What About Equity? Neighborhood Deprivation and Cannabis Retailers in Portland, Oregon

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ABSTRACT

The impacts of recently legalized cannabis retail markets on urban neighborhoods are largely unknown. More cannabis retailers may be operating in neighborhoods experiencing deprivation because of regulations that limit where cannabis businesses can operate. Increased exposure to cannabis retailers in deprived neighborhoods could have negative consequences on the perceived safety and social cohesion within neighborhoods, and the availability of commercialized cannabis could have negative health impacts for both youth and adults if it promotes risky use. On the other hand, cannabis businesses potentially provide for economic growth in deprived areas and divert illicit activities. This study uses integrated nested Laplace approximation (INLA) spatial regression to estimate the association between neighborhood deprivation and the distribution of cannabis retailers in city-defined neighborhoods in Portland, Oregon, September 2017. Across Portland, 66% of 117 neighborhoods had at least one cannabis retailer (range 0-8 retailers). Model results indicated that a one-standard deviation increase in neighborhood deprivation corresponded with 73% more cannabis retailers (aRR 1.73, 95% CI: 1.32–2.27) after adjusting for availability of eligible commercial property, population density, and neighborhood size. Findings of this study support the hypothesis that cannabis retailers are more likely to be located in relatively deprived neighborhoods, suggesting the need to consider spatial equity in cannabis policies to mitigate disproportionate exposure to retailers, particularly if retailer exposure is associated with negative consequences.

Key words: cannabis retailers, inequity, neighborhood area deprivation, spatial epidemiology, cannabis policy, built environment, land use, cannabis legalization, marijuana legalization, equity

By the summer of 2019, eleven U.S. states and the District of Columbia have legalized non-medical cannabis use for adults, and a majority of states have legalized some form of cannabis for medical use; however, cannabis use, possession and sales remain illegal at the federal level. Some common features across legalized states include the adoption of a market-oriented, for-profit

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cannabis industry that allows for the production, distribution, and sale of cannabis products to adults ages 21 or older (Alcohol Policy Information System, 2019).

There is growing concern that exposure to cannabis retailers and storefront advertisement could have detrimental effects at both the individual and neighborhood level. Legalization of medical and retail cannabis in the U.S. has exposed vulnerable communities to storefront marketing of cannabis retailers (Cao, Carrillo, Zhu, & Shi, 2019; Fiala, Dilley, Firth, & Maher, 2018). The legalization of cannabis has also resulted in increased availability of high potency products (concentrates and edibles) which could have negative health impacts for both youth and adults (Carlini, Garrett, & Harwick, 2017). Specifically for youth, exposure to cannabis retailers may alter social norms by reducing the perceived harm of cannabis use and lead to an increase in cannabis consumption and further criminal prosecution of minors who use cannabis (Ammerman, Ryan, & Adelman, 2015). For adults, proximity to cannabis retailers has been associated with both an increase in any cannabis use and frequent use (Everson, Dilley, Maher, & Mack, 2019).

At the neighborhood level, the nature and direction of the impacts of legalization and the opening of commercial cannabis markets on social cohesion, perceived safety, and local economies are unknown, but could prove to have a destabilizing effect on vulnerable neighborhoods. Research on alcohol outlets found that off-premise liquor outlets have negative impacts on the social capital of neighborhoods, drinking behaviors, hospital admissions, and violent crime (Fone et al., 2016; Theall et al., 2009). Further, increases in neighborhood socioeconomic status was associated with decreases in alcohol use (Brenner, Borrell, Barrientos-Gutierrez, & Diez Roux, 2015). The opening of cannabis retailers may impact neighborhoods in a similar manner as liquor stores (Berg, Henriksen, Cavazos-Rehg, Haardoerfer, & Freisthler, 2018). In Colorado, cannabis retailers were disproportionately located in census tracts with lower household incomes and higher proportions of racial/ethnic minorities (Shi, Meseck, & Jankowska, 2016), cannabis outlets in Washington state were more likely to be co-located in census tracts with liquor stores (Tabb, Fillmore, & Melly, 2018) and areas experiencing the greatest disadvantage (Amiri, Monsivais, McDonell, & Amran, 2019), and census tracts with shorter life expectancy were more likely to have unlicensed cannabis retailers but not licensed retailers in Los Angeles County (Nicholas et al., 2019). Prior research on the distribution of medical dispensaries in California found that dispensaries were concentrated in areas of poverty, racial/ethnic minorities, and alcohol outlets (Morrison, Gruenewald, Freisthler, Ponicki, & Remer, 2014; Thomas & Freisthler, 2017), and dispensaries in Denver, Colorado were more likely in areas of high crime rates (Boggess, Pérez, Cope, Root, & Stretesky, 2014). In light of evidence, there is reason to believe that commercial cannabis markets will be disproportionately distributed across urban areas and concentrate in neighborhoods experiencing disadvantage. A limitation of these previous studies, however, is that they did not consider the state-specific regulations that determine where cannabis retail stores can operate and the availability of this eligible property. Not accounting for the influence of business regulations on where cannabis retailers can operate will ultimately bias associations between neighborhood characteristics and cannabis retailers.

