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THE EFFECT OF MARIJUANA LEGALIZATION
ON NEIGHBORHOOD CRIME

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The Effect of Marijuana Legalization on Neighborhood Crime

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Abstract

This paper studies the effects of marijuana legalization on neighborhood crime using unique geospatial data from Denver, Colorado. We construct a highly local panel data set that includes changes in the location of marijuana dispensaries and changes in neighborhood crime. To account for endogenous retail dispensary locations, we use a novel identification strategy that exploits exogenous changes in demand across different locations. The change in geographic demand arises from the increased importance of access to external markets caused by a change in state and local policy. The results imply that retail dispensaries lead to reduced crime in the neighborhoods where they are located. Reductions in crime are highly localized, with no evidence of benefits for adjacent neighborhoods. The spatial extent of these effects are consistent with a policing or security response, and analysis of detailed crime categories provides indirect evidence that the reduction in crime arises from a disruption of illicit markets.

Keywords: legalization, drugs, crime, policy evaluation
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1 Introduction

After Colorado and Washington became the first U.S. states to legalize recreational marijuana in 2012, the number of states legalizing or decriminalizing the sale and use of marijuana quickly expanded. After a wave of ballot initiatives in 2016, the sale and use of marijuana for recreational purposes was legal in 7 states, and another 22 states had legalized medical use. As states legalize the manufacturing, distribution, and sale of marijuana, the local health, economic, crime, and safety effects of marijuana dispensaries have become an important public policy issue. The local effects of marijuana dispensaries on neighborhoods are important for understanding aggregate effects of legalization and for policies designed to address concerns of residents who are broadly open to legalization but have a "not in my backyard" attitude toward dispensaries near their homes.[1]

The economic welfare and public policy implications of marijuana legalization are broad in scope and stem from several primary sources. First, given that legalization improves access to marijuana and presumably reduces prices, in the long run, legalization could affect local health, economic, crime, and safety outcomes due to increased marijuana use.[2] Second, legalization may displace illicit markets affecting neighborhood outcomes, including crime or access to other illegal drugs.[3] Third, marijuana dispensaries may have social or economic spillover effects that may affect welfare. Finally, there are direct implications for public finance through increased tax revenue and decreased enforcement costs.[4]

Our paper focuses on the short-run causal effects of marijuana legalization on neighborhood crime. To date, we are unaware of any research that studies the effects of full marijuana legalization on local crime, although several papers have analyzed local effects of decriminalization polices or legalization of medical marijuana.[5] Two papers study aggregate effects of crime from decriminalization and legalization policies. Adda, McConnell, and Rasul (2014) study the effects of a

[1] The *Denver Post* reported that, "So far, the conflicts over pot sales ... have been confined to individual neighborhoods and are driven largely by a 'not in my backyard' mentality rather than by a wider denunciation of the entire industry." Aguilar (2015),

[2] Becker, Grossman, and Murphy (2006) provide an economic theory of prohibition that considers price elasticities of supply and demand.

[3] Displacement of illicit markets for marijuana or other illegal drugs can have important implications given that drug markets are subject to returns to scale in both supply and demand. See Jacobson (2004) for detailed discussion of the interaction between crime and drug markets.

[4] We provide a review of recent related literature and the broader policy implications of legalization in Section 2.

[5] In addition, two recent papers have looked at the local effects of legalization on house prices: Cheng, Mayer, and Mayer (2016) and Conklin, Diop, and Li (2016).

depenalization policy in a borough of London, exploiting time variation from a policy change. The authors found that the decriminalization policy led to an aggregate decrease in crime arising from reallocation of police resources but also a decrease in home values, suggesting a welfare loss. Huber, Newman, and LaFave (2016) use cross-sectional variation in state policies and panel data between 1970 and 2012 and find evidence that the legalization of medical marijuana reduces robberies, larcenies, and burglaries, although they find that decriminalization has no effect on crime. We expand on these aggregate studies by considering local variation in crime outcomes within a jurisdiction that has legalized marijuana. Our approach is related to that of Freishtler, Ponicki, Gaidus, and Greunewald (2016) who study the effect of medical marijuana on neighborhood crime in Long Beach, California, and exploit a change in policy that led to the closing of dispensaries. They show that there was no change in crime locally but found positive correlations between increased crime and the dispensary density in adjacent neighborhoods. In addition, Chang and Jacobson (2017) also exploit the unexpected closing of dispensaries in California to identify the effect on crime. They find the somewhat different result that there is a temporary increase in crime very near the dispensaries after the have closed that dissipates over time.[6] Our research expands on this work in an important way by accounting for the endogenous location of dispensaries in neighborhoods. In addition, we study both recreational and medical marijuana dispensaries and utilize panel data that capture both dispensary openings and closings.

In this paper, we investigate the local effects of marijuana legalization on neighborhood crime in Denver, Colorado, which was the first state to fully legalize marijuana use, sales, and production for medical and recreational purposes. One contribution of our research is the construction of a unique and rich geospatial data set.[7] To measure dispensary locations, we use panel data from the State of Colorado that provide exact locations of dispensary licenses at monthly frequencies. Our primary measure of crime comes from the city of Denver and includes the location, date, and type of crime committed. We construct a detailed location-specific measure of available land using data on zoning, geographic features, and legal restrictions on dispensary locations, which we augment with demographic and employment data provided by the U.S. Census.

[6] We also find that the presence of a dispensary results in a reduction in crime, but our results suggest the effect is more permanent. Our results are also similar in terms of the geographic extent of the effects and the types of crime that are affected.

[7] See Section 5 for a detailed description of the data.

Initial analysis of the data shows that the locations of dispensaries are not randomly allocated across space or neighborhood characteristics. Dispensaries are more concentrated in areas with higher poverty, higher minority populations, and higher initial employment density. Correlations between the growth of new dispensaries and neighborhood characteristics have strengthened over time, demonstrating the importance of controlling for endogenous dispensary locations. Previous studies on local crime effects have not directly addressed the endogeneity of dispensary locations.

A major contribution of our paper is that we employ a novel identification strategy that exploits shifts in demand across location over time to analyze causal effects of marijuana legalization on crime. While the legalization of recreational marijuana in 2014 applied to the entire state, many municipalities within Colorado prohibit sales within their own jurisdictions. Residents living in municipalities near Denver that prohibit recreational sales often travel to Denver to purchase marijuana. Therefore, locations within Denver that have more access to demand from neighboring municipalities show more growth in their dispensary density, ceteris paribus. In addition, out-of-state tourists could purchase marijuana starting in 2014, further increasing the demand for dispensaries in locations with access to broader outside markets. In the empirical analysis, we use two geospatial variables to proxy for access to outside demand: a neighborhood's proximity to municipal borders and proximity to major roads or highways. These variables are then used to instrument for changes in locations of dispensaries over time.[8] We combine our instrumental variables (IV) with our panel data to compare changes in crime with changes in dispensary density and use month fixed effects to control for municipality-level changes in crime.

Note that a particular advantage of our identification strategy relative to others is that it relies on variation within a single jurisdiction. Studies that use differences in policies across jurisdictions suffer from endogeneity if the policy decision is correlated with unobserved characteristics of a municipality. In our setting, the policy change is the same for all locations in the study, and the variation in treatment is due to an exogenous shift in external demand.

Our main IV results imply that receiving a dispensary in a neighborhood causes a reduction in crime. In particular, an additional dispensary per 10,000 residents is associated with a reduc-

[8] Although the details of identification strategy are different, this approach is related to the literature that uses policy discontinuities across jurisdictional borders for other applications. Examples include Harding, Leibtag, and Lovenheim (2012) (cigarette taxes); Agrawal (2015) (local sales taxes); Holmes (1998) (manufacturing activity); and Card and Krueger (1994) (minimum wage).

tion of 17 crimes per 10,000 residents per month. The magnitude of these results is substantial given that the average number of crimes per 10,000 residents is 90 per month. These IV results are robust across a number of specifications. The results from the ordinary least squares (OLS) specification, on the other hand, are positive, reflecting that dispensaries are on average selected into neighborhoods with increasing crime.

In addition to finding an overall reduction in crime when a dispensary is added to a neighborhood, we also find that there is some variation across crime categories. The effect is generally strongest for nonviolent crimes; specific crimes most affected include criminal trespassing, public-order crimes, criminal mischief, and simple assault. There are also reductions in violent crimes driven by a decrease in aggravated assault, although results are not statistically significant. Reductions in these crimes are consistent with disruption of illicit markets. We do not find strong evidence that legalization disrupts the sale of other illicit drugs. While our point estimates suggest that sales of other drugs decline, the estimates are not statistically significant. In addition, we do not find significant increases in marijuana-related crimes, which are tracked separately by the City of Denver, which implies that there are not large crime effects from increased marijuana use itself.

Lastly, we find that the reduction in crime is very localized and contained within the census tract of the dispensary's location. We test for spillover effects by regressing changes in crime on the predicted change in dispensary density both within that tract and from the closest neighboring tract (from our first-stage regression). We find no significant effects of neighboring dispensary density on crime.

Overall, our results suggest that dispensaries cause an overall reduction in crime in neighborhoods, with no evidence of spillover to surrounding neighborhoods. Reductions in specific crimes are consistent with the disruption of illicit markets, and there is no evidence that increased marijuana use itself results in additional crime. Furthermore, the local nature of these effects would also be consistent with increased policing or private security response near the dispensaries. These findings may point to an aggregate reduction in crime due to legalization, but further investigation would be needed to rule out a reshuffling of crime to other neighborhoods. More generally, there is potential for further research to understand the underlying mechanisms that lead to the change in crime after legalization.

The rest of the paper is organized as follows. Section 2 discusses the policy implications of

legalization and related literature. Section 3 provides background and descriptive data analysis of legalization in Colorado. Section 4 outlines the empirical methodology and identification strategy. Section 5 gives a detailed description of data collection and construction. Section 6 presents the main results. Section 7 provides some additional analysis and discussion. Finally, Section 8 concludes.

2 Policy Implications and Related Literature

This section outlines the important policy implications of legalization and summarizes existing literature. Caulkins, Kilmer, and Kleiman (2016), Anderson and Rees (2014), and Miron and Zweibel (1995) provide more comprehensive summaries of the broad issues surrounding legalization than are provided here. Recent research provides insights on some of the potential effects of legalization. Given that legalization will likely lead to increased consumption, the effects of marijuana use itself could become more prevalent.[9] Previous research suggests that increased consumption could decrease educational obtainment, negatively affect health and well-being, inhibit brain development, or increase fatalities and injuries from drugged driving.[10] Dispensaries could also be perceived to be a disamenity by the public, thus decreasing local housing prices or harming local businesses. In contrast, legalization could also have positive effects. Increased accessibility could provide positive medicinal effects or may be a substitute for the consumption of other more harmful drugs.[11] Legalization might also improve social outcomes from decreases in incarceration rates and enforcement costs. In addition, there are direct impacts on local and state budgets from increased

[9] Jacobi and Sovinsky (2016) estimate the effects of increased access on consumption using Australian data and predict that consumption could increase by nearly 50 percent under legalization. In the case of alcohol, Dills, Jacobson, and Miron (2005) find evidence of decreased consumption during the prohibition in the U.S. between 1920 and 1933.

[10] Van Ours and Williams (2009) find small negative effects of early cannabis use with educational obtainment. Van Ours and Williams (2013) use data from the Netherlands, and their "results suggest that cannabis use reduces the mental well-being of men and women and the physical well-being of men." Blake and Finlaw (2014) outline public policy concerns over drugged driving. Anderson, Hansen, and Rees (2013) show that marijuana legalization is associated with an 8 to 11 percent decrease in traffic fatalities resulting from a substitution effect between marijuana and alcohol.

