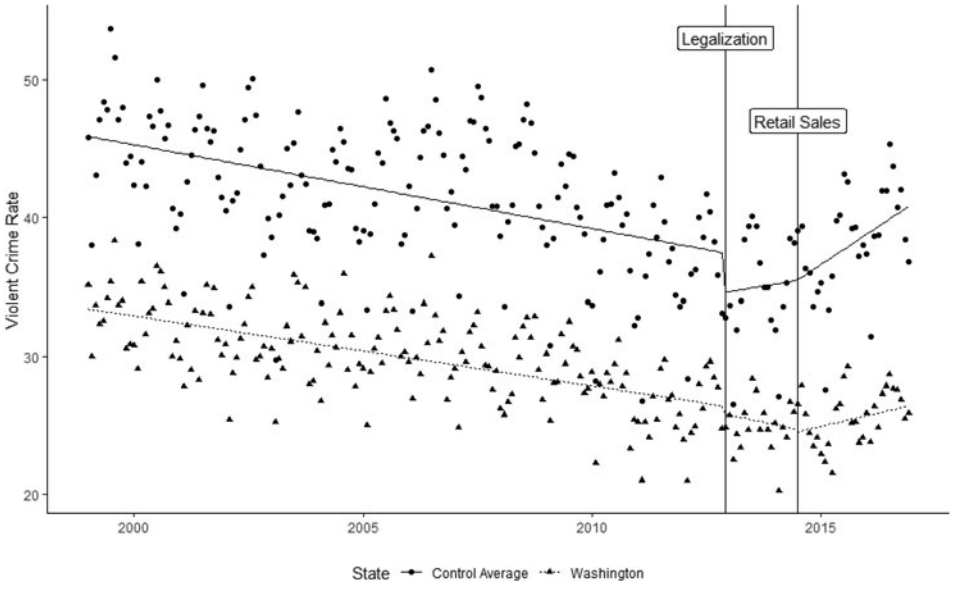

Figure 3. Violent Crime Rate per 100,000 in Washington from 1999 to 2016.

time, property crime rates in Colorado may end up increasing since the start of retail sales.

Supplementary analyses

Though the multi-intervention models presented above are a staple of the segmented interrupted time-series approach, there is some concern that the relatively short-time period between legalization and sales makes it difficult to parse out the independent effects of policy. In essence, each interruption point forces a new intercept on that particular segment of the regression line, which, when dealing with short time periods, could affect the slopes. As a robustness check, we estimated the above models again with only a single interruption point (the start of retail sales). Though we estimated single interruption models using both the point of legalization and the start of retail sales, we present the models using the start of retail sales as the intervention point below. These models are substantively similar, but if marijuana policy is to have a large effect on serious crimes, using retail sales as the intervention seems somewhat more reasonable. While legalization made marijuana legal to possess, it did not necessarily make marijuana more prevalent in the state, whereas the start of retail sales corresponded with the opening of several stores in both states and presumably increased the availability of marijuana in both states. These results are presented in Tables 4 and 5 below.

Put simply, these models further suggest that marijuana legalization has not statistical significantly affected serious crime in Washington or Colorado. The most noteworthy results from these models are the statistically significant increase for auto-theft in Colorado following the start of sales and a statistically significant decrease in violent crime in general and aggravated assault in Washington following the start of retail sales. Given the relatively high rho value, divergent Durbin Watson statistic, and

Table 4. Colorado ITSA results for start of retail sales only.

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between CO and control prior to intervention	−3.614** (1.417)	−41.057** (3.463)	−3.189** (.295)	8.249** (.788)	−18.866** (.853)	−30.445** (2.251)	−1.089* (.536)
Trend prior to retail (Control)	−.055** (.004)	−.647** (.033)	−.033** (.003)	−.078** (.008)	−.069** (.008)	−.501** (.021)	−.020** (.001)
Trend prior to retail (CO)	.047** (.004)	−.075* (.037)	.032** (.003)	−.046** (.008)	−.051** (.009)	.021 (.024)	.009** (.002)
Immediate effect after retail (Control)	−4.981** (1.417)	−19.122 (12.301)	−3.787** (1.047)	−.934 (3.038)	−10.877** (2.867)	−7.401 (7.849)	−1.089* (.536)
Immediate effect difference between control and CO after retail	.298 (1.670)	.688 (13.887)	.134 (1.183)	−6.292* (3.164)	5.592 (3.418)	1.416 (9.027)	−.235 (.771)
Trend after retail (Control)	.240** (.043)	.415 (.371)	.166** (.032)	.152 (.092)	−.095 (.086)	.361 (.237)	.040* (.016)
Trend after retail (CO)	−.077 (.050)	.820 (.420)	−.066 (.036)	.359** (.095)	.086 (.103)	.377 (.272)	−.003 (.023)
Constant	34.864** (.570)	270.518** (4.948)	21.675** (.421)	16.222** (1.218)	65.447** (1.152)	189.206** (3.157)	9.415** (.209)
LRT	730.445**	571.157**	749.176**	554.935**	829.506**	734.460**	591.085**
AR(1) rho	.159	.192	.191	.246	.150	.178	−.022
Corrected Durbin-Watson	2.202	2.320	2.227	2.430	2.220	2.275	1.974