The state of Oregon legalized the local production, processing, and sale of cannabis to persons 21 and older for non-medical use by voter initiative in 2014. Early restricted retail sales of cannabis products began in October 2015 in existing medical dispensaries and full retail sales commenced in January 2017. By the end of 2017, 486 retail cannabis stores were operating across Oregon (Oregon Liquor Control Commission, 2017); 31% of these retailers (150 stores) were operating in the city of Portland, Oregon's most populous city.

We use an interdisciplinary approach and innovative methods to address our research question: site suitability assessments, a technique from urban planning, and spatial epidemiological methods. This study aims to assess the relationship between neighborhood area deprivation and the distribution of cannabis retailers while accounting for cannabis business regulations that restrict where retailers can operate. We hypothesize that licensed cannabis retailers will be more likely to operate in neighborhoods experiencing disadvantage even

when adjusting for availability of eligible commercial property. Findings from this study will further our understanding about where cannabis retailers are located in one urban area that has legalized cannabis and provide insights to support equity-focused cannabis policies in other urban areas with emerging retail cannabis markets.

METHOD

Study Design

We conducted an ecological cross-sectional spatial analysis of the association between neighborhood deprivation and distribution of cannabis retailers in Portland, Oregon.

Neighborhood Area Definition

Areas within Portland that have registered with the Office of Neighborhood Involvement and have an established neighborhood association with clearly defined geographic boundaries are considered neighborhoods for the purposes of our study. Locally-defined neighborhood boundaries are more relevant to policy makers and communities than census tracts which often do not align with conceptions of a neighborhood (Sperling, 2012). In the city of Portland, neighborhood coalitions are well established and positioned to influence business operations – including cannabis retailers—within their neighborhood boundaries (City of Portland Office of Neighborhood Involvement, 2005). Our results will provide stakeholders with more representative data and support policy solutions to ensure equitable impacts of cannabis legalization. In addition to the 92 registered neighborhoods, Portland has 21 areas where multiple neighborhoods share jurisdiction of an area, and 4 unclaimed areas of land (The City of Portland, n.d.). Shared regions and unclaimed land were considered as neighborhoods in our analysis in order to provide contiguous, mutually exclusive, and full coverage of our study area. This resulted in 117 neighborhood areas included in analysis (see Figure 1).