[11] The Institute of Medicine released a comprehensive report on the medical benefits of marijuana in 1999, which was summarized by Watson, Benson, and Joy (2000). The report found moderate evidence of some medicinal benefits, and encouraged increased research. Bachuber, Saleoner, and Cunningham (2014) find decreased opioid overdoes and mortality rates in states with medical marijuana. Anderson, Hansen, and Rees (2013) find evidence suggesting that marijuana acts as a substitute for alcohol among adolescents and that legalization would therefore be associated with a reduction in alcohol-related traffic accidents.

tax revenues.[12] The state sales tax rate in Colorado is substantial at 27.9 percent for recreational marijuana (plus municipal taxes where applicable). This amounted to revenues each year between 2014 and 2016 of $44.9, $76.2, and $102.7 million, respectively.[13]

In this paper, we focus on the short-run effects of legalization on crime. Existing theories provide different predictions for the effects of legalization on crime. Crime may increase if drug use itself contributes to criminal behavior. For example, Grogger and Willis (2000), using cross-city comparisons, find evidence of increased crime during the crack epidemic in the 1980s and 1990s. Luca, Owens, and Sharma (2015) also find that prohibition of alcohol reduces violence against women. Nevertheless, previous researchers, including Resignato (2000), have found little evidence of a connection between marijuana use and criminal behavior. Increases in crime may also occur from legalization if marijuana arrests lead to incarceration of individuals prone to criminal activity. The evidence for this is indirect and mixed. Kuziemko and Levitt (2004) find a small correlation between increased incarceration and reduced crime, while Green and Winik (2010) find that incarceration has no effect on recidivism, using variation from random judge assignments. Legalization can increase local crime if dispensaries become targets for crime. An important characteristic of marijuana dispensaries is that they are primarily a "cash only" business. This stems from the fact that, since marijuana is illegal at the federal level, dispensaries are banned from accessing traditional banking services. Therefore, marijuana dispensaries could potentially have a differential impact on crime compared to other types of retail estabilshments.

Legalization will reduce crime if it disrupts illicit markets, which are susceptible to criminal activity. This is the conventional wisdom for explaining the increase in crime during alcohol prohibition in the 1920s. Owens (2014) indeed finds that prohibition of alcohol led to increases in organized crime, even if there were some benefits due to decreased alcohol consumption. Similarly, Bisschop, Kastoryano, and van der Klaauw (2017), using evidence from legal prostitution zones in Dutch cities, find that legalization of prostitution leads to a reduction of crime. In addition, crime reductions may occur from legalization due to the shifting of resources away from marijuana enforcement toward other criminal activity. Crime within a neighborhood may decrease after a

[12]Research includes work by Kling (2006), who finds no effect on labor market outcomes using variation in prison sentence duration, and Charles and Luoh (2010), who find negative effects for women from male incarceration through general equilibrium effects in the marriage market.

[13]Data provided by the State of Colorado. "Marijuana Tax Data." Department of Revenue. Accessed February 9, 2017. https://www.colorado.gov/pacific/revenue/colorado-marijuana-tax-data.

new dispensary is opened if the new dispensary increases private security or if police change their enforcement responses around dispensaries.[14]

The contradicting theories for how legalization will affect crime rates call for further research. Initial evidence on legalization suggests a reduction in crime.[15] Our research complements and builds on this literature while accounting for both the endogeneity of policy and the endogeneity of retail dispensary locations. In addition, we provide further insights into the mechanisms that lead to this reduction in crime.

3 Background and Descriptive Statistics

3.1 Legalization in the U.S.

Legalization of marijuana is becoming increasingly common, with many countries adopting varying decriminalization or legalization policies. In the United States, while marijuana is still technically illegal under federal law, the federal government largely defers to states with regard to local enforcement, particularly since 2009.[16] Legalization at the state level has since accelerated. While decriminalization of marijuana possession became common in the 1970s, California was the first state to formally legalize marijuana use for medical purposes in 1996 under California Proposition 215. The law allowed for the cultivation, manufacture, and sale of marijuana through retail dispensaries but required a medical reason to possess or use the drug. In subsequent years, other states followed suit by enacting medical marijuana laws in varying forms.

In 2012, Colorado and Washington became the first states to legalize marijuana for recreational use, with sales permitted to anyone over the age of 21 regardless of state of residence, and the first recreational dispensaries began appearing in Colorado in January 2014. The new laws also allowed for legal production of marijuana.

[14] Freisthler, Kepple, Sims, and Martin (2013) show that security measures implemented by dispensaries may have had the effect of reducing crime in those neighborhoods.

[15] See research by Freisthler, Ponicki, Gaidus, and Gruenewald (2016); Huber, Newman, and LaFave (2016); and Adda, McConnell, and Rasul (2014) mentioned previously.

[16] The U.S. Department of Justice issued a memorandum in 2009 that deprioritized enforcement of marijuana offenses that were in compliance with state laws.

3.2 Legalization in Colorado

On November 7, 2000 Colorado residents voted for Amendment 20, which would allow patients with "debilitating medical conditions" and their caregivers to possess up to two ounces of marijuana and six cannabis plants.[17] To become a medical user, potential patients have to acquire a written diagnosis from a physician, register with the Colorado Department of Public Health and Environment (CDPHE), and pay an administrative fee of $110; if approved, patients received a registry ID card.[18] In 2000, each caregiver could only have at most five patients, creating an effective prohibition on commercial distribution of marijuana by caregivers. In 2006, decriminalization for the possession of marijuana (under an ounce) was extended to those over the age of 20 but left the sale, growing, and public use of marijuana illegal.[19]

In 2007, the Denver District Court struck down the five-to-one patient-to-caregiver ratio cap, leading to the creation of an informal medical marijuana market where medical marijuana stores could operate under the legal standing of "caregivers." By January 2010, there were over 250 businesses functioning as "dispensaries" under the role of a caregiver, and over 53,000 individuals held registry ID cards.[20]

In November 2012, Colorado voters passed Amendment 64 legalizing and regulating the growth, manufacturing, and sale of marijuana in a system of legal establishments as well as allowing individuals over the age of 20 to possess, use, display, purchase, transport, and transfer up to one ounce of marijuana and own up to six marijuana plants.[21] On January 1, 2014 retail marijuana stores were open to the public for nonmedical (recreational) use, and non-Colorado residents could purchase marijuana from legal businesses for the first time.

Amendment 64 gave substantial local control to cities and counties to regulate and/or prohibit the cultivation, production, and sale of marijuana.[22] Localities have been heterogeneous in their approach to local rule. Some localities allow only medical sales, while other localities created new

[17] Colorado Constitution, Article XVIII S. 14.
[18] CDPHE (2009)
[19] Colorado Legislative Council (2006).
[20] Rocky Mountain High Intensity Drug Trafficking Area (2013) and CDPHE (2017b).
[21] Colorado Constitution, Article XVIII S. 16
[22] Specifically, Amendment 64 allowed localities to enact ordinances or regulations "governing the time, place, manner, and number of marijuana establishment operations" and allowed localities to "prohibit the operation of marijuana cultivation facilities, marijuana product manufacturing facilities, marijuana testing facilities, or retail marijuana stores through the enactment of an ordinance or through an initiated or reffed measure" (Colorado Constitution, Article XVIII S. 16).

zoning requirements, fees/special taxes, or fire codes for marijuana-related businesses.[23] Many localities delayed the licensing of recreational stores hoping to learn lessons from other localities, while other localities enacted "liberal" regulations early to benefit from excise taxes and business spillovers.

In January 2014, 18 municipalities had at least one recreational dispensary license and by December 2014, the number municipalities nearly doubled to 29, covering 42 percent of Colorado residents. Figure 1 shows the growth of licenses in Denver (panel 1a) and Colorado (panel 1b). The growth of recreational licenses after 2014 was modest, rising to cover 32 municipalities and 47 percent of residents. By municipality, medical licenses are more prominent; 50 and 51 municipalities, respectively, had at least one license in 2014 and 2015. In Denver, most dispensaries offer both medical and recreational sales.

[Figure 1 goes here]

3.3 Dispensary Locations

In this section, we provide a description of the geographic distribution of dispensaries and correlations between dispensary locations and neighborhood characteristics. A complete description of the data used here and in subsequent empirical results is found in section 5. The City of Denver is the clear mecca of recreational marijuana sales in Colorado. In January 2014, Denver had approximately 68 percent of 147 total recreational licenses despite only accounting for approximately 12 percent of the state's population. Figure 1a shows that stores that sell recreational marijuana make up a larger share of all stores in Denver than in other counties and that colocation of medical and recreational stores is much more prevalent in Denver.

The contrast in dispensaries between Denver and its neighboring municipalities is particularly pronounced. Of the 18 municipalities/unincorporated areas that border Denver, only three municipalities (Wheat Ridge, Lakeside, and Edgewater) had at least one retail license by June 2014. Since the legalization of recreational marijuana, the per capita number of dispensaries in Denver has been at least three times higher than the per capita rate in neighboring cities. Figure 2 shows the contrast between the per capita number of recreational stores in Denver compared with neigh-

[23] Aguilar (2014a)

boring municipalities. The "+" indicates a store location (medical or recreational) that opened for the first time between 2014 and 2016. The result of heterogeneous local regulation is that individuals travel from "prohibition localities" to "nonprohibition localities" to purchase recreational marijuana, a pattern documented by business owners in the Denver area.[24]

[Figure 2 goes here]

Within Denver, the location of new dispensaries became highly regulated starting in 2014. During 2014 and 2015, licenses could only be granted to owners of medical dispensaries in good standing, and owners of medical licenses could choose to colocate their medical and recreational stores or to open a recreational store in a new location. Under the bill, any new location of a dispensary (medical or recreational) must be at least 1,000 feet from any school, child care establishment, alcohol or drug treatment facility, or another marijuana dispensary. New location proposals also require public hearings where local stakeholders can object to the new license. If the director of the Denver Department of Excise and Licenses finds "evidence that the issuance of the license will adversely impact the health, welfare or public safety of the neighborhood" then she can reject the application for a license. Medical licenses for stores in new locations are subject to the same location restrictions and public hearings (Council Bill 13-0570, 2013). Given these requirements, it is likely that the locations of new stores would be correlated with neighborhood characteristics.

Table 1 shows the average year-over-year changes in dispensaries (per 10,000 residents) cross-tabbed over quantiles for different neighborhood characteristics. The average growth in dispensaries per capita in the top quartile for poverty rate and for percentage Hispanic population is eight times and five times, respectively, that of the bottom quartile for each measure. Dispensary growth is also highly correlated with employment, but there is no clear correlation with the percentage of black residents. Figure 3 shows heat maps of tract-level characteristics compared with the initial

[24] An owner of a medical marijuana dispensary in Lakewood (a municipality on the western border of Denver) told the *Denver Post* that residents of Lakewood are driving to Denver to purchase marijuana (Aguilar, 2014a). An owner of a recreational store in a western suburb of Denver says that her location is better than locations in central Denver because "many of her customers hail from [other] western suburbs, such as Lakewood and Golden, where moratoriums on recreation pot shops are in effect, or Morrison, where the businesses are banned" (Aguilar, 2014b). One gas station in Denver partnered with a dispensary to provide discounted gas to drivers who purchase marijuana (McClure, 2016) and a restaurant owner located along Interstate-76 reported an increase in customers from people traveling between cities to purchase marijuana (Aguilar, 2016).

location of medical dispensaries in December 2013. These maps show similar correlations between store locations in 2013 and cross-sectional neighborhood characteristics.

[Table 1 goes here]

[Figure 3 goes here]

The bottom portion of Table 1 shows average dispensary growth cross-tabbed across Colorado counties. The relationship between demographic factors and changes in dispensary density is weaker at the county level. This might be explained by the fact that preferences toward store locations and the social and political influence of individuals are more diluted at the county level than at the tract level.

The correlation between neighborhood characteristics and dispensary location has important policy implications in and of itself given that local effects of legalization will clearly have unequal consequences among different subpopulations. In addition, this presents a challenge for identifying the causal effect of legalization on neighborhood outcomes given that the locations of dispensaries are highly nonrandom. This suggests a quasi-experimental approach is necessary.

3.4 Crime Trends

Figure 4 shows a scatter plot of the number of crimes per 10,000 residents for Denver and all other Colorado counties between January 2013 and December 2014 (the lines show a 3-month moving average). Crime per 10,000 residents in Denver increased by 1.7 percent between 2013 and 2014 from 56.2 to 57.2 incidents a month, while crime per 10,000 residents in other counties decreased by 0.2 percent from 38.4 to 38.3 incidents a month. Crime rates follow seasonal patterns, are persistently higher in Denver, and show no major changes when retail marijuana sales started in January 2014. It is of interest that we find that crime decreases in neighborhoods that gain dispensaries despite an overall increase in crime in Denver after legalization.[25]

[Figure 4 goes here]

[25] In order to compare Denver to the rest of the state, the data used here come from the Federal Bureau of Investigations' National Incident-Based Reporting System accessed through the National Archive of Criminal Justice Data (University of Michigan). These are different from the data used in the main analysis, which come from the city of Denver and are more comprehensive.