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

Table 5. Washington ITSA results for start of retail sales only.

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between WA and control prior to intervention	−10.671** (.339)	23.765** (3.072)	−8.787** (.266)	14.870** (.567)	2.699** (.921)	6.223** (1.960)	−1.213** (.110)
Trend prior to retail (Control)	−.056** (.003)	−.659** (.024)	−.034** (.002)	−.076** (.006)	−.081** (.006)	−.502** (.016)	−.021** (.001)
Trend prior to retail (WA)	.012** (.004)	−.048 (.033)	.005 (.003)	−.007 (.006)	.007 (.010)	.368 (.255)	.012** (.001)
Immediate effect after retail (Control)	−5.780** (1.428)	−21.023 (13.138)	−4.723** (1.037)	−2.422 (3.478)	−10.436* (3.504)	−7.840 (8.934)	−1.011 (.613)
Immediate effect difference between control and WA after retail	1.945 (2.005)	26.589 (18.160)	2.109 (1.562)	−2.669 (3.376)	13.083* (5.409)	15.462 (11.608)	.282 (.650)
Trend after retail (Control)	.264** (.041)	.495 (.375)	.193** (.030)	.185 (.099)	−.065 (.100)	.368 (.255)	.040* (.018)
Trend after retail (WA)	−.127* (.057)	−.192 (.518)	−.090* (.045)	.063 (.096)	−.235 (.154)	−.002 (.331)	−.036 (.019)
Constant	35.016** (.392)	269.044** (3.625)	21.928** (.278)	16.743** (.967)	64.894** (.926)	187.732** (2.495)	9.046** (.172)
LRT	1118.349**	664.296**	1119.074**	717.845**	452.847**	507.110**	755.982**
AR(1) rho	.006	.022	−.072	.299	−.104	.081	.241
Corrected Durbin-Watson	1.996	2.034	1.901	2.511	1.841	2.119	2.273

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

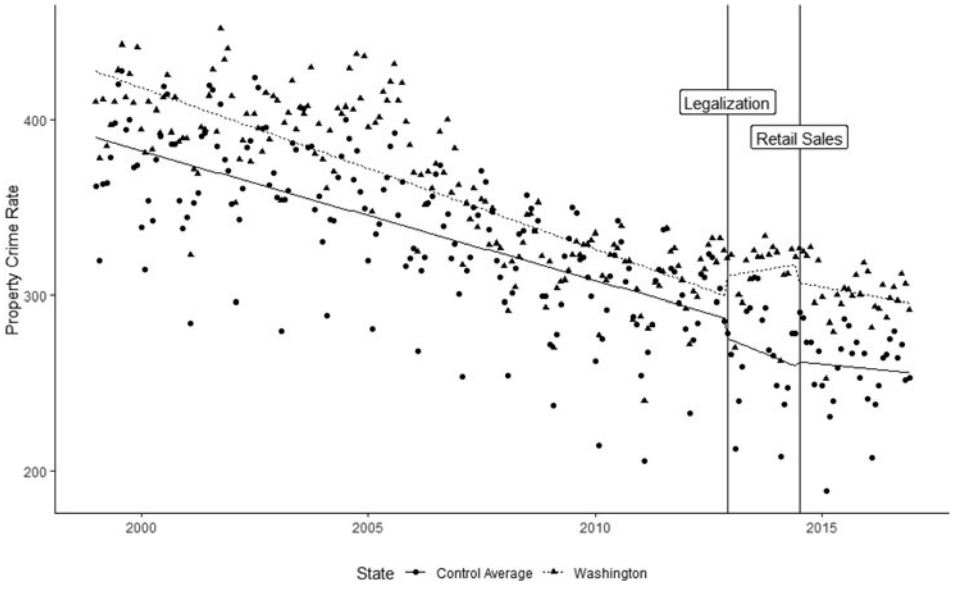

Figure 4. Property Crime Rate per 100,000 in Washington from 1999 to 2016.

nonstationarity results for auto-theft, these results, while statistically significant, must be viewed cautiously. Lastly, we also estimated a pooled time-series regression model in which Washington and Colorado were included with the 21 states which had no marijuana legalization or mediazation laws. These results (available upon request) were substantively similar, showing no general effect of marijuana legalization or sales on index crime rates.