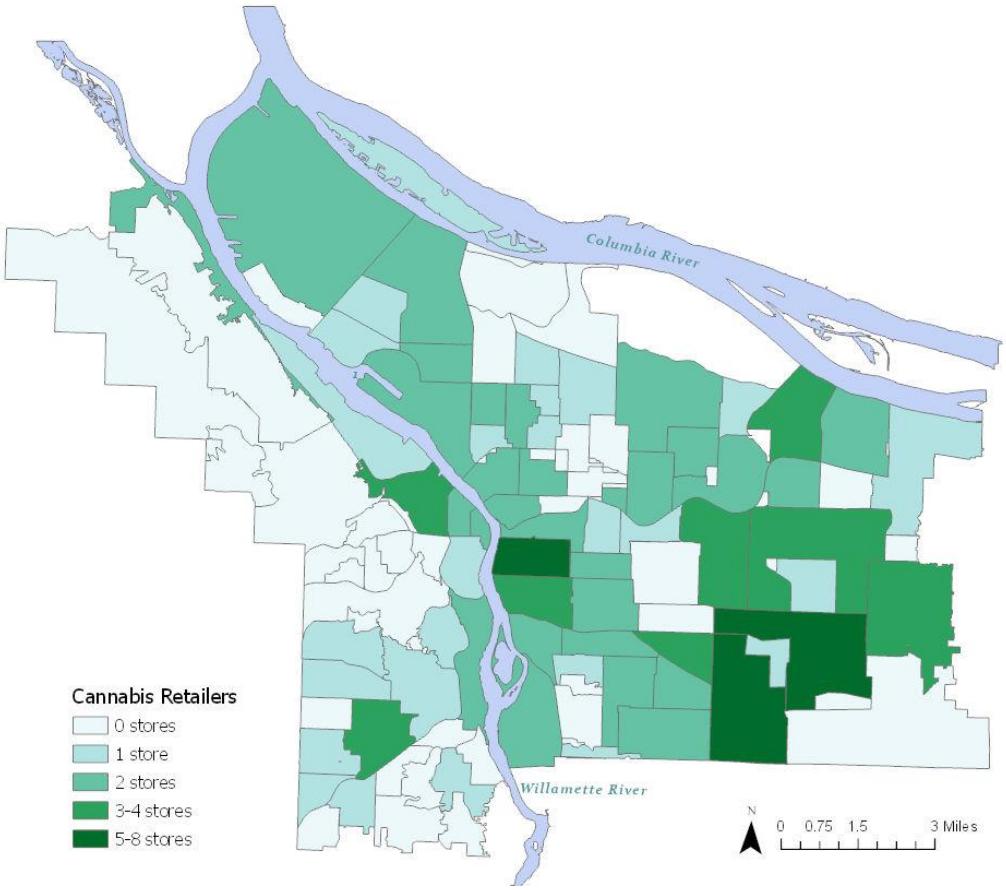

Figure 1. *Cannabis Retailers in Portland, Oregon Neighborhoods, 2017*

Exposure: Neighborhood Deprivation Index

A neighborhood deprivation index (NDI) was constructed from American Community Survey (ACS) 2012–2016 5-year estimates at the census block group-level. This data were the most current available during September 2018 when analysis was conducted. Thirty-three ACS variables were included in a principal component analysis (PCA) to calculate a Portland-specific deprivation index. Variables included in the PCA draw from the domains of income/poverty, demographics, occupation, education, housing, and assets (Supplemental Table 1). These domains represent aspects of the neighborhood context intrinsically tied to economic disadvantage, increases in health risk behaviors, and poor health outcomes (Messer et al., 2006). Variables included in the PCA are consistent with other survey-based estimations of neighborhood socioeconomic status or deprivation indices (Powell-Wiley et al., 2014). We implemented a three-step PCA approach that uses data mining techniques to reduce variable redundancy and optimize the proportion of variance explained by the first component (*SESIndexCreator* version 1.0 and *FactoMineR* version 1.41 statistical packages in R software (Lalloué et al., 2015, 2013)). The *SESIndexCreator* procedures have been described in detail elsewhere (Lalloué et al., 2013). Three successive steps were followed to create the Portland NDI:

1) Reduction of redundant variables through PCA. For variables that represented a similar construct, a PCA was performed on each group of similar variables. One variable was selected from each PCA that had the largest correlation with the first component of the PCA. Each selected variable was then used in subsequent steps. Five variable groups were candidate for variable reduction: occupation categories, education attainment, health insurance, active transportation, and food stamps (see Table 1). The correlation coefficients from the first component of the PCA were reported in Table 1, column 2 for each variable. The five selected variables (one from each PCA) were: percent of residents with a management-level occupation, adults 25+ years with a high school diploma, percent of residents without health insurance, percent of residents who bike or walk to work, and percent of residents who received food stamps.

2) *Preliminary PCA was conducted*. The goal of the preliminary PCA was to identify variables that were best correlated with the first component. Variables that had an above average correlation with the first component were used in the final step. The preliminary PCA included 23 variables (5 selected variables from step one and 18 remaining variables). The first component of this PCA had an eigenvalue of 9.78 and explained 43% of the variance in the data. Twelve variables that had a correlation with the first component >0.6 or < -0.60 were included in the final PCA (step 3) and reported in Figure 2. Correlation coefficients from the first component were reported Table 1, column "Step 2: Preliminary PCA" for each variable.

3) *A final PCA was conducted to construct the neighborhood deprivation index*. The first component of this final PCA was interpreted as the neighborhood deprivation component and was used to calculate the NDI for each census block group. The first component had an eigenvalue of 8.27 and explained 69% of the variance in the data. Correlation coefficients from the first component were reported Table 1, column "Step 3: Final PCA" for each variable. Factors most positively correlated with neighborhood deprivation included: receipt of food stamps, household income < $50,000, no health insurance, poverty, no post-secondary education, single female head of household, rental housing, and limited English spoken at home.

To estimate NDI for each locally-defined neighborhood, area-weighted estimation was used to assign census block groups to Portland neighborhoods. Area-weighted estimation is a GIS technique that overlays neighborhood boundaries on census block groups to determine which portions of each block group are contained within a particular neighborhood. For example, if the geographic area of a neighborhood contains 30% of block group A and 70% of block group B then the population of the neighborhood (N_p) would be the sum of weighted block groups estimates (N_p = 0.3(population of block group A) + 0.7(population of block group B). Therefore, every neighborhood population or prevalence estimate is the sum of weighted census block group estimates. Area-weighted estimation was conducted using the *SF* statistical package version 0.7-1 in R software (Edzer Pebesma, 2018). The number of block groups within each Portland neighborhood varied

Table 1. *Variables Included in Principal Component Analysis of Neighborhood Deprivation, from American Community Survey, 2012-2016 Five-Year Census Block Group Estimates*

Indicators	Step 1: Reduce redundancy with PCAs	Step 2: Preliminary PCA	Step 3: Final PCA
Income & Poverty			
Median household income (in dollars)[1]		-0.87	-0.87
Percent of households making <50k		0.94	0.93
Percent of families in poverty with children < 18 years old[2]		0.84	0.83
Percent of individuals in poverty		0.90	0.89
Food stamps:			
Percent who receive food stamps	0.98	0.93	0.94
Percent who are on disability and receive food stamps	0.98		
Percent of income attributed to public assistance		0.72	0.75
Dividends, interest, or net rental income (in dollars)		-0.86	-0.88
Occupation[3]			
Percent of unemployed		0.61	
Percent in labor force		-0.19	
Occupation type:			
Percent with an occupation in a management role	0.93	-0.51	
Percent with an occupation in the business sector	0.91		
Percent with an occupation in food service	-0.39		
Demographics			
Population density		0.16	
Percent of single female head of households		0.72	0.72
Percent of single female head of households with children < 18 years old[2]		0.60	
Percent of households where limited English is spoken		0.67	0.67
Percent of households that have move at least once in the past year		0.42	
Health insurance:			
Percent of all persons not covered by health insurance	0.98	0.88	0.90
Percent of adults 18-34 years covered by health insurance	0.88		
Percent of adults 35-64 years covered by health insurance	0.93		
Education			
Percent of adults 25+ years with less than a high school diploma	0.90		
Percent of adults 25+ years with a high school diploma	0.96	0.79	0.8
Percent of adults 25+ years with some college	0.85		
Percent of adults 25+ years with a college degree	-0.92		
Percent of adults 25+ years with graduate school education	0.95		
Housing			
Number of housing units		0.08	
Percent of households in rental housing		0.71	0.70
Median contract rent (in dollars)		-0.44	
Percent of households in new homes (2014 or newer construction)		0.20	