4 Methodology

In this section, we outline our estimation strategy to recover the causal effect of retail marijuana dispensaries on neighborhood crime. The basis of our estimation strategy is a linear regression of the change in per capita crime on the change in per capita dispensaries for individual census tracts. Start by considering the following baseline OLS regression:

$$\Delta crime_{j,t} = \beta_0 + \beta_1 \Delta disp_{j,t} + \beta_2 \mathbf{X}_j + \delta_t + \epsilon_{j,t}, \tag{1}$$

where $\Delta crime_{j,t}$ is the 12-month change in crime per 10,000 residents for the j^{th} tract at time t; $\Delta disp_{j,t}$ is the 12-month change is marijuana dispensaries per 10,000 residents; $\mathbf{X}_j$ is a vector of tract-level time-constant control variables (e.g., race, poverty level, retail employment, available land, and distance to the central business district); and δ_t are time fixed effects. We use 12-month changes to address prominent seasonal patterns in crime data, which can be seen in Figure 4. Fixed effects account for aggregate time trends and ensure that identification arises from differences between tracks within the same time period as opposed to differences across time periods.

In the absence of endogeneity concerns, β_1 would be interpreted as the average treatment effect of a per capita change in dispensaries on per capita crime. However, we suspect that the OLS estimate of β_1 is biased by unobserved tract characteristics that are correlated with changes in the dispensary density and changes in crime rates.[26]

To address the potential bias in the OLS estimates, we propose using the smallest distance between a tract to the Denver municipal border and a tract to a major roadway as instrumental variables for changes in dispensary density. We then use these instruments in a standard two-stage least-squares approach. After January 2014, demand for retail marijuana from non-Denver residents drastically increased, and tracts with more access to *external demand* (measured by distance to municipal borders and major roads) showed larger changes in the number of dispensaries per capita. In what follows, we outline and discuss the identification argument.

The legalization of recreational marijuana in January 2014 increased the demand for retail

[26]Examples of potential sources of endogeneity include (1) simultaneous causality arising from a neighborhood's ability to stop license applications through public hearings, (2) changes in local demand for marijuana, (3) license owner's expectations about neighborhood growth factors, or (4) changes in vacancy rates for commercial space. We suspect that sources of local heterogeneity exist that are correlated with changes in dispensary locations and changes in crime rates, which underscores the importance of identifying a source of exogenous variation.

marijuana across all Colorado locations. Between 2013 and 2014, total marijuana sales more than doubled from approximately $328 million in 2013 to over $700 million in 2014.[27] As documented in Section 3.3, Denver is the clear center for recreational marijuana sales in Colorado, and there is evidence that residents from neighboring municipalities travel to Denver to purchase retail marijuana.[28] This means that locations that have better access to neighboring municipalities are more profitable and that we would expect to see larger positive changes in dispensary densities near borders and major roadways.[29]

A second source of external demand comes from increased tourist demand. Using data submitted by dispensaries in March 2014, Light, Orens, Lewandowski, and Pickton (2014) estimated that 44.5 percent of purchases for recreational marijuana use were made by customers using an out-of-state ID. The majority of "out-of-state ID" purchases are made by tourists who travel along major roadways and stay in hotels located along these roadways. Given that out-of-state residents could not purchase marijuana prior to 2014, this new source of demand increases the profitability in neighborhoods near major roadways. This tourist traffic provides further reasons to expect increases in dispensary densities near major roadways.

The importance of external demand in the recreational market relative to the medical market suggests that locations close to the municipal border or highways were better able to capture increasing demand after the legalization of recreational sales, making these locations more profitable for businesses. Therefore, we would expect the density of dispensaries in these locations to increase after 2014 relative to other locations in Denver. We thus run the following first-stage regression:

$$\Delta disp_{j,t} = \alpha_0 + \alpha_1 m2b_j + \alpha_2 m2r_j + \alpha_1 \mathbf{X}_j + \delta_t + \eta_{j,t}, \tag{2}$$

where $m2b_j$ (miles to border) is the distance of the centroid of a census tract to the nearest

[27] See Breathes (2014) and Ingraham (2015). Potential causes for the increase in demand include (1) individuals without a disabling condition being able to legally purchase marijuana, (2) legalization removing fixed costs associated with acquiring a registry ID (time, money, or perceived risk of being in a government data base of known marijuana users), (3) increased publicity and advertising, (4) changes in cultural norms making marijuana consumption more permissible, and (5) perceived decrease in risk of purchasing or consuming marijuana.

[28] In addition, recreational dispensaries were much more concentrated in Denver relative to medical dispensaries, as was seen previously in Figure 1, making external demand even more relevant after the legalization of recreational sales.

[29] The idea that retail establishments locate to maximize demand based on the geographic distribution of customers (and competition) is related to the classic work by Hotelling (1929). Work by Davis (2006) represents a more recent application of this theory.

municipal border and $m2r_j$ (miles to road) is the shortest distance to a major roadway. We also include important observable characteristics and time fixed effects, consistent with the OLS specification outlined previously. We expect α_1 and α_2 to both be negative, reflecting that the change in dispensary density is decreasing as you move away from a road or border.

We construct our IVs to exploit variation in the profitability of locations based on external demand, which we expect to be independent of unobserved neighborhood factors. The concerns regarding the endogeneity of the OLS regression come from unobserved neighborhood factors that affect the dispensary locations. These factors include local resistance at public hearings, availability of commercial space, and local demand for dispensaries. Our IVs are based on external demand and, therefore, are unlikely to be correlated with these unobservable characteristics. Nonetheless, there still may be some concern about the validity of the instruments. Next, we discuss and address some of these potential concerns.

The general concern is that changes in crime are correlated with proximity to major roadways and borders. It is first useful to look at out-of-sample data to rule out persistent correlations between changes in crime and our instruments that might arise from broader trends. To check for this persistence, we compare reduced-form regressions before and after legalization. Specifically, we regress annual changes in tract-level crime on our vector of control variables $\mathbf{X}_{j,t}$, a tract's distance to a major road, and its distance to a municipal border and include time fixed effects. We run this regression using annual changes in crime from before legalization of recreational marijuana in 2012 and compare it to annual changes after legalization in 2014. Results are shown in Table 2.[30]

[Table 2 goes here]

The coefficients on miles to border and major roadways in the "after" regression (column 2) are positive, which is consistent with our main findings presented subsequently.[31] The miles to border coefficient before legalization (column 1) is negative. This suggests that the positive relationship between distance to the border and crime is unique to 2014, as opposed to some persistent unobserved factor in locations. The miles to roadway coefficient is positive in the "before" regression,

[30] Denver crime data from 2011 are not available for vintages published after 2016. Since this table requires data from 2011, we use a vintage of data downloaded in 2016 (other results use a vintage from 2017).

[31] We find that changes in crime are lower where there are positive changes in dispensary densities and that positive changes in dispensary densities occur closer to the Denver border and major roadways. Therefore, we would expect crime to be higher in locations that are further from the border or from major roadways, consistent with positive coefficients on miles to border and miles to major roadways.

however it is statistically insignificant and less than one-fourth the magnitude of the coefficient in the "after" regression. This suggests that the strong relationship between distance to the major roadway and changes in crime is a feature that is uniquely present after the legalization of recreational marijuana and not a persistent characteristic of neighborhoods near major roadways.

While the out-of-sample regressions suggest no persistent correlations between the IVs and changes in crime, this does not rule out that correlations might be present in our sample period from one-time shocks occurring at the same time as legalization. A specific concern is that there could be spatial correlations that arise from the particular geography of Denver. To account for the particular city structure, we control for distance to the central business district as well as employment density. In addition, we include a specification with police precinct fixed effects which allows for identification through variation within different regions of the city rather than across regions. If there are institutional differences between districts, then they would be accounted for in this specification.

To address more general endogeniety concerns, we run regressions for each IV in isolation and find similar results. This provides particularly strong evidence of the validity of the results, given that the IVs are orthogonal both statistically and in geographic space.[32] This orthogonality arises from the fact that major roads primarily radiate from the center of the city, while the border surrounds the city, meeting the roads at right angles. Therefore it is unlikely that the same source of unobserved heterogeneity is correlated with both IVs and changes in crime rates and is idiosyncratic to the sample period, which lends additional support to the validity of the instruments.

5 Data

For the empirical analysis, we require local time-varying data on the location of dispensaries and detailed information on crime. In addition, the instrumental variable identification strategy, outlined above, requires data on major roads and municipal borders. We also collect data on local demographics, land use, and other neighborhood characteristics for use as controls.

The data on dispensary locations come from the Colorado Department of Revenue, which starting in January 2013 has published a monthly list of each medical and recreational license.[33]

[32]The correlation of the two IVs is .032 and not statistically significant.

[33]The data were accessed at www.colorado.gov/pacific/enforcement/archived-med-medical-and-retail-marijuana-

We geocode the address associated with each license and use an algorithm to identify medical and recreational stores that are colocated.[34] This is aggregated to create a monthly panel of the number of store fronts within each census tract in Denver to be used in our primary empirical analysis.[35] We also aggregate the data to the county level to be used for state-wide analysis. Overall, our sample covers 36 months between 2013 and 2016 for 143 census tracts in the City of Denver.

We obtain data on crime from several sources. The local crime data for our analysis of Denver come from the City and County of Denver, which maintains an extensive online data catalog.[36] The data include the specific time and location of each incident, which we aggregate to the census tract level at a monthly frequency. The data also contain detailed information covering over 190 different crime categories, which allows us to use various levels of aggregation to get a better picture of the precise changes in neighborhood crime.[37] Each incident in the data may contain multiple charges. Therefore, we use the Federal Bureau of Investigation's (FBI) Uniform Crime Reporting Program hierarchy to order the charges related to a single incident and assign the incident to the crime category of the highest crime.[38] In addition to the local crime data, we collect data at the county level for the entire state. For this, we use the FBI Uniform Crime Reporting Program data for cross-county comparisons.[39]

The data for our instrumental variables are both taken from the U.S. Census TIGER database.[40]

licensee-lists in January 2017.

[34]Geospatial data were processed primarily using ESRI ArcGIS. Geocoding was completed using the Census Geocoder accessed August 16, 2016 at www.census.gov/geo/maps-data/data/geocoder.html and supplemented with Google Maps at maps.google.com. Our algorithm utilizes a customized cross-walk that identifies licenses assigned to the same address (e.g. matches 250 W. Colfax to 250 West Colfax) and identifies the co-location of medical and recreational based on the name of the business holding the licenses (since recreational licensees were granted only to the license holders of medical license). We then manually update 11 instances where the algorithm cannot identify colocation.

[35]We exclude Denver International Airport which is spatially disconnected from the rest of Denver.

[36]The crime data were accessed at www.denvergov.org/opendata/dataset/city-and-county-of-denver-crime in February 2017. The catalog contains detailed geographic information including data on municipal government, health, safety, and education for Denver. Much of the data is available in GIS compatible formats.

[37]One challenge in using this data is a change in data reporting starting in May 2013. At this time, Denver began using a "Unified Summons and Complaint Process" that changed the frequency of reporting for certain crime categories. In our analysis, we use time fixed effects to account for this change and conduct tests to that show that the change in data reporting does not bias our results (see Appendix A for details).

[38]For instance, if someone breaks into a store, steals money from the cash register, and kills the clerk with a gun, then the incident would be categorized as murder and not burglary or theft. The hierarchy comes from the U.S. Department of Justice. "Summary Reporting System User Manual." June 20, 2016, V1.0.

[39]Source: U.S. Department of Justice. Federal Bureau of Investigation. Uniform Crime Reporting Program Data: National Incident-Based Reporting System, 2014. ICPSR36398-v1. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2016-03-21. doi.org/10.3886/ICPSR36398.v1

[40]U.S. Department of Commerce, Bureau of the Census, Geography Division. www.census.gov/geo/maps-data/data/tiger-line.html

For the borders, we use the border of Denver (excluding the airport) from the TIGER "Boundary" file, and for the major roads in Denver, we use the "Major Roadways" file. We then calculate distances as the distance from the geographic centroid of the census tract to the nearest border/roadway.

We use the 2014 American Community Survey (ACS) 5-year sample data, which provide information on race, ethnicity, income, and poverty to control for demographic factors.[41] These data are also used to calculate crime and dispensary density per 10,000 residents using the ACS total population counts. In addition, we collect employment data by industry from 2013 U.S. Census Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics.