Conclusions

Authors of previous studies (Berenson, 2019; NHIDTA, 2016; Smart Approaches to Marijuana. (2018) argue that legalization is associated with an increase in crime. Our results suggest that cannabis laws more broadly, and the legalization of recreational marijuana more specifically, have had minimal effect on major crime in Colorado or Washington State. We observed virtually no statistically significant long-term effects of recreational marijuana legalization or retail sales on violent or property crime rates, except for a significant decline of burglary rates in Washington. There were some immediate increases in crime at the point of legalization, but these did not result in long-term effects. It is difficult to study trends for less serious crimes, as the UCR only includes arrest data for these offenses and not offenses known. Though NIBRS data presents an attractive alternative, not all of Washington is NIBRS compliant and many of the agencies that are reporting NIBRS data have not done so for a long enough period of time pre-legalization for time series modeling to be examined. Still, the results related to serious crime are quite clear: the legalization of marijuana has not resulted in a significant upward trend in crime rates. Our results are robust in that we examined the first two states to legalize marijuana and compared them to states with no marijuana laws at all. Moreover, we estimated our models in a variety of manners,

including models with different interruption points, single-group interrupted time series analyses, and as a set of pooled cross-sectional models. None of our models revealed long term effects of marijuana legalization on serious crime rates.

In concert with recent research results from Makin et al. (2019), our results from Colorado and Washington suggest that legalization has not had major detrimental effects on public safety. Having said this we would caution that it would also be premature to suggest that legalization renders substantial increases in public safety, as the rates of most crimes remained steady in this study in the post-legalization period and because crime is not the only measure of public safety. Additional work is needed to examine the effect of legalization on other public safety outcomes, including public and mental health measures.

Though our results are robust to modeling choices and control group specifications and the multiple-group interrupted time series methodology is excellent for calculating estimated causal effects, these results are not without limitations. As previously mentioned, our results examine changes in serious crime and it is possible that marijuana laws might be more likely to affect other types of crime, including cannabis related DUIs. In addition to this, we cannot rule out the possibility that marijuana laws might have different effects on different types of communities within a state. Given that this is not a true experiment, it is important to acknowledge that these results are ultimately correlational in nature, though we have attempted to marshal as much comparative logic as possible to document changes that can be attributable to marijuana laws. In terms of specific limitations, the auto-theft models continue to exhibit issues related to autocorrelation and nonstationarity. As such, these results should be viewed as tentative.

Another broad shortcoming is that crime rates are also affected by criminal sanctions, law enforcement efforts, and a variety of other possible factors. For example, many states that have legalized recreational marijuana have earmarked tax revenue for increased law enforcement resources (Bryant, 2017), which, if effective, could be compensating for cannabis's tendency to increase criminality. Though we believe that state-level differences are an important starting point (indeed, our analysis echoes much of the prior work examining state-based medical marijuana laws), future work should examine individual jurisdictions to see if some communities are more or less affected by the legalization of marijuana. Indeed, a disaggregated approach is essential to fully understand the scope of marijuana laws and their effects on crime, law enforcement, and public safety.

As aforementioned, a lack of robust research studies and overreliance on limited pre-post analysis perpetuate a state of confusion concerning to what extent legalization influences crime. As we conclude, we believe it is an opportune moment to restate that this is but one study, and we would be remiss to offer to policy makers that it is proof-evidence that legalization did not affect crimes negatively. Rather, the present study is but one of many that are needed to provide the public and policy makers with results generated from more robust and rigorous research designs. Importantly, this design, and improved versions, must be replicated, because it is through replication that we will find an ultimate answer to the question of the impact of the legalization of marijuana on crime.

Given the likelihood of further liberalization of state and even federal marijuana laws, it is imperative that policy makers and research funders allocate the necessary resources to conduct these more rigorous and intensive types of contextualized studies. Large-scale policy shifts can take a considerable amount of time to produce stable and understandable effects. It took 40 years following the repeal of alcohol prohibition for alcohol consumption to reach pre-prohibition levels (Hall, 2010), and research to date on cannabis legalization suggests that it is likely too soon to fully understand the effects of marijuana legalization in the United States (Hall & Lynskey, 2016).