Transportation		
Percent of households with no vehicle		0.39
Active Transportation:		
Percent of person who use active transportation (bike or walk) to get to work	0.85	0.10
Percent of persons who use public transportation to get to work	0.85	

Note. [1] For 5 census block groups the sample size was too small for ACS to provide an estimate of median income. Estimates were imputed by assigning the corresponding census tract's median income value to the block group. [2] For 3 block groups were no families lived, estimates were imputed with census tract estimates. [3] Occupation type was restricted to occupations that were common in Portland, Oregon, and showed variety in type of occupation.

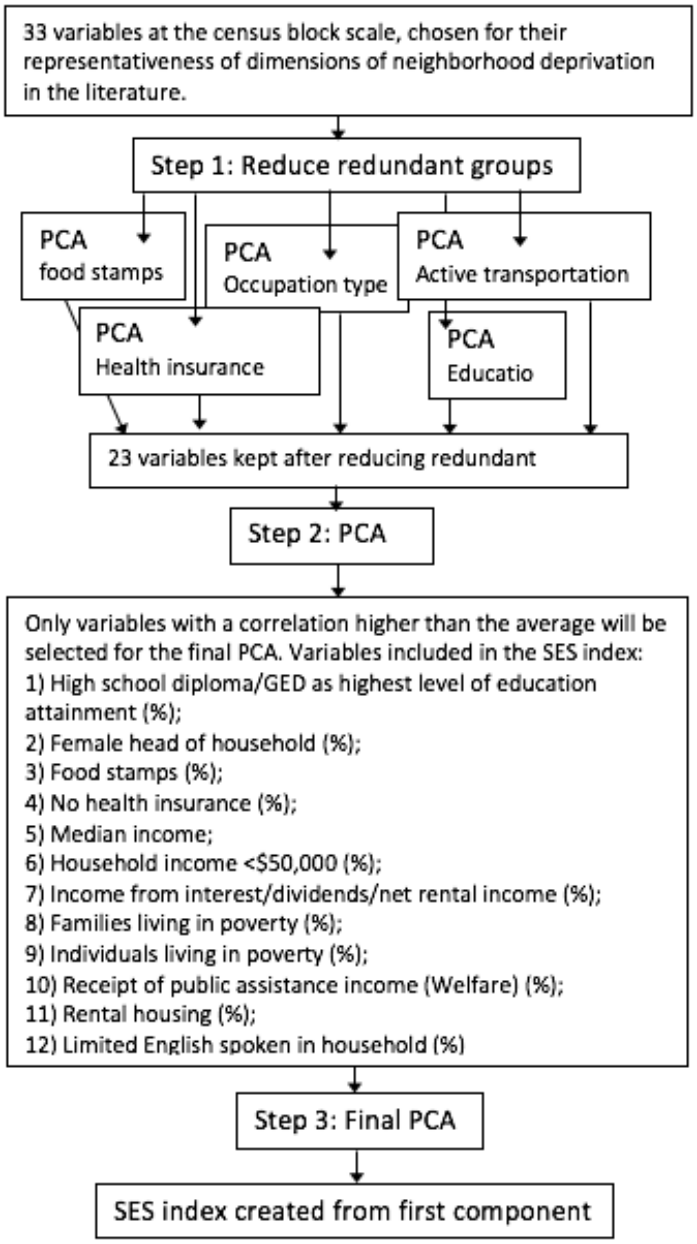

Figure 2. *Creation of Neighborhood Deprivation Index Using a Three-Step Principal Component Analysis Approach.*

from 1 to 28. For analysis, the neighborhood-level NDI was transformed into a Z-score and the mean score was 0 with a 1-unit difference representing one standard deviation away from the mean. Higher values of the NDI indicate more deprived neighborhoods.

Outcome: Count of Cannabis Retailers

The outcome of interest was the count of observed cannabis retailers within a defined Portland neighborhood (see Figure 1). To calculate the count of cannabis retailers within each neighborhood, each of the 150 active cannabis retailers registered with the Oregon Liquor Control Commission (OLCC) on September 28th 2017 were geocoded and spatially assigned to a neighborhood.

Covariate: Availability of Eligible Commercial Property

Cannabis business regulations determine where cannabis retailers can operate. Criteria for operating a cannabis business are mandated by state legislature and the City of Portland cannabis program (City of Portland Office of Neighborhood Involvement, 2018). Regulations require that properties 1) must be zoned for commercial use, 2) maintain a minimum 1,000 foot buffer from primary and secondary schools, and 3) must be at least 1,000 foot buffer between all established cannabis retailers (City of Portland Office of Neighborhood Involvement, 2018). In order to assess the association between neighborhood deprivation and the distribution of cannabis retailers, we needed to account for the availability of properties that could operate as licensed cannabis businesses in each neighborhood.