We also need to control for existing land uses and restrictions, as these are important determinants of dispensary locations. Importantly, with the start of legalization, the City of Denver restricted new dispensaries from being located 1,000 feet from existing dispensaries, child care facilities, schools, and drug and alcohol treatment facilities, for which we collect data from several sources.[42] We also collect geographic data zoning designations and bodies of water available through the City and County of Denver's Community Planning and Development Department. We then combine these data to develop a measure of usable area for dispensaries in each location.[43] Finally, we calculate the distance of each tract to the central business district and collect data on police districts as additional controls.

6 Results

In this section, we outline our main results. We start by presenting the results of the first-stage regressions, which are summarized in Table 3.[44] Columns (1) and (2) show the first-stage results using only miles to border or miles to major road as an instrumental variable. Column (3) shows results using both instruments, and column (4) shows results using a time trend (instead of time

[41] We access data through the Minnesota Population Center. National Historical Geographic Information System: Version 11.0 [Database]. Minneapolis: University of Minnesota. 2016.

[42] The locations of childcare facilities were obtained from the license data available from the City and County of Denver, while school locations were obtained from a digitized map that was then georeferenced. Drug and alcohol treatment facility locations were obtained through a Google search.

[43] Specifically, we take the total land area of each tract and subtract locations within 1000 feet of restricted facilities, bodies of water, and locations that are restricted through zoning (e.g., residentially zoned locations). This area is then normalized by tract population to be consistent with the normalization of crime and dispensaries, which are per capita measures.

[44] Summary statistics for each variable are included in the second column.

fixed effects). As expected, the coefficients on miles to border and miles to road are negative and statistically significant in each regression, which implies that locations near highways and borders saw a larger increase in dispensaries after 2014 than locations further away. For example, the coefficient in the first row, column (3) implies that the year-over-year change in dispensaries per 10,000 residents is 0.182 higher for locations next to a major road than for locations a mile away. Other location characteristics are also significant and consistent across all specifications. Dispensary densities after 2014 increased more in neighborhoods with higher poverty rates, with higher levels of employment, that are closer to the central business district, and where there is more usable land.

[Table 3 goes here]

Table 4 shows the primary second-stage results for several specifications. The table first shows the OLS regression (column 1) results, followed by IV regression results using only the miles to border IV (column 2), only the miles to major roadway IV (column 3), both IVs (column 4), and both IVs without time fixed effects (column 5). Test statistics for first-stage weak IVs are shown for each specification at the bottom of the table. Results are significant and robust across all IV regressions (columns 2-5). Consider the estimated effect of the change in store density on crime using the specification with both IVs (column 4). The negative and significant coefficient means that, on average, census tracts that gained a dispensary (per 10,0000 residents) show a decrease of 17 crimes per month (per 10,000 residents) compared with a neighborhood that had no change in its dispensary density, ceteris paribus. The magnitude of these coefficients are substantial; the average number of crimes per neighborhood across our observation period is 90 crimes per 10,000 residents. Thus a decrease of 11 or 21 crimes (per 10,000 residents) would be equivalent to a 12 or 23 percent decrease in crime relative to the average crime rate over this period. When we use both IVs, we get a coefficient of 17, which is equivalent to a 19 percent decrease in crime over our observation period.

[Table 4 goes here]

Other control variables show similar relationships across the OLS and IV specifications. The positive coefficient on poverty rates shows that crime increased in areas with higher poverty rates. We also see a negative coefficient on distance to the central business district(CBD) showing that

crime increased faster near the center of the city compared with those locations further from the city center. The coefficient on per capita usable land is positive, indicating that tracts with more usable land saw increases in their crime rate.[45]

It is of note that the OLS results for the effect of a change in dispensary density are substantially different than IV results. In the OLS results, we observe a small positive relationship between changes in store density and changes in crime. This supports concerns that changes in dispensary densities are correlated with unobserved neighborhood characteristics associated with increasing crime during the sample period, underlining the importance of using a source of exogenous variation to identify the effects of dispensaries on neighborhood level crime.

Table 5 shows five robustness checks of the baseline regression (shown in column (1) for reference). Looking across the top row of the table, our headline results (coefficient on 12-month change in store density) are maintained for each of the regression specifications. Column (2) shows the base regression with the inclusion of statistics for the number of schools, rehab centers, and child care licenses in each tract (per capita). This specification is a check to ensure the usable land is not being used as a proxy measure for the density of schools, rehab centers, and child care licenses in each tract. In column (3), we change our choice of control variables (median income replaces poverty rate, retail employment replaces employment, and percent black and percent Hispanic jointly replace percent white non-Hispanic).

[Table 5 goes here]

In column (4), we present results where the distance IVs are replaced with dummy variables as a proxy for proximity to a highway; specifically we use a dummy variable that equals one if the distance to the border is more than two miles (and zero otherwise) and a dummy variable that equals one if the distance to a major roadway is more than half a mile and zero otherwise. This addresses the fact that external market access may not be a linear function of distance to a highway or border. Column (5) excludes marijuana store locations that only sell recreational marijuana, controlling for the potential that store fronts without medical sales are different than those that include medical sales.[46] The results are even stronger when we exclude stores that sell

[45] Large values of usable land are negatively correlated with the number of schools and child care programs in a neighborhood, which may help to suppress crime rates.

[46] Examining stores that only sell medical marijuana is not an appropriate robustness check, since most medical-only stores in 2013 converted to selling both types in 2014, and medical-only stores would be less sensitive to external

exclusively recreational marijuana, meaning that any bias caused by our homogeneous treatment of store density is likely to be attenuation bias.

Lastly, we use police district fixed effects (crossed with monthly fixed effects).[47] Using district fixed effects controls for differences in police behavior across districts and controls for idiosyncratic differences across districts. This specification is of interest given the way that police districts are constructed (the central business district along with the surrounding area is its own district, and suburbs with similar characteristics are grouped into districts). In this case, the coefficient is similar, but statistical significance is lost.

7 Discussion

We find that the overall effect of adding a dispensary to a neighborhood of 10,000 residents is a reduction of crime of around 17 crimes per month. In this section, we further analyze and decompose the data in order to provide a better sense of the underlying mechanisms that lead to this crime reduction and to compare these findings with existing theories about the effect of legalization on crime. To do so, we first use the detailed nature of the crime data to look at how dispensaries affect different types of crime. Then we consider the geographic extent of these effects by looking at census tracts adjacent to neighborhoods that received dispensaries. The evidence presented here provides indirect evidence to support existing theories about the relationship between crime and legalization, and could inform future in-depth research.

7.1 Effects by Crime Type

While there is significant variation across crime categories in the response to legalization, some broad patterns emerge. Table 6 shows results using different subsets of crimes as the dependent variable (still using both IVs and time fixed effects). In columns (2) and (3), we divide the universe of crimes into violent and nonviolent crimes.[48] The majority (93 percent) of the reduction in crime is due to a decrease in nonviolent crimes. We also divide the universe of crimes into crimes against

demand. Examining stores that only sell recreational marijuana is not possible, since there were no recreational dispensaries in 2013.

[47] See Appendix C for a map of police districts.

[48] We use the FBI's Uniform Crime Reporting Program definition of violent and nonviolent crime.

persons, property, society, and "other" as shown in columns (4) through (7).[49] The decrease in crimes against persons is mostly driven by declines in simple and aggravated assaults. Decreases in "other" crimes are driven by decreases in criminal trespassing, public-order crimes,[50] and other criminal mischief.[51]

[Table 6 goes here]

We also examine the effects of dispensaries on drug-related crimes; results are shown in Table 7 using the same techniques as above. Column (1) shows that adding a dispensary to a neighborhood of 10,000 residents decreases the change in the drug crime rate by roughly 2.3 crimes per month which is just under 14 percent of effect of the dispensary on all crimes.[52] Columns (2) and (3) show that dispensaries have almost no effect on the number of marijuana crimes or marijuana-related crimes.[53] Columns (4) through (6) show that, while not significant, we find decreases in the number of methamphetamine, cocaine, and heroin crimes committed in tracts that gain dispensaries.

[Table 7 goes here]

Our results for different crime categories are consistent with the theory that marijuana legalization decreases crime through the displacement of illicit markets. Underlying such a theory is the belief that criminal organizations resort to violence to enforce contracts and that illicit markets for marijuana are horizontally integrated with markets for other types of drugs (methamphetamine, cocaine, and heroin). If increases in legal dispensaries displace illicit markets, then we would expect to see decreases in assaults as well as crimes related to sales of other illegal drugs including methamphetamine, cocaine, and heroin in those neighborhoods. Our results, however, are inconsistent with theories that would suggest that marijuana dispensaries increase local cannabis crimes (since we do not find increases in marijuana crimes such as cultivation, possession, or sales nearby) or that dispensaries increase crimes through increased intoxication (since there is essentially no

[49] We utilize definitions from the FBI's National Incident-Based Reporting System standards (City and County of Denver, 2016b).

[50] Excluding public fighting or disturbing the peace.

[51] Other criminal mischief involves the intentional destruction/damaging of property that is not graffiti or damage to a motor vehicle.

[52] Drug crimes include the manufacture, sale, and possession of illegal drugs.

[53] According to the Denver Police Department, marijuana-related crimes are "crimes reported to the Denver Police Department which, upon review, were determined to have clear connection or relation to marijuana."

change in the number of crimes with marijuana as a "contributing factor" near locations that gain dispensaries). These findings are consistent with previous research that has found no link between marijuana use and criminal behavior.[54]

7.2 Geographic Extent and Distribution of Effects

Next, we examine the geographic extent of the crime reduction. First, we look at whether or not the opening or closing of a dispensary affects crime in neighboring census tracts. To test for spillover effects, we use a modified version of the two-stage least-squares approach used previously. We first run the standard first-stage regressions (see equation (2)) for each tract. We then substitute the predicted change in dispensary density for each tract ($\Delta\widehat{disp}_{j,t}$) as well as the predicted change in dispensaries for the tract that is closest to the j^{th} tract ($\Delta\widehat{neighbordisp}_{j,t}$) into the second-stage regression given by the following equation:

$$\Delta crime_{j,t} = \beta_0 + \beta_1 \mathbf{X}_j + \beta_2 \Delta\widehat{disp}_{j,t} + \beta_3 \Delta\widehat{neighbordisp}_{j,t} + \delta_t + \epsilon_{j,t}. \quad (3)$$

We show the results of equation (3) in column (4) in Table 8.[55] For comparison, we show the OLS and IV results for both the base model and the model including neighboring tracts. The coefficient for the 12-month change in dispensary density is relatively unchanged with the inclusion of the nearest neighbor. Importantly, we see that the coefficient on the 12-month change in dispensary density for the neighboring tract (β_3) is positive but not significant. This suggests that the effects of dispensaries on crime are very localized.[56]

The lack of spillover effects into neighboring tracts is consistent with the theory that dispensaries decrease crime in their neighborhood through increased private surveillance and the theory that law enforcement may change their enforcement behavior in the direct vicinity of dispensaries. Our findings are somewhat different but generally consistent with those of Freisthler, Ponicki, Gaidus, and Gruenewald (2016) who find no effect in the neighborhoods with dispensaries but increased

[54] See White and Gorman (2000) for a review of the literature on the relationship between drug use and crime.

[55] Note that the standard errors generated by this exercise do not include corrections typically conducted in two-stage least-squares estimation, given the complexity of using predicted values for two right-hand variables. Standard errors would be larger if proper adjustments were made. However, the estimates of the coefficient on "nearest neighbor" are not statistically significant, so the different errors would not change the conclusions.

[56] In addition to the nearest neighbor results, we also ran regressions at the county level. These results, shown in Appendix B, provide evidence that increased dispensary density leads to reduced crime at the county level. However, the results are weaker, which would be consistent with the fact that crime effects are localized.

crime in nearby neighborhoods. The differences in the conclusions may be due to the fact that the current analysis considers the effects of both openings and closures and accounts for selection bias arising from nonrandom location of dispensaries.

[Table 8 goes here]

Finally, it is useful to think about the distributional effects of dispensary locations on crime. As discussed in Section 3.3, neighborhoods with higher poverty rates, larger Hispanic populations, and more employment on average saw substantially larger increases in dispensary density compared with other tracts. Neighborhoods with these characteristics also tend to have higher initial crime rates. Since we find the increases in dispensary densities have a depressive effect on crime, then the net result of the heterogeneous location of dispensaries is that crime distributions are more equitably distributed across these neighborhood characteristics compared with a counterfactual without changes in dispensary density.