Disclosure statement

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Appendix A: Colorado ITSA results on the natural logarithm of specific crime rates per month

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between CO and control prior to interventions	−.094** (.013)	−.173** (.012)	−.125** (.015)	.380** (.022)	−.336** (.016)	−.181** (.011)	−.175** (.024)
Trend prior to legalization (Control)	−.001** (.0001)	−.002** (.0001)	−.001** (.0001)	−.004** (.0003)	−.001** (.0001)	−.002** (.0001)	−.002** (.0002)
Trend prior to legalization (CO)	.001** (.0001)	−.001** (.0001)	.001** (.0002)	−.0004 (.0002)	−.001** (.0002)	−.0004** (.0001)	.001** (.002)
Immediate effect after recreational legalization (Control)	−.067 (.039)	−.049 (.041)	−.080 (.045)	−.080 (.103)	−.100* (.046)	−.029 (.037)	−.082 (.060)
Immediate effect difference between control and CO after recreational legalization	−.008 (.047)	.107* (.044)	−.092 (.053)	.152 (.081)	.069 (.057)	.111* (.041)	.079 (.083)
Trend after recreational legalization (Control)	.003 (.005)	.002 (.006)	.003 (.006)	.011 (.014)	−.004 (.006)	.004 (.005)	−.002 (.008)
Trend after recreational legalization (CO)	−.004 (.006)	−.006 (.006)	.002 (.007)	−.011 (.011)	−.003 (.008)	−.007 (.006)	−.015 (.011)
Immediate effect after retail (Control)	−.079 (.052)	−.041 (.056)	−.093 (.061)	−.011 (.145)	−.110 (.061)	−.023 (.050)	−.071 (.080)
Immediate effect difference between control and CO after retail	−.006 (.062))	−.099 (.059)	.051 (.071)	−.276* (.108)	−.014 (.076)	−.094 (.054)	−.165 (.112)
Trend after retail (Control)	.003 (.005)	−.001 (.006)	.003 (.006)	−.002 (.014)	.002 (.006)	−.002 (.005)	.006 (.008)
Trend after retail (CO)	.003 (.006)	.010 (.006)	−.004 (.007)	.020 (.011)	.005 (.008)	.009 (.006)	.017 (.012)
Constant	3.579 (.016)	5.613** (.017)	3.089** (.019)	2.763** 9.044)	4.207** (.019)	5.253** 9.016)	2.259** (.025)
LRT	727.785**	611.371**	762.374**	555.870**	892.325**	753.788**	595.617**
AR(1) rho	.148	.236	.170	.458	.125	.227	.010
Corrected Durbin-Watson	2.177	2.387	2.177	2.779	2.180	2.341	2.009

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

Appendix B: Washington ITSA results on the natural logarithm of specific crime rates per month

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between WA and control prior to interventions	−.337** (.009)	.046** (.011)	−.462** (.010)	.633** (.016)	−.014 (.015)	.003 (.010)	−.152** (.013)
Trend prior to legalization (Control)	−.001** (.0009)	−.002** (.0008)	−.001** (.0001)	−.004** (.0003)	−.001** (.0001)	−.002** (.0001)	−.002** (.0001)
Trend prior to legalization (WA)	−.002 (.001)	−.0003** (.0001)	−.0005** (.0001)	.001** (.0002)	−.0004* (.0002)	−.0004** (.0001)	.001* (.0001)
Immediate effect after recreational legalization (Control)	−.072** (.024)	−.037 (.024)	−.085** (.027)	−.036 (.078)	−.088** (.029)	−.018 (.023)	−.096* (.041)
Immediate effect difference between control and WA after recreational legalization	.043 (.026)	.085** (.033)	.067* (.031)	.014 (.049)	.204** (.046)	.056 (.031)	.051 (.040)
Trend after recreational legalization (Control)	.003 (.002)	−.001 (.002)	.003 (.002)	.005 (.007)	−.008** (.003)	.001 (.002)	.004 (.004)
Trend after recreational legalization (WA)	−.003 (.002)	.004 (.003)	−.005 (.003)	.007 (.004)	−.002 (.004)	.005 (.003)	−.001 (.004)
Immediate effect after retail (Control)	−.095* (.044)	−.059 (.044)	−.128** (.049)	−.094 (.152)	−.130* (.052)	−.033 (.042)	−.047 (.076)
Immediate effect difference between control and WA after retail	−.028 (.048)	.049 (.060)	.031 (.056)	.005 (.089)	.079 (.084)	.053 (.056)	−.024 (.073)
Trend after retail (Control)	.004 (.002)	.002 (.002)	.005 (.003)	.005 (.008)	.006* (.003)	.001 (.002)	.004 (.004)
Trend after retail (WA)	.001 (.003)	−.004 (.003)	.003 (.003)	−.009 (.005)	−.002 (.005)	−.005 (.003)	−.002 (.004)
Constant	3.578** (.012)	5.614** (.012)	3.098** (.013)	2.752** (.03)	4.220** (.013)	187.365** (2.596)	2.224** (.020)
LRT	1237.999**	731.653**	1276.559**	977.192**	541.402**	592.087**	785.702**
AR(1) rho	.223	.043	.176	.561	−.146	.045	.298
Corrected Durbin-Watson	2.206	2.064	2.120	2.901	1.804	2.066	2.297