The number of eligible commercial properties in each neighborhood was estimated by conducting site suitability assessments. This is a common practice in real estate and urban planning disciplines to inform where particular business can operate (Meyer & Grabaum, 2008). We analyzed all properties within the city that were recorded in Multnomah County Tax Assessor data. Our data file was compiled during the spring of 2018 (Metro Regional Government, 2017). The first step was to determine the universe of possible locations where cannabis retailers could legitimately open. Using a GIS approach, the number of suitable sites within each neighborhood was reduced in stepwise fashion. Among the 13,844 commercial properties with an existing structure in Portland, 807 were deemed eligible to open as a cannabis retailer based on the criteria described above (and summarized in Supplemental Table 1). Seven eligible properties (0.9%) had structures built in 2017. We then estimated the number of eligible cannabis retailers within each neighborhood based on the reference probability of an eligible commercial property becoming a cannabis retailer. The reference probability was the proportion of total number of current cannabis retailers out of the total number of eligible sites in the city (150/807). The sum of eligible cannabis retailers within Portland was 148 and ranged from 0 to 13 within each neighborhood, and 77 of 117 (66%) neighborhoods were eligible to have least one cannabis retailer. All GIS analyses were performed in ArcGIS Pro 2.1.2.

Covariate: Adult Population

The number of adults (21+ years) living in each neighborhood was a covariate in our analysis. In analysis, the number of adults was log transformed to address its non-normal distribution. Adults serve as the customer base for cannabis retailers and thus neighborhoods with a larger adult population may attract more retailers.

Covariate: Expected Value

In the absence of cannabis business regulation, the expectation is that cannabis retailers would be evenly distributed across neighborhoods in Portland. The expected value for each neighborhood was calculated by multiplying the probability of the proportion of operating cannabis retailers out of total land area for the city of Portland (150 retailers/149.8 square miles) by the area of each neighborhood (in square miles). The median neighborhood expected value was 0.80 retailers with a range from 0.01–12.29 retailers. The expected value was used as the reference risk in statistical models.

Statistical Analysis

Data processing and mapping of cannabis retailers and neighborhood deprivation in Portland were conducted in ArcGIS Pro 2.12. We fit statistical models with spatial smoothing for observed counts of cannabis retailers to test the association with neighborhood deprivation. This method allowed us to assess the risk surface of cannabis retailers at the neighborhood-level by neighborhood deprivation. In models, the primary independent variable is the neighborhood deprivation index (NDI). The dependent variable was the count of observed cannabis retailers within each neighborhood. Availability of eligible commercial property and log-transformed population density (adults 21+ years) were included as covariates in analysis. We fit a series of Poisson models and used as an offset the natural log of the expected value of cannabis retailers within each neighborhood. An offset (or reference risk) was included to estimate the relative risk within each neighborhood.

(Model 1)

$$\begin{cases} Y_i = \mu_i \\ \log(\mu_i) = \log(E_i) + \beta_0 + \beta_1 \boldsymbol{x}_i + \beta_2 \boldsymbol{x}_i + \beta_3 \boldsymbol{x}_i + S_i + \varepsilon_i \end{cases}$$

Y_i Count of cannabis retailers within a neighborhood (outcome)
μ_i Marginal mean
E_i Expected value
β_0 Intercept
β_1 Neighborhood deprivation index (exposure)
β_2 Availability of eligible commercial property (covariate)
β_3 Log-transformed adult population (21+ years) (covariate)
$\boldsymbol{x}_i$ Unit of analysis, measurement at the neighborhood level
S_i Spatial random effects
ε_i Non-spatial random effects

First, we fit a quasi-Poisson model to estimate the amount of overdispersion in the data. To address overdispersion, we then fit a series of Poisson models with neighborhood random effects and spatial smoothing using integrated nested Laplace approximation (INLA) (Lindgren & Rue, 2015; Rue, Martino, & Chopin, 2009). INLA is an efficient Bayesian estimation approach for areal spatial data that produces estimates of the marginal posterior distributions of the parameters (Taylor & Diggle, 2014). Incorporating a spatial component into the model controls for spatial confounding that may be present if an association is isolated to a particular region within the study area. Spatial effects were specified using a modified Besag-York-Molli´e model (BYM2) that calculated both spatial and non-spatial random effects (Model 1) (Riebler et al., 2016). The BYM2 was chosen because it allows two contributions to the residuals in each area: one allows for "shocks" in each area that are independent of the residuals in other areas while the other allows dependence between residuals of neighboring areas. The spatial contribution of the BYM2 model allows for the count of cannabis retailers within each neighborhood to depend on the values of the counts in neighboring areas (defined as areas that share boundaries). This approach allows us to examine whether there is spatial structure in the counts of cannabis retailers across neighborhoods. The regression part of the model estimated the log relative risk between neighborhood deprivation and the distribution of cannabis retailers.