8 Conclusion

We use a novel identification strategy to show significant crime reductions in neighborhoods that receive marijuana dispensaries. To our knowledge, our research is the first research to use exogenous variation in dispensary locations to identify local crime effects of marijuana dispensaries. We find that adding a dispensary to a neighborhood (of 10,000 residents) decreases changes in crime by 19 percent relative to the average monthly crime rate in a census tract. These results are robust to many alternative specifications, are unique to time periods after legalization, and diminish quickly over space. Our results are consistent with theories that predict that marijuana legalization will displace illicit criminal organizations and decrease crime through changes in security behaviors.

These neighborhood results are important to policy makers in states that recently legalized marijuana, as law makers consider regulating the location of dispensaries. Our research can also inform local public hearings about dispensary locations and the decisions of future voters in states and municipalities that have ballot initiatives regarding marijuana legalization. If it is the case that municipal-level changes in crime are an aggregation of neighborhood effects on crime, then our research would suggest that the legalization of legal marijuana markets would decrease crime

at the municipal level.

There are questions about the external validity of this study, given that data come from a single municipality and are therefore vulnerable to idiosyncrasies specific to Denver. Future research could use similar methods to analyze the effects of legalization in other municipalities and states as more data become available. While the single municipality of study limits the external validity of our research, it improves the internal validity of our results, since we do not compare differences between municipalities that have different regulatory environments. Our research is also only applicable to short-term outcomes, and in future years more research should be done to determine the long-run general equilibrium effects of legalization on crime. Other opportunities for future research include examining the effects of legal marijuana distribution on other neighborhood amenities and further dissecting the underlying mechanisms that lead to reduced crime.

9 References

Adda, Jerome, Brendon McConnell, and Imran Rasul. "Crime and the Depenalization of Cannabis Possession: Evidence from a Policing Experiment." *Journal of Political Economy* 122.5 (2014): 1130-1202.

Agrawal, David R. "The Tax Gradient: Spatial Aspects of Fiscal Competition." *American Economic Journal: Economic Policy* 7.2 (2015): 1-29.

Anderson, Mark, Benjamin Hansen, and Daniel Rees. "Medical Marijuana Laws, Traffic Fatalities, and Alcohol Consumption'." *The Journal of Law and Economics* 56.2 (2013):333-3699.

Anderson, Mark and Daniel Rees. "The Legalization of Recreational Marijuana: How Likely Is the Worst-Case Scenario." *Journal of Policy Analysis and Management* 33.1 (2014):221-222.

Aguilar, John. "Colorado Cities and Towns Take Diverging Paths on Recreational Pot." *Denver Post*. December 19, 2014a (updated on October 2, 2016).

Aguilar, John. "Pot shops in Denver's Suburbs Fewer and Farther Between Than in City" *Denver Post*. May, 31, 2014b.

Aguilar, John. "Marijuana Gap Divides Colorado Towns That Sell Pot, Those That Don't." *Denver Post*. October 2, 2016.

Aguilar, John. "Local Resistance to Burgeoning Colorado Pot Scene on Rise." *Denver Post*, February 6, 2015.

Bachhuber, Marcus A., Brendan Saloner, Chinazo O. Cunningham, and Colleen L. Barry. "Medical cannabis laws and opioid analgesic overdose mortality in the United States, 1999-2010." *JAMA Internal Medicine* 174, no. 10 (2014): 1668-1673.

Bisschop, Paul, Stephen Kastoryano, and Bas van der Klaauw. "Street Prostitution Zones and Crime." *American Economic Journal: Economic Policy* (2017), forthcoming.

Becker, Gary S., Kevin M. Murphy, and Michael Grossman. "The Economic Theory of Illegal Goods: The Case of Drugs." *Journal of Political Economy* 114.1 (2006).

Blake, David and Jack Finlaw. "Marijuana Legalization in Colorado: Lessons Learned," *Harvard Law and Policy Review* 359, 371 (2014).

Breathes, William. "Medical Marijuana Revenues in Colorado in 2013: $328 Million-plus." *Westword*, January 15, 2014. Accessed October 28, 2016.

Card, David, and Alan B. Krueger. "Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania." *American Economic Review* 84 (1994): 772-793.

Caulkins, Jonathan P., Beau Kilmer, and Mark AR Kleiman. *Marijuana Legalization: What Everyone Needs to Know?*. Oxford University Press, 2016.

Chang, Tom, and Mireille Jacobson. "Going to Pot? The Impact of Dispensary Closures on Crime." *Journal of Urban Economics* (2017).

Charles, Kerwin Kofi, and Ming Ching Luoh. "Male Incarceration, the Marriage Market, and Female Outcomes." *The Review of Economics and Statistics* 92.3 (2010): 614-627.

Cheng, Cheng, W. Mayer, and Yanling Mayer. "The Effect of Legalizing Retail Marijuana on Housing Values: Evidence from Colorado." Working Paper, The University of Mississippi, 2016.

Colorado Department of Public Health and Environment, "2009 Medical Marijuana Registry." www.colorado.gov/pacific/cdphe/2009-medical-marijuana-registry-statistics. 2016.

Colorado Department of Public Health and Environment, "2010 Medical Marijuana Registry." www.colorado.gov/pacific/cdphe/2010-medical-marijuana-registry-statistics. 2016.

Colorado Legislative Council. "Analysis of the 2006 Ballot Proposals." Colorado General Assembly. Accessed through www.colorado.gov/pacific/cga-legislativecouncil/historical-ballot-information. September 14, 2006.

Conklin, James Neil, Moussa Diop, and Herman Li. "Contact High: The External Effects of Retail Marijuana Establishments on House Prices." Working Paper (2016).

Council Bill 13-0570, Denver City Council. (2013)(enacted). Chapter 6 Article V.

Davis, Peter. "Spatial Competition in Retail Markets: Movie Theaters." *RAND Journal of Economics* 37.4 (2006): 964-982.

Denver Police Department. "2013 Archive Statistics — Denver Police Department." 2013. Accessed December 05, 2016. www.denvergov.org/content/denvergov/en/police-department/crime-information/crime-statistics-maps/2013-crime-statistics-maps.html.

Dills, Angela K., Mireille Jacobson, and Jeffrey A. Miron. "The Effect of Alcohol Prohibition on Alcohol Consumption: Evidence from Drunkenness Arrests." *Economics Letters* 86.2 (2005): 279-284.

Freisthler, Bridget, William R. Ponicki, Andrew Gaidus, and Paul J. Gruenewald. "A MicroTemporal Geospatial Analysis of Medical Marijuana Dispensaries and Crime in Long Beach, California." *Addiction* (2016).

Freisthler, Bridget, Nancy J. Kepple, Revel Sims, and Scott E. Martin. (2013), "Evaluating Medical Marijuana Dispensary Policies: Spatial Methods for the Study of Environmentally-Based Interventions." *American Journal of Community Psychology*, 51: (2013) 278-288.

Green, Donald P., and Daniel Winik. "Using Random Judge Assignments to Estimate the Effects of Incarceration and Probation on Recidivism Among Drug Offenders." *Criminology* 48.2 (2010):

357-387.

Grogger, Jeff, and Michael Willis. "The Emergence of Crack Cocaine and the Rise in Urban Crime Rates." *Review of Economics and Statistics* 82.4 (2000): 519-529.

Harding, Matthew, Ephraim Leibtag, and Michael F. Lovenheim. "The Heterogeneous Geographic and Socioeconomic Incidence of Cigarette Taxes: Evidence from Nielsen Homescan Data." *American Economic Journal: Economic Policy* 4.4 (2012): 169-198.

Holmes, Thomas J. "The Effect of State Policies on the Location of Manufacturing: Evidence from State Borders." *Journal of Political Economy* 106.4 (1998): 667-705.

Hotelling, Harold, "Stability in Competition," *Economic Journal*, 39 (1929): 41-57.

Huber III, Arthur, Rebecca Newman, and Daniel LaFave. "Cannabis Control and Crime: Medicinal Use, Depenalization and the War on Drugs." *B.E. Journal of Economic Analysis & Policy* (2016).

Ingraham, Christopher. "Colorado's Legal Weed Market: $700 Million in Sales Last Year, $1 Billion by 2016." *Washington Post*, February 12, 2015. Accessed October 28, 2016.

Jacobi, Liana, and Michelle Sovinsky. "Marijuana on Main Street? Estimating Demand in Markets with Limited Access." *American Economic Review* 106.8 (2016): 2009-2045.

Jacobson, Mireille. "Baby Booms and Drug Busts: Trends in Youth Drug Use in the United States, 1975-2000." The *Journal of Economics* 119, no. 4 (2004): 1481-1512.

Kling, Jeffrey R. "Incarceration Length, Employment, and Earnings." *American Economic Review* 96.3 (2006): 863-876.

Kuziemko, Ilyana, and Steven D. Levitt. "An Empirical Analysis of Imprisoning Drug Offenders." *Journal of Public Economics* 88.9 (2004): 2043-2066.

Light, Miles, Adam Orens, Brian Lewandowski, and Todd Pickton. "Market Size and Demand for Marijuana in Colorado Report." *The Marijuana Policy Group.* Final (v16). Colorado Department of Revenue. (2014).

Luca, Dara Lee, Emily Owens, and Gunjan Sharma. "Can Alcohol Prohibition Reduce Violence Against Women?." *American Economic Review* 105.5 (2015): 625-629.

Miron, Jeffrey A., and Jeffrey Zwiebel. "The Economic Case Against Drug Prohibition." *Journal of Economic Perspectives* 9.4 (1995): 175-192.

Owens, Emily G. "The American Temperance Movement and Market-Based Violence." *American Law and Economics Review* 16.2 (2014): 433-472.

Resignato, Andrew J. "Violent Crime: a Function of Drug Use or Drug Enforcement?" *Applied Economics* 32.6 (2000): 681-688.

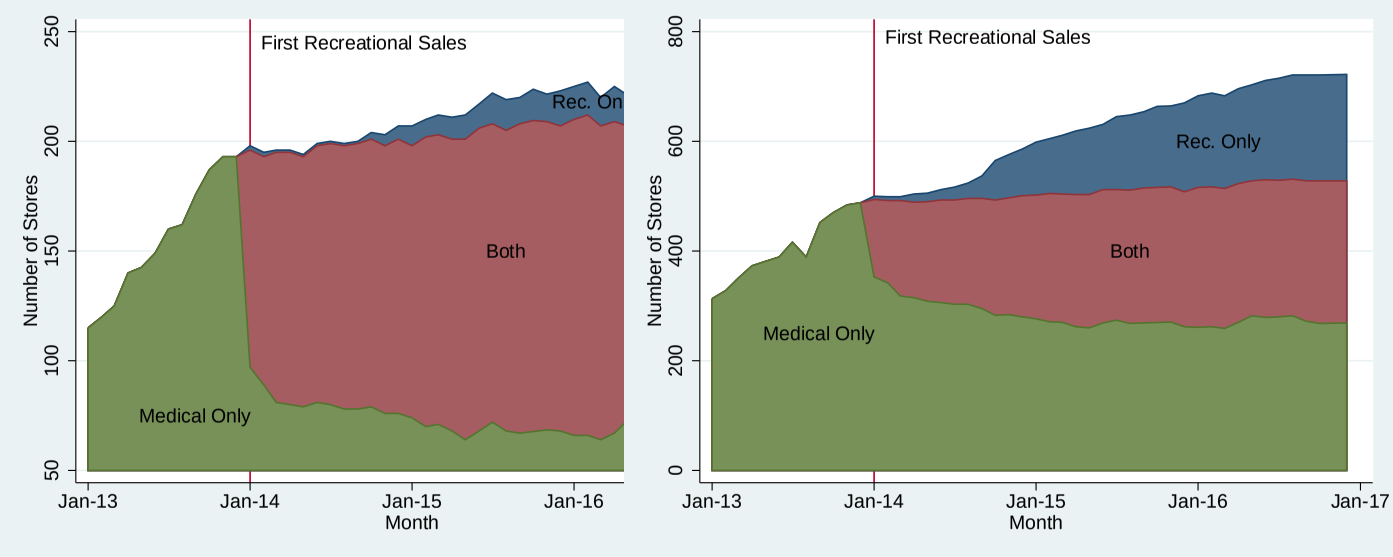
Rocky Mountain High Intensity Drug Trafficking Area, "The Legalization of Marijuana in Colorado: The Impact - A Preliminary Report." Volume 1. August 2013.