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

Appendix C: Colorado ITSA results on the natural logarithm of specific crime rates per month for start of retail sales only

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between CO and control prior to intervention	−.102** (.011)	−.160** (.011)	−.145** (.012)	.402** (.019)	−.325** (.013)	−.163** (.010)	−.179** (.020)
Trend prior to retail (Control)	−.001** (.0001)	−.002** (.0001)	−.001** (.0001)	−.004** (.0003)	−.001** (.0001)	−.002** (.0001)	−.002** (.0001)
Trend prior to retail (CO)	.001** (.0001)	−.001** (.0001)	.001** (.0001)	−.0002 (.0002)	−.001** (.0001)	−.0002* (.0001)	.0007** (.0002)
Immediate effect after retail (Control)	−.132** (.039)	−.081* (.040)	−.156** (.047)	−.094 (.106)	−.178** (.047)	−.051 (.037)	−.131* (.060)
Immediate effect difference between control and CO after retail	−.006** (.045)	−.009 (.044)	−.021 (.051)	−.148 (.078)	.044 (.054)	−.0006 (.040)	−.082 (.080)
Trend after retail (Control)	.006** (.001)	.001 (.001)	.007** (.001)	.009** (.003)	−.002 (.001)	.002 (.001)	.005* (.002)
Trend after retail (CO)	−.001** (.001)	.004** (.001)	−.002 (.002)	.009** (.002)	.002 (.002)	.003* (.001)	.001 (.002)
Constant	3.565** (.016)	5.606** 9.016)	3.072** (.019)	2.759** (.041)	4.175** (.019)	189.206** (3.157)	2.237** (.024)
LRT	712.209**	602.424**	732.718**	751.558**	867.413**	740.265**	575.842**
AR(1) rho	.186	.218	.225	.454	.174	.215	.047
Corrected Durbin-Watson	2.227	2.361	2.254	2.781	2.253	2.329	2.048

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

Appendix D: Washington ITSA results on the natural logarithm of specific crime rates per month for start of retail sales only

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between WA and control prior to intervention	−.332** (.007)	.085** (.010)	−.454** (.008)	.658** (.013)	.048** (.014)	.036** (.009)	−.140** (.010)
Trend prior to retail (Control)	−.001** (.0001)	−.002** (.0001)	−.001** (.0001)	−.004** (.0001)	−.002** (.0009)	−.002** (.0001)	−.002** (.0001)
Trend prior to retail (WA)	−.0001 (.0001)	.0001 (.0001)	−.0004** (.0001)	.001* (.0001)	.0002 (.0001)	−.0001 (.0001)	.001** (.0001)
Immediate effect after retail (Control)	−.152** (.040)	−.082* (.040)	−.194** (.044)	−.148** (.131)	−.164** (.051)	−.046 (.038)	−.113 (.068)
Immediate effect difference between control and WA after retail	.011 (.041)	.095 (.058)	.029 (.048)	−.010 (.078)	.215** (.080)	.076 (.053)	.017 (.062)
Trend after retail (Control)	.007** (.001)	.002 (.001)	.008 (.001)	.011** (.004)	−.001 (.001)	.002 (.001)	.004* (.002)
Trend after retail (WA)	−.001 (.001)	−.001 (.002)	−.002 (.001)	−.002 (.002)	−.004 (.002)	−.002 (.002)	−.004* (.002)
Constant	3.561** (.011)	5.602** (.011)	3.078** (.012)	2.756** (.034)	4.167** (.013)	5.247** (.010)	2.187** (.019)
LRT	1224.793**	6984.329**	1260.254**	964.821**	501.924**	544.074**	772.397**
AR(1) rho	.262	−.035	.212	.570	−.125	.021	.340
Corrected Durbin-Watson	2.247	1.946	2.156	2.919	1.814	2.031	2.348