We reported the 95% credible interval, similar to a confidence interval, for neighborhood-area residual relative risks along with the proportion of residual variability explained by spatial dependence. All analyses were conducted in R studio using INLA version 18.07.12 package and *SpatialEpi* version 1.2.3 package. Analysis was conducted December 2018 and revised in Summer of 2019.

RESULTS

Descriptive Statistics

Across the 117 neighborhood areas within Portland, 66 had at least one cannabis retailer operating by September 2017. The range of cannabis retailers within each neighborhood was 0 to 8. The city of Portland is sometimes described in terms of East or West Portland, as divided by the Willamette River. The majority of cannabis retailers (122, 81%) were located in the 79 neighborhoods in East Portland (Map 1) and the remaining 28 retailers (19%) were within the 38 neighborhoods of West Portland.

Neighborhood deprivation varied greatly across Portland. Areas experiencing the most deprivation were predominately located in outer South East Portland and the least deprived neighborhoods were in North East and West Portland. Neighborhood characteristics included in the NDI are summarized in Table 2 for areas with the highest (Glenfair) and lowest (Bridlemile) NDI score (see Figure 3). Within the most deprived neighborhood, Glenfair, the median income was $48,000, over half (54%) of residents lived in households that earn less than $50,000 annually, 21% of residents lived in poverty, and the majority of residents (64%) lived in rental housing. Across the city in West Portland, Bridlemile residents earned a median household income of $167,000 annually, 14% of residents lived in households earning less than $50,000, only 1% of residents lived in poverty or received food stamps, and 3% of households lived in rental housing.

Spatial Regression Models

The quasi-Poisson model found overdispersion in the data: the variance exceeded the marginal mean by 67%. Given the presence of overdispersion, the spatial regression models used a Poisson model with neighborhood-level random effects (Model 1). Across neighborhoods, a one-unit (or one standard deviation) increase in neighborhood deprivation was associated with 81% more cannabis retailers (RR 1.81, 95% CI: 1.38–2.40) than the expected value in crude analysis (Table 3). When the count of eligible commercial properties within each neighborhood was adjusted for, the effect of neighborhood deprivation increased such that a one-unit change corresponded to 87% more retailers (aRR 1.87, 95% CI: 1.44– 2.45). Though, when adult population was also adjusted for, the effect of neighborhood deprivation was slightly attenuated towards the null (aRR 1.73, 95% CI: 1.32–2.27).

Both adult population density and eligible commercial property were associated with the count of cannabis retailers beyond the expected value. Greater adult population density (on the log scale) was associated with more cannabis retailers (aRR 1.54, 95% CI: 1.15–2.14). While, availability of eligible commercial property was associated with fewer cannabis retailers when holding neighborhood deprivation and adult population density constant (aRR 0.85, 95%CI: 0.75–0.95).

Table 2. *Neighborhood Characteristics among the Most and Least Deprived Neighborhoods, Portland, Oregon*

	NDI Score	Food Stamps	Poverty	High School Diploma	Female Head of Household
Most Deprived: Glenfair	2.44	44%	21%	29%	45%
Least Deprived: Bridlemile	-1.70	1%	1%	4%	10%
	Annual income <$50k	Median Income	No Health Insurance	Rental Housing	Limited English Spoken
Most Deprived: Glenfair	54%	$48k	18%	64%	12%
Least Deprived: Bridlemile	14%	$167k	2%	3%	0%

Table 3. *Association between Neighborhood Deprivation and Distribution of Cannabis Retailers, Portland, Oregon 2017*

Neighborhood Deprivation		Count of eligible commercial property locations		Log(Population 21+ years)	
RR	(95% CI)	RR	(95% CI)	RR	(95% CI)
1.81	(1.38–2.40)				
1.87	(1.44–2.45)	0.92	(0.82–1.02)		
1.73	(1.32–2.27)	0.85	(0.75–0.95)	1.54	(1.15–2.14)

Note. Spatial models used integrated nested Laplace approximation and incorporated both spatial and non-spatial random effects that were specified with a modified Besag-York-Molli´e model. RR=Relative Risk.