Van Ours, Jan C., and Jenny Williams. "Why Parents Worry: Initiation into Cannabis use by Youth and their Educational Attainment." *Journal of Health Economics* 28.1 (2009): 132-142.

Van Ours, Jan C., and Jenny Williams. "The Effects of Cannabis Use on Physical and Mental Health." *Journal of Health Economics* 31.4 (2012): 564-577.

Watson, Stanley J., John A. Benson, and Janet E. Joy. "Marijuana and Medicine: Assessing the Science Base: A Summary of the 1999 Institute of Medicine Report." *Archives of General Psychiatry* 57.6 (2000): 547-552.

White, Helene R., and Dennis M. Gorman. "Dynamics of the Drug-Crime Relationship." *Criminal Justice* 1.15 (2000): 1-218.



(a) Denver (b) Colorado

Figure 1: Dispensary Growth 2013-2016

The panels of this figure show the total number of store fronts (calculated using data from Colorado Department of Revenue) cross tabbed by stores that sell only medical marijuana (green), both medical and recreational marijuana (red), and only recreational marijuana (blue). The vertical red line shows the first date (January 1, 2014) when recreational sales were legal.

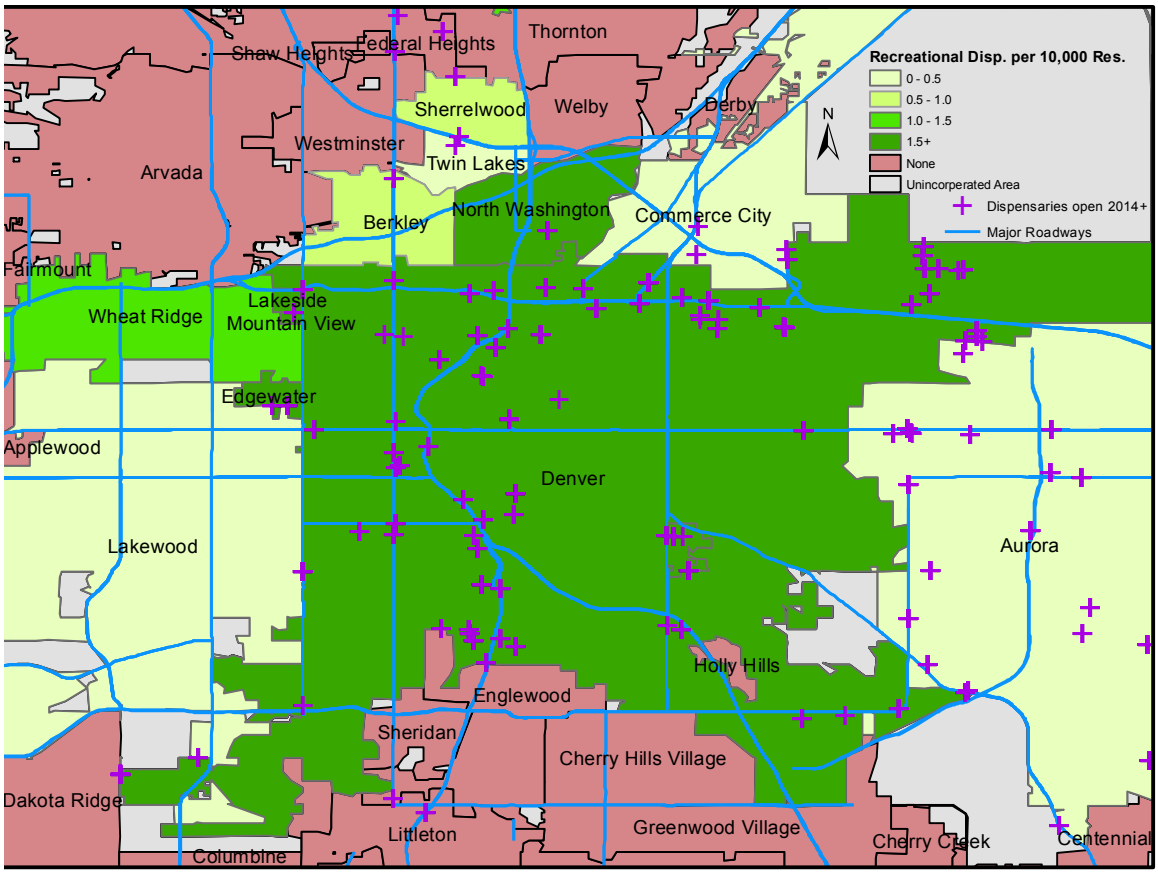
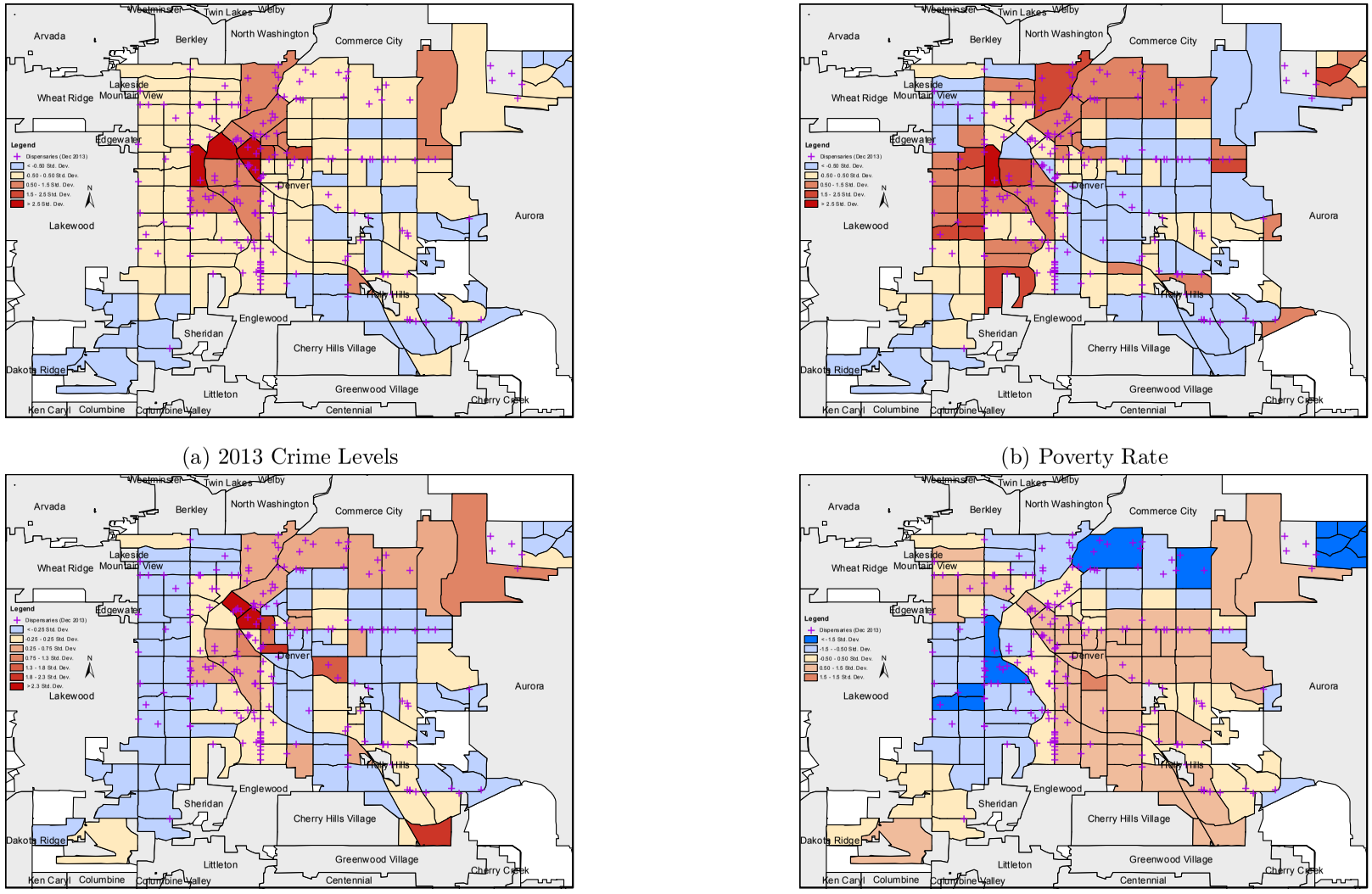


Figure 2: Recreational Store Density and New Store Openings

This heat map shows the average number of recreational dispensaries per 10,000 residents (between 2014 and 2016) for municipalities in the Denver area. The "'+" symbols indicate the opening of a store front after 2014 in a location where there was no store front in 2013. Major roadways are shown in blue. Data from the Colorado Department of Revenue.



(a) 2013 Crime Levels

(b) Poverty Rate

(c) Employment

(d) Percent White Non-Hispanic

Figure 3: Neighborhood Characteristics with 2013 Dispensaries

These heat maps compare neighborhood characteristics with dispensary locations before the legalization of recreational marijuana. 2013 medical dispensary locations are shown using "+" symbols. In panel (a), we show average crime rates in 2013; beige-colored tracts have crime rates within half a standard deviation of the average tract's crime rate, red tracts have a crime rate that is more than half a standard deviation above the average, and blue tracts show tracts that are below half a standard deviation of the average. The other panels show tract-level poverty rates (b), employment levels (c), and percent of the population that are white and non-Hispanic (d) (we use the same standard deviation color schemes in all panels). Dispensary data come from Colorado Department of Revenue, demographic data come from the Census' 2014 American Community Survey 5-year sample, and employment data comes from the Census' 2013 Origin-Destination Employment Statistics.

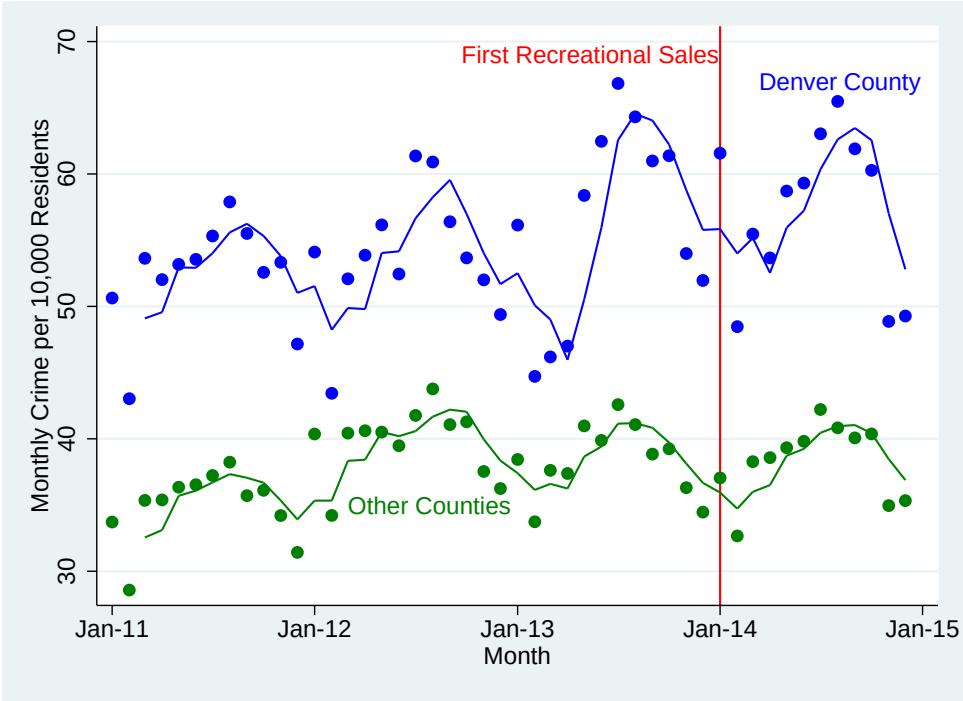


Figure 4: Monthly Crime Across Counties

Blue and green dots show the monthly crime rates (per 10,000 residents) for Denver and the average of all other Colorado counties, respectively. Solid lines show corresponding three-month moving averages and the vertical red line shows the first date (January 1, 2014) when recreational sales were legal. Data provided by the Federal Bureau of Investigations' National Incident-Based Reporting System accessed through the National Archive of Criminal Justice Data (University of Michigan).