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$

Appendix E: Colorado ITSA models for start of legalization only

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between CO and control prior to intervention	−3.366** (0.489)	−45.423** (3.963)	−2.824** (.348)	7.949** (.923)	−19.987** (.993)	−33.388** (2.589)	−.1493** (.228)
Trend prior to legalization (Control)	−.051** (.004)	−.633** (.037)	−.030** (.003)	−.079** (.009)	−.050** (.008)	−.503** (.023)	−.018** (.002)
Trend prior to legalization (CO)	.049** (.005)	−.115** (.041)	.035** (.004)	−.049** (.010)	−.061** (.010)	−.005 (.027)	.009** (.002)
Immediate effect after legalization (Control)	−3.512** (.834)	−10.747 (7.453)	−2.614** (.602)	−.527 (1.830)	−8.357** (1.659)	−1.853 (4.694))	−1.088* (.319)
Immediate effect difference between control and CO after legalization	−.387 (1.014)	12.597 (8.222)	−.963 (.721)	−1.584 (1.916)	4.606* (2.059)	9.593 (5.370)	.077 (.471)
Trend after legalization (Control)	.180** (.027)	.116 (.237)	.120** (.019)	.143* (.058)	−.245** (.053)	.217 (.149)	.032** (.010)
Trend after legalization (CO)	−.068* (.032)	.634* (.262)	−.048* (.023)	.234** (.061)	.154* (.065)	.245 (.171)	−.013 (.015)
Constant	35.344** (.594)	271.646** (5.311)	22.027** (.429)	16.125** (1.301)	67.470** (1.180)	188.651** (3.347)	9.640** (.219)
LRT	732.061**	793.367**	760.772**	524.686**	851.414**	886.101**	604.899**
AR(1) rho	.135	.208	.147	.244	.112	.182	−.049
Corrected Durbin-Watson	2.169	2.347	2.166	1.509	2.170	2.279	1.944

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.

Appendix F: Washington ITSA models for start of legalization only

	Violent Crime	Property Crime	Agg. Assault	Auto Theft	Burglary	Larceny	Robbery
Difference between WA and control prior to intervention	−11.020** (.418)	12.367** (3.484)	−9.132** (.324)	14.346** (.707)	−1.273 (1.029)	−.727 (2.312)	−1.345** (.138)
Trend prior to legalization (Control)	−.051** (.003)	−.634** (.028)	−.030** (.329)	−.079** (.008)	−.050** (.007)	−.504** (.018)	−.018** (.001)
Trend prior to legalization (WA)	.009* (.004)	−.152** (.036)	.002 (.003)	−.012 (.007)	−.029** (.011)	−.112** (.024)	.011** (.001)
Immediate effect after legalization (Control)	−3.653** (.618)	−10.873 (5.533)	−2.745** (.449)	−.712 (1.500)	−8.444** (1.386)	−1.941 (3.670)	−1.090** (.258)
Immediate effect difference between control and WA after legalization	2.207* (.865))	33.805** (7.216)	1.858** (.669)	.843 (1.468)	13.890** (2.122)	19.161** (4.789)	.714* (.285)
Trend after legalization (Control)	.183** (.020)	.114 (.176)	.123** (.014)	.149** (.048)	−.244** (.044)	.214 (.117)	.032** (.008)
Trend after legalization (WA)	−.121** (.028)	.051 (.230)	−.071** (.021)	−.007 (.047)	−.114 (.067)	.170 (.152)	−.042** (.009)
Constant	35.615** (.432)	271.373** (3.912)	22.394** (.308)	16.448** (1.061)	68.210** (.940)	187.295** (2.598)	9.358** (.184)
LRT	1121.926**	697.734**	1120.984**	720.538**	531.921**	554.895**	766.807**
AR(1) rho	.008	.075	−.059	.289	−.092	.074	.208
Corrected Durbin-Watson	2.001	2.113	1.921	2.491	1.868	2.104	2.230

n = 432. Prais-Winsten Corrected standard errors in parentheses.
$^{+}p < .1$.
$^{*}p < .05$.
$^{**}p < .01$.