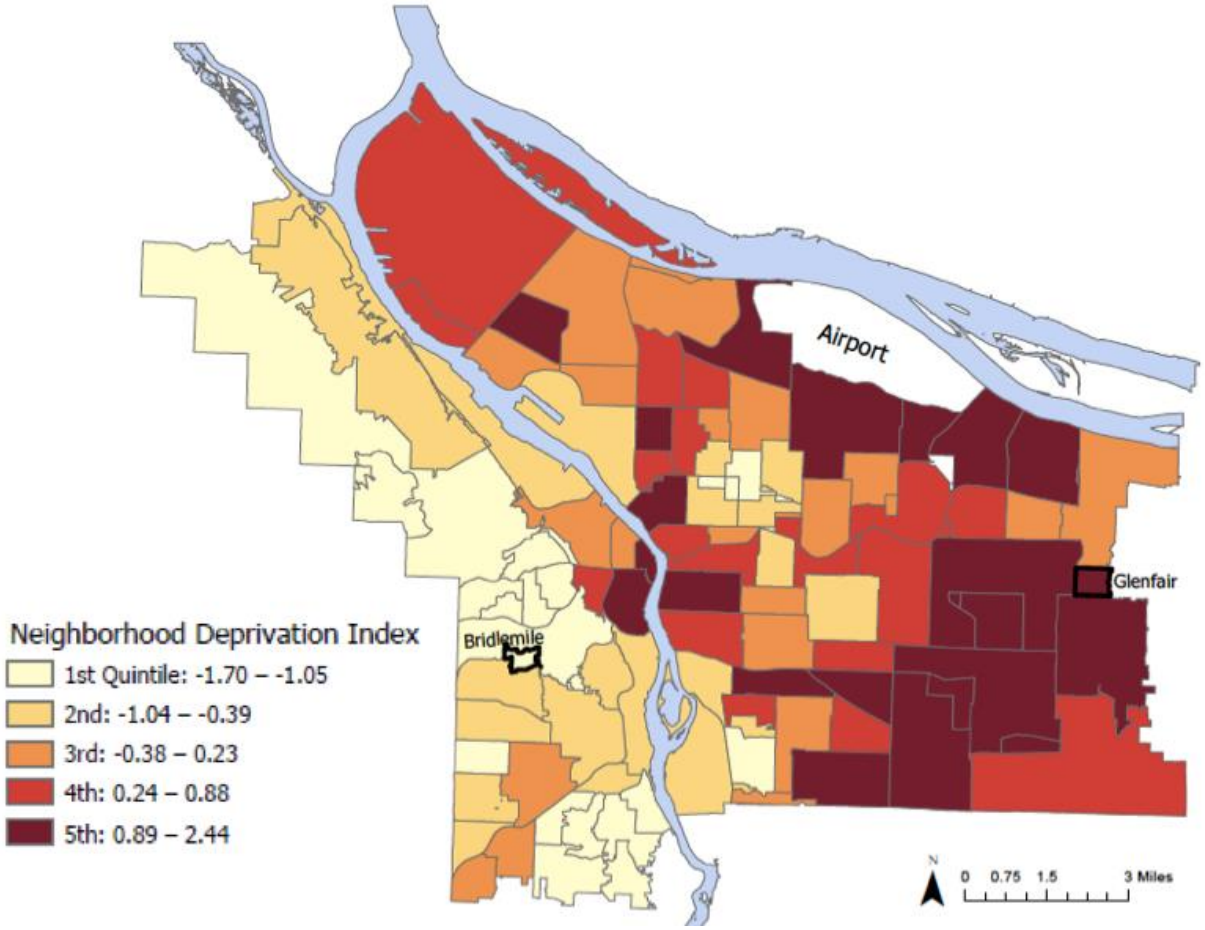

Figure 3. *Neighborhood Deprivation in the City of Portland, Oregon, 2012-2016.*
Note. Neighborhood deprivation index was derived from the American Community Survey data at the census block group-level and spatially weighted to neighborhood boundaries, 2012-2016. Higher values indicate more deprivation.

DISCUSSION

To date, no study had considered the spatial restrictions that cannabis siting regulations impose when examining the distribution of cannabis retailers in a fully legalized market. A previous study analyzed changes in the count of medical marijuana dispensaries in Los Angeles (2012–2014) and considered percent of commercially-zoned area, restaurants, bars, and off-premise alcohol outlets in their analysis (Thomas & Freisthler, 2017). Though, the study was conducted prior to California's legalization of retail markets and regulations for medical marijuana dispensaries did not include zoning and buffer requirements like those incorporated in our site suitability assessment. Considering the spatial implications of cannabis business regulations is an improvement upon previous methods when describing the distribution of cannabis retailers (Shi et al., 2016; Tabb et al., 2018). Another improvement from previous research is that this study used geographic neighborhood boundaries defined by the city of Portland Office of Neighborhood Involvement instead of using census-defined areas. Using locally-defined neighborhood boundaries provided relevant neighborhood deprivation data to neighborhood coalitions and city planners.

This study identified that neighborhoods experiencing disadvantage in Portland were more likely to have higher concentrations of cannabis retailers than neighborhoods that experienced less disadvantage. If two neighborhoods had the same number of adults and amount of eligible commercial property, but they differed by one-unit on the deprivation index, the more deprived neighborhood would have 73% more cannabis retailers. Our results are consistent with recent studies in other legalized states that found cannabis retailers to be more likely to be located in census tracts with greater poverty in both Washington state and Colorado (Shi et al., 2016; Tabb et al., 2018), and retailers were more prevalent in the most deprived census tracts in Washington state (Amiri et al., 2019). Further, there is consistency between the Washington state area deprivation index (Amiri et al., 2019) and the Portland neighborhood deprivation index that both include domains of poverty, housing, employment, and education.

Neighborhoods with more available commercial property were less likely to have operating cannabis retailers. In other words, areas with the greatest amount of available commercial property, which tend to be located on the outskirts of the city, were not enticing for cannabis retailer businesses. Such business characteristics like business size (square footage), parking lots, and road visibility may be important factors for retailer owners and were not considered in this analysis. This finding is similar to a spatial analysis conducted on medical marijuana dispensaries in Los Angeles, California, that identified dispensaries were more likely to be located in census tracts of more African American residents and fewer in areas zoned for commercial use (Thomas & Freisthler, 2017). Similarly, redevelopment zones and urban revitalization in historically deprived neighborhoods could contribute to the placement of cannabis retailers and targeting business development in specific deprived neighborhoods.