Table 1: Average Change in Dispensary Density by Local Characteristics

	Panel A: Across Tracts in Denver			
	Pov. Rate	Pct. Black	Pct. Hisp	Employment
1st Quartile	0.097	0.212	0.077	0.170
2nd Quartile	0.095	0.389	0.094	0.082
3rd Quartile	0.373	0.504	0.575	0.323
4th Quartile	0.823	0.270	0.541	0.811
Denver Average	0.344	0.344	0.344	0.344
	Panel B: Across Counties in Colorado			
	Pov. Rate	Pct. Black	Pct. Hisp	Employment
1st Quartile	0.080	0.112	0.081	0.217
2nd Quartile	0.142	0.113	0.071	0.031
3rd Quartile	0.042	0.106	0.142	0.076
4th Quartile	0.221	0.145	0.220	0.147
Colorado Average	0.119	0.119	0.119	0.119

This table shows the average 12-month change in dispensary density (between 2014 and 2016) cross-tabbed by local characteristics. Panel A shows dispensary growth for census tracts in Denver and panel B shows dispensary growth for counties in Colorado. In column two, we divide tracts/counties into four quartile bins based on their poverty rate (lowest to highest using populations weights) and show the average dispensary growth within each bin. We repeat this process in column three using percent of the population that is black, in column four using percent of the population that is Hispanic, and in column five using total employment. Dispensary data come from Colorado Department of Revenue, demographic data comes from the U.S. Census 2014 American Community Survey 5-year sample, and employment data comes from the U.S. Census 2013 Origin-Destination Employment Statistics.

Table 2: 12-Month Changes in Crime and Neighborhood Characteristics Before and After Legalization

	(1) Before	(2) After
Miles to Border	-0.698	1.572
	(1.200)	(3.669)
Miles to Major Road	1.378	7.507**
	(1.952)	(2.920)
Poverty Rate	-19.984**	81.615***
	(8.883)	(18.507)
Employment (1,000s)	0.022	2.042**
	(0.233)	(0.682)
Pct. White Non-Hispanic	-8.119*	-1.052
	(4.051)	(5.002)
Miles to CBD	-0.723	-1.487**
	(0.440)	(0.540)
Usable Land/10,000 Res.	3.541*	9.906***
	(1.941)	(2.716)

In the "before" column, we regress the 12-month change in crime rates during 2012 on miles to border, miles to a major roadway, and our control variables (including time fixed effects). In the "after" column, we repeat the exercise using crime data from 2014. Heteroskedastic robust standard errors are shown in parentheses, and significance is denoted by * = 0.10, ** = 0.5, and *** = 0.01. Crime data provided by the City of Denver in an October 2016 vintage.

Table 3: First-Stage Regression Results

	μ [σ]	(1) m2b only	(2) m2r only	(3) all IV	(4) No Time FE
Miles to Major Road	1.07 [0.84]		-0.269***	-0.182***	-0.182**
			(0.065)	(0.054)	(0.073)
Miles to Border	0.18 [0.12]	-0.171***		-0.138***	-0.138***
		(0.043)		(0.039)	(0.041)
Poverty Rate	2.97 [6.55]	3.273***	3.158***	3.114***	3.114***
		(0.573)	(0.597)	(0.603)	(0.626)
Employment (1,000s)	0.56 [0.26]	0.021***	0.018***	0.021***	0.021***
		(0.004)	(0.003)	(0.004)	(0.005)
Pct. White Non-Hispanic	4.36 [2.71]	-0.019	-0.093	-0.081	-0.081
		(0.146)	(0.162)	(0.161)	(0.186)
Miles to CBD	0.64 [0.89]	-0.062***	-0.016**	-0.049***	-0.049***
		(0.015)	(0.007)	(0.012)	(0.012)
Usable Land/10,000 Res.	0.49 [0.34]	0.271***	0.261***	0.261***	0.261***
		(0.033)	(0.034)	(0.034)	(0.031)
F-Statistic		56.311	62.191	56.082	38.082

This table shows first-stage results for the 12-month change in store density (per 10,000 residents) using time fixed effects. The second column shows the mean and standard deviation for each covariate (between 2014 and 2016). Regression (1) only uses miles to border as an IV, regression (2) only uses miles to roads as an IV, and regression (3) uses both IVs. In regression (4), we use both IVs and do not use time fixed effects, but do include a time trend (coefficient suppressed). Heteroskedastic robust standard errors are shown in parentheses, and significance is denoted by * = 0.10, ** = 0.5, and *** = 0.01.

Table 4: Second-Stage Regression Results

	(1) OLS	(2) m2b - IV	(3) m2r - IV	(4) ALL IV	(5) No time FE
12-M Chg Store Den.	1.924***	-20.575**	-10.980*	-17.009**	-17.009**
	(0.459)	(8.742)	(6.617)	(7.035)	(7.197)
Poverty Rate	14.427	91.791**	58.798**	79.530**	79.530**
	(13.247)	(37.686)	(29.991)	(32.448)	(33.490)
Employment (1,000s)	0.403	0.794*	0.627	0.732*	0.732*
	(0.370)	(0.408)	(0.406)	(0.402)	(0.414)
Pct. White Non-Hispanic	0.579	0.689	0.642	0.671	0.671
	(3.799)	(5.881)	(4.880)	(5.472)	(5.628)
Miles to CBD	-1.302**	-1.848***	-1.615***	-1.762***	-1.762***
	(0.579)	(0.693)	(0.627)	(0.659)	(0.667)
Usable Land/10,000 Res.	5.390**	11.655***	8.983**	10.662***	10.662***
	(2.225)	(4.011)	(3.558)	(3.688)	(3.738)
Weak IV Test Statatistic		17.560	13.393	10.415	10.308

This table shows the second-stage results for the 12-month change in crime rate (per 10,000 residents) using time fixed effects. For comparison, we include OLS regression results in regression (1). In regression (2), we use only the miles to border IV, in regression (3) we use just the miles to roads IV, and in regression (4), we use both variables as IVs. In regression (5) we use both IVs, but do not use time fixed effects; we include a time trend (coefficient suppressed). Heteroskedastic robust standard errors are shown in parentheses and significance is denoted by * = 0.10, ** = 0.05, and *** = 0.01. The bottom row shows the Kleibergen-Paap Wald F statistic for weak IV.

Table 5: Second-Stage Robustness Regressions

	(1) Base	(2) w/locations	(3) Diff. Contr.	(4) dummy IVs†	(5) Excl. Rec.	(6) Police FE
12-M Chg Store Den.	-17.009**	-17.286**	-11.487**	-16.445***	-35.555**	-12.284
	(7.035)	(7.011)	(4.837)	(5.704)	(14.702)	(9.685)
Poverty Rate	79.530**	63.947**		77.592***	38.413**	55.768
	(32.448)	(27.602)		(22.269)	(16.967)	(34.461)
Employment (1,000s)	0.732*	0.604		0.722*	0.571	0.613
	(0.402)	(0.407)		(0.389)	(0.400)	(0.462)
Pct. White Non-Hispanic	0.671	-8.326		0.669	-6.347	-5.141
	(5.472)	(5.862)		(5.401)	(5.366)	(8.598)
Miles to CBD	-1.762***	-1.984***	-2.894***	-1.748***	-1.864***	-1.526*
	(0.659)	(0.757)	(0.768)	(0.668)	(0.681)	(0.782)
Usable Land/10,000 Res.	10.662***	9.407***	10.021***	10.505***	9.189***	9.470**
	(3.688)	(3.386)	(3.337)	(3.515)	(3.209)	(4.351)
Schools/10,000 Res		-2.120***				
		(0.680)				
Rehab Centers/10,000 Res		4.060***				
		(1.457)				
Child Care Liscense/10,000 Res		0.509***				
		(0.166)				
Median Income			-0.171***			
			(0.047)			
Retail Employment (1,000s)			0.004**			
			(0.002)			
Percent Black			22.431***			
			(7.648)			
Percent Hispanic			3.668			
			(3.251)			
Weak IV Test Statatistic	10.415	11.310	22.858	28.536	14.675	4.465

This table shows robustness checks of our main results (shown in regression (1)) for the 12-month change in crime rate (per 10,000 residents). Regression (2) includes controls for the density of schools, rehab centers, and child care licenses (per 10,000 residents) in each tract. Regression (3) substitutes control variables; specifically we substitute median income for poverty rate, retail employment for employment, and percent black and percent Hispanic for percent white non-Hispanic. †In regression (4) we use dummy variables for our IVs, specifically an IV that equals one if a neighborhood is more than two miles from a border (and zero otherwise) and an IV that equals one if a neighborhood is than half a mile from a major roadway (and zero otherwise). Regression (5) only uses the store locations of medical marijuana, and regression (6) uses police district and time fixed effects. All regressions use time fixed effects. Heteroskedastic robust standard errors are shown in parentheses, and significance is denoted by * = 0.10, ** = 0.05, and *** = 0.01. The bottom row shows the Kleibergen-Paap Wald F statistic for weak IV.

Table 6: IV Results by Crime Category

	(1) all	(2) violent	(3) nonviolent	(4) persons	(5) property	(6) society	(7) other
12-M Chg Store Den.	-17.009**	-1.125	-15.884**	-2.834**	-0.421	-2.845*	-8.440**
	(7.035)	(0.806)	(6.814)	(1.266)	(2.852)	(1.673)	(3.694)
Poverty Rate	79.530**	2.776	76.753**	9.215	13.733	11.364*	33.793**
	(32.448)	(3.532)	(31.352)	(6.252)	(11.326)	(6.835)	(16.260)
Employment (1,000s)	0.732*	0.070**	0.662*	0.208***	0.041	0.141	0.284
	(0.402)	(0.031)	(0.394)	(0.042)	(0.130)	(0.121)	(0.203)
Pct. White Non-Hispanic	0.671	-0.387	1.058	-0.456	2.564	-0.023	1.350
	(5.472)	(0.537)	(5.309)	(0.973)	(2.013)	(1.121)	(2.640)
Miles to CBD	-1.762***	-0.086	-1.676***	-0.224**	0.087	-0.308**	-0.779**
	(0.659)	(0.057)	(0.649)	(0.090)	(0.314)	(0.155)	(0.340)
Usable Land/10,000 Res.	10.662***	0.409	10.253***	0.912*	0.830	1.303	5.247***
	(3.688)	(0.320)	(3.626)	(0.506)	(1.697)	(0.840)	(1.881)

This table divides crimes into subsets and regresses the 12-month change of each subset on the 12-month change in store density and our control variables (using month fixed effects and both distance to border and major roadway IVs). We provide our headline result in (1) for reference. In regressions (2) and (3) we regress the 12-month change in violent and nonviolent crimes (per 10,000 residents). In columns (4) through (7) we divide the universe of crimes into crimes against persons, property, society, and other. Heteroskedastic robust standard errors are shown in parentheses, and significance is denoted by * = 0.10, ** = 0.05, and *** = 0.01.

Table 7: IV Results by Crime Category - Drugs

	(1) All Drugs	(2) Marj.	(3) Marj. Rel.	(4) Meth	(5) Cocaine	(6) Heroine
12-M Chg Store Den.	-2.252	-0.076	0.143	-0.232	-0.059	-0.651
	(1.517)	(0.779)	(0.237)	(0.400)	(0.478)	(0.564)
Poverty Rate	8.532	0.631	-0.251	0.747	0.639	1.027
	(5.786)	(2.905)	(1.268)	(1.760)	(1.837)	(2.009)
Employment (1,000s)	0.110	0.022	-0.006	0.024	-0.001	0.037
	(0.116)	(0.089)	(0.005)	(0.022)	(0.014)	(0.027)
Pct. White Non-Hispanic	0.515	0.057	0.035	-0.186	0.272	-0.338
	(0.974)	(0.467)	(0.206)	(0.297)	(0.256)	(0.396)
Miles to CBD	-0.209	0.002	0.006	-0.049	0.004	-0.096
	(0.150)	(0.059)	(0.020)	(0.040)	(0.041)	(0.076)
Usable Land/10,000 Res.	0.942	0.008	-0.015	0.158	-0.057	0.439
	(0.801)	(0.302)	(0.119)	(0.219)	(0.219)	(0.402)

This table shows the second-stage results for 12-month change in drug crimes (per 10,000 residents) regressed on the 12-month change in store density and our control variables (using month fixed effects and both distance to border and major roadway IVs). Regression (1) shows results for the 12-month change in all drug crimes. In column (2), we show results for marijuana crimes, and in column (3), we show results for marijuana related crimes (data provided by City of Denver). Columns (4), (5), and (6) show results for methamphetamine, cocaine, and heroin crimes. Heteroskedastic robust standard errors are shown in parentheses and significance is denoted by * = 0.10, ** = 0.05, and *** = 0.01.