Impliciations for Future Research

The effects that disproportionate exposure to cannabis retailers will have on neighborhoods remains unclear. Studies are needed to identify both positive and negative effects that cannabis regulatory policies have on the placement of cannabis retailers and the subsequent impacts on neighborhoods and residents. Individuals living in deprived areas with more exposure to cannabis retailers may be at greater risk of increasing cannabis use, particularly use of high potency products sold in cannabis retailers, that put youth and naïve users at heightened risk for poisoning and emergency department visits (Allen et al., 2017; Barrus et al., 2016). At the neighborhood level, the presence of cannabis retailers may disrupt neighborhood social cohesion or increase crime. On the other hand, cannabis businesses may build the local economy and reduce illicit cannabis enterprises.

The city of Portland recently implemented a cannabis social equity grant program (April 2019) that has reserved a proportion of local cannabis sales tax for minority-owned businesses (Office of Community & Civic Life, 2019). Other legalized urban areas that have implemented similar social equity programs (Oakland (City of Oakland, 2018), Los Angeles (Department of Cannabis

Regulation, n.d.), and the state of Massachusetts (Cannabis Control Commission, 2018)) prioritize cannabis business licenses for low income residents who have been formally convicted of a cannabis crime or live in a low socioeconomic area. Such initiatives help alleviate barriers that have prevented small business owners and communities disproportionately affected by previous cannabis laws from entering into the cannabis industry. To date, no evaluation has been conducted on the impacts that these equity programs have on neighborhood economies and population health.

This study provides a methodological framework for measuring disproportionality of cannabis retailers in other urban areas. Methods should be replicated in other areas that are establishing retail cannabis markets. Variations in cannabis policies between urban areas, legalized states, provinces, and countries may offer insight into policies that effectively mitigate the disproportionate burden of cannabis retailers across neighborhoods. As more areas continue to liberalize cannabis laws, local policy efforts should consider how zoning restriction will contribute to the concentration of cannabis retailers in deprived areas.

Limitations

The ecological cross-sectional design of our study limits the ability to infer a causal relationship between neighborhood deprivation and the establishment of cannabis retailers. Further, our results did not assess changes in the distribution of cannabis retailers over time. Given that the cannabis industry is still in its infancy, it may be that retailers are first opening stores in areas perceived as 'low risk' where community resistance is minimal. In the future, retailers may begin to move into more advantaged neighborhoods and the distribution of cannabis retailers across neighborhoods may change. Longitudinal data will be needed to assess future changes. Further, we only assessed the potential confounding effects of eligible commercial property and neighborhood population, unmeasured confounding could have inflated our estimated effect of neighborhood deprivation on the distribution of cannabis retailers. For instance, accounting for all commercially-zoned property within a neighborhood –not just commercial property eligible to operate as a cannabis retailer—could contribute to our understanding of why retailers open within particular neighborhoods. Our study was interested in assessing 'who' was most exposed to cannabis retailers and future research could assess built environment characteristics to identify 'how' or 'why' cannabis retailers operate within particular neighborhoods.

The measure of neighborhood deprivation used in analysis was specific to Portland and captured neighborhood characteristics that are most relevant to deprivation within the city. Though this is a strength of our analysis, the index created may not translate well to other urban areas that have legalized cannabis. Further, the index was compiled with the most current available ACS data at the time of analysis (2012–2016). Therefore, the possibility exists that neighborhood deprivation could have changed between the time when NDI data were collected and our sample of cannabis retailers was compiled in September 2017.

Prior to retail cannabis legalization, the siting of legitimate medical cannabis dispensaries across the city may have influenced the location of cannabis retailers included in our study. Though the exact number is unknown, many cannabis retailers operating in Portland during 2017 were believed to be previously operating as licensed medical dispensaries (Oregon Liquor Control Commission, 2016; Oregon Medical Marijuana Program, 2018). If the earlier siting practices for medical dispensaries had influenced the location of currently operating retail cannabis stores and these previous dispensary practices are different from current retailer regulations, this could have affected the results of our adjusted models. In other words, the estimates of the number of available properties to operate as cannabis retailers within each neighborhood may not be relevant to some retailers if the shops were previously operating under medical dispensary regulations. Though, the impact of this bias appears to be minimal because both crude and adjusted models found a similar magnitude in the association between neighborhood deprivation and cannabis retailers.

Conclusion

Neighborhood deprivation was associated with more cannabis retailers in the city of Portland, Oregon regardless of availability of commercial property eligible to operate as a cannabis retailer and adult population density. Our results support further research to understand specific built environment features and policy mechanisms that contribute to the disproportionate distribution of cannabis retailers in deprived neighborhoods. This study is an initial step in considering the implications that cannabis business regulations have on neighborhoods in an urban setting. Replicating this work over time and in other urban areas that have opened commercial cannabis markets will inform policies and support prioritizing equity in the development of cannabis business regulations.

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