Table 8: Nearest Neighbor

	(1) Base OLS	(2) Base 2SLS	(3) OLS w/ Neighbors	(4) 2SLS w/ Neighbors
12-M Chg Store Den.	1.924***	-17.009**	1.910***	-18.679***
	(0.459)	(7.035)	(0.459)	(5.437)
Nearest Neighbor 12-M Chg Store Den.			-0.461	1.543
			(0.305)	(1.106)
Poverty Rate	14.427	79.530**	15.274	83.116***
	(13.247)	(32.448)	(13.340)	(23.893)
Employment (1,000s)	0.403	0.732*	0.399	0.758**
	(0.370)	(0.402)	(0.370)	(0.356)
Pct. White Non-Hispanic	0.579	0.671	0.529	1.211
	(3.799)	(5.472)	(3.789)	(4.315)
Miles to CBD	-1.302**	-1.762***	-1.329**	-1.716***
	(0.579)	(0.659)	(0.579)	(0.644)
Usable Land/10,000 Res.	5.390**	10.662***	5.466**	10.892***
	(2.225)	(3.688)	(2.230)	(3.391)

For regressions (2) and (4), we use both IVs (miles to major road and miles to border) and all regressions use time fixed effects. For comparison, regression (1) contains our OLS base model, and regression (2) contains the base model using both instruments. Regression (3) shows the OLS results with the inclusion of the dispensary density in the nearest neighboring tract. In regression (4) we use our fist-stage predictions of changes in dispensary density for each tract and for the change in dispensary density for the nearest tract (this regression does not include standard error corrections). Heteroskedastic robust standard errors are shown in parentheses, and significance is denoted by * = 0.10, ** = 0.05, and *** = 0.01.

A Change in Crime Tracking Methods

"In May 2013 the Denver Police Department implemented the Unified Summons and Complaint (US and C) process. This process unifies multiple types of paper citations, excluding traffic tickets, into an electronic process. That information is transmitted to the Denver Sheriff, County Court, City Attorney and District Attorney through a data exchange platform as needed" (Denver Police Department, 2013). As a result of this change in tracking, certain crime categories (such as curfew, gambling, or disturbing the peace) show large increases in the number of crimes reported under the new system. For instance, in 2013 there was a total of 1,811 "Disorderly Conduct/Disturbing the Peace" incidents in the Denver crime database of which 798 incidents would not have been reported under the old system.

The percent increase of incidents caused by the change in reporting in decreasing order are curfew (97%), liquor law/drunkenness (93%), disorderly conduct/disturbing the peace (44%), criminal trespassing (40%), drug/narcotics violations (29%), gambling (25%), prostitution (17%), weapons laws (13%), intimidation (10%), larceny (10%), simple assault (8%), and embezzlement (8%). Categories with less than 8% change include counterfeiting/forgery, criminal mischief/damaged property, fraud, family offenses(nonviolent), violation of a restraining/court order, and harassment. Categories not affected by the change in the tracking system were murder, aggravated assault, kidnapping/abduction, arson, bribery, burglary, theft from motor vehicle, motor vehicle theft, robbery, and stolen property.

We control for changes in crime reporting levels across Denver by using time fixed effects. As long as the increases in crime incidents caused by the new reporting system are uncorrelated with our IVs, then the changes in the reporting system do not jeopardize our results. A a check, we divide crimes into two categories: those that show large changes in the number of incidents reported from the new system (more than a 15% difference) and those that show small changes in the number of crimes reported from the new system (less than a 15% difference). Table 9 shows the IV results using each set of crimes. The coefficient on the 12-month change in store density is statistically significant for those crimes that show only small changes under the new reporting system (column (2)) and is consistent with our other results. The coefficient for crimes largely affected by the change in reporting systems (column (3)) is also significant and negative.

The consistently negative and statistically significant coefficients on the 12-month change in store density across both crime groupings suggest that the new reporting system did not substantially change the results.

[Table 9 here]

B County-Level Results

While this paper is primarily about neighborhood-level effects of dispensaries, it is useful to consider the effects of crime at the county level. While we would expect external demand to also be important in location of dispensaries among counties, the instruments used in our tract-level regressions are not useful at the county level given the concentration of dispensaries in urban areas and the coarseness of the geography. Instead we use ex-ante employment in industries that serve tourist populations to instrument for dispensary locations.[57] We separate these into two standard industry categories, defined by the economic census: employment in entertainment, recreation, and art; and employment in accommodation and food services. There are concerns that these instruments suffer from endogeneity, in that they may be correlated with changes in crime during the sample period, and thus these results should be considered with some skepticism. Table 10 shows the county-level results along with the tract-level results presented earlier. The OLS results are shown in column (3), while the IV results using the two instruments both separately and together are shown in columns (4) through (6). The OLS estimates show no significant correlation between changes in dispensary density and changes in crime at the county level. The IV estimates are consistent with the tract-level results, showing some evidence of reduced crime in counties that received more dispensaries. The results, however, are weaker both economically and statistically, which is to be expected given that we have shown that the effects tend to be contained at the neighborhood level where the dispensaries are located.

[Table 10 goes here]

[57] Anecdotally, there is a clear concentration of recreational dispensaries near ski resorts in the Rocky Mountains.

C Police Districts

Figure 5 shows the police districts for the City of Denver.

[Figure 5 goes here]

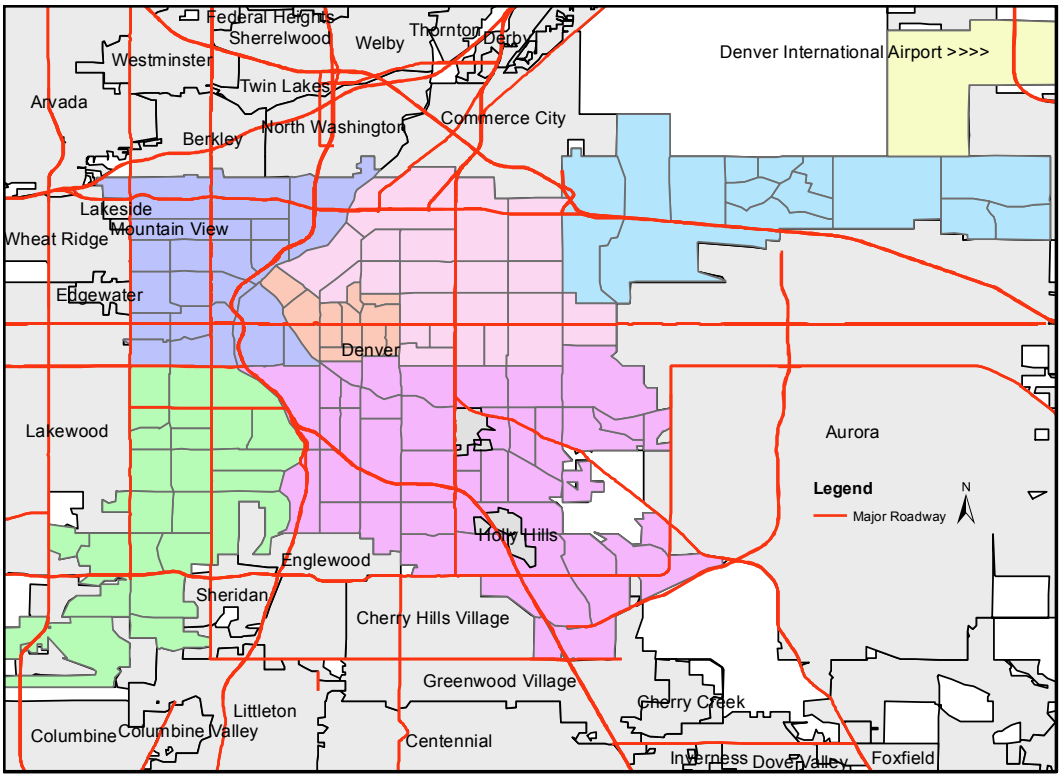


Figure 5: Police Districts

Each police district is shown in a different color (major roadways shown in red). Police district data provided by the City of Denver.

Table 9: Regressions by Crimes Minimally vs. Substantially Affected by Changes in Crime Tracking

	(1) Base	(2) Minimimally Effected†	(3) Substantially Effected‡
12-M Chg Store Den.	-17.009**	-10.401**	-6.608*
	(7.035)	(4.866)	(3.539)
Poverty Rate	79.530**	51.558**	27.972*
	(32.448)	(23.170)	(15.178)
Employment (1,000s)	0.732*	0.532**	0.200
	(0.402)	(0.213)	(0.236)
Pct. White Non-Hispanic	0.671	-1.201	1.873
	(5.472)	(3.909)	(2.486)
Miles to CBD	-1.762***	-1.069**	-0.693**
	(0.659)	(0.450)	(0.345)
Usable Land/10,000 Res.	10.662***	6.423**	4.239**
	(3.688)	(2.512)	(1.913)

For comparison, our base IV results for the change in 12-month crime on 12-month changes in dispensary density (using month fixed effects and both distance to border and major roadway IVs) are shown in column (1). The City of Denver changed its crime tracking system in May of 2013 (the crime levels of some categories were minimally effected by the change while other categories of crimes showed substantial increases in levels). We divide all crimes into two categories: those minimally affected (†), defined by crime categories effected less than 15% by the change in tracking, and those substantially effected (‡) by the change (if crime levels were effected by more than 15%). We then run our main model on each subset of crimes (shown in columns (2) and (3)). Heteroskedastic robust standard errors are shown in parentheses, and significance is denoted by * = 0.01, ** = 0.05, and *** = .01. Crime data provided by the City of Denver.

Table 10: County-Level Regressions

	Tracts in Denver		Counties in Colorado			
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	ALL IV	OLS	Ent/Rec/Art IV	Acomed/Food IV	BOTH IV
12-M Chg Store Den.	1.924***	-17.009**	0.891	-3.121**	-6.878	-3.002*
	(0.459)	(7.035)	(0.570)	(1.588)	(5.236)	(1.564)
Poverty Rate	14.427	79.530**	-1.839	5.788	12.929	5.562
	(13.247)	(32.448)	(7.111)	(7.985)	(12.603)	(7.947)
Employment (1,000s)	0.403	0.732*	-0.002	0.002	0.005	0.001
	(0.370)	(0.402)	(0.003)	(0.003)	(0.005)	(0.003)
Pct. White Non-Hispanic	0.579	0.671	-0.319	-0.597	-0.857	-0.589
	(3.799)	(5.472)	(3.071)	(2.961)	(3.060)	(2.962)
Miles to CBD	-1.302**	-1.762***	-0.013*	-0.005	0.003	-0.005
	(0.579)	(0.659)	(0.007)	(0.007)	(0.011)	(0.007)
Usable Land/10,000 Res.	5.390**	10.662***				
	(2.225)	(3.688)				
Weak IV Test Statistic		10.415		120.599	9.569	62.104

For comparison, our base OLS and IV results for the 12-month change in crime date (for Denver) are included in (1) and (2) (our IV results use both miles to major road and miles to border as IVs for change in dispensary density and use time fixed effects). In regressions (3) through (6) we show county-level regression results of 12-month changes in crime rates (per 10,000 residents) on 12-month changes in dispensary density (per 10,000 residents). Regression (3) shows OLS results. In regression (4), we use the number of employees in entertainment, recreation, or art industries as an IV for changes in dispensary density, and regression (5) uses the number of employees in accommodation or food industries as an IV. In regression (6) we use both the IVs in the first stage. Denver regressions use crime data provided by City of Denver (between 2013 and 2016) and county-level regressions use crime data provided by the FBI (for between 2013 and 2014). Heteroskedastic robust standard errors are shown in parentheses and significance is denoted by * = 0.10, ** = 0.05, and *** = 0.01. The bottom row shows the Kleibergen-Paap Wald F statistic for week IV.