Published in final edited form as:
Int J Drug Policy. 2014 May ; 25(3): 508–515. doi:10.1016/j.drugpo.2013.12.009.

The Economic Geography of Medical Marijuana Dispensaries in California

Chris Morrison, M.P.H.[1,2,*], **Paul J. Gruenewald, Ph.D.**[1], **Bridget Freisthler, Ph.D.**[1,3], **William R. Ponicki, M.A.**[1], and **Lillian G. Remer, M.A.**[1]

[1] Prevention Research Center, Berkeley, California

[2] Monash University, Department of Epidemiology and Preventive Medicine, Melbourne, Australia

[3] UCLA, Department of Social Welfare, Los Angeles, California

Abstract

Background—The introduction of laws that permit the use of marijuana for medical purposes has led to the emergence of a medical marijuana industry in some US states. This study assessed the spatial distribution of medical marijuana dispensaries according to estimated marijuana demand, socioeconomic indicators, alcohol outlets and other socio-demographic factors.

Method—Telephone survey data from 5,940 residents of 39 California cities were used to estimate social and demographic correlates of marijuana demand. These individual-level estimates were then used to calculate aggregate marijuana demand (i.e. market potential) for 7,538 census block groups. Locations of actively operating marijuana dispensaries were then related to the measure of demand and the socio-demographic characteristics of census block groups using multilevel Bayesian conditional autoregressive logit models.

Results—Marijuana dispensaries were located in block groups with greater marijuana demand, higher rates of poverty, alcohol outlets, and in areas just outside city boundaries. For the sampled block groups, a 10% increase in demand within a block group was associated with 2.4% greater likelihood of having a dispensary, and a 10% increase in the city-wide demand was associated with a 6.7% greater likelihood of having a dispensary.

Conclusion—High demand for marijuana within individual block groups and within cities is related to the location of marijuana dispensaries at a block-group level. The relationship to low income, alcohol outlets and unincorporated areas indicates that dispensaries may open in areas that lack the resources to resist their establishment.

---

[*] Corresponding author For correspondence: Chris Morrison, MPH Visiting Scholar Prevention Research Center 1995 University Avenue, Suite 450 Berkeley, CA 94704 Phone: 510-883-5775 Fax: 510-644-0594 cmorrison@prev.org.

CONFLICT OF INTEREST
None declared

Keywords

Marijuana dispensaries; medical marijuana; marijuana demand; market potential; Bayesian spatial models

Medical marijuana use has been permitted in California since 1996 (California Police Chiefs' Association [CPCA], 2009), however medical marijuana dispensaries continue to attract substantial opposition. The US Department of Justice lists marijuana as a prohibited Schedule 1 substance (Drug Enforcement Agency, 2011), and its Drug Enforcement Agency periodically raids dispensaries and prosecutes operators (Linthicum & Blankstein, 2012). Besides the moral and ethical debate about the drug itself, much of the public discourse centers around unresolved questions on the relationships between marijuana dispensaries, marijuana laws, crime (Kepple & Freisthler, 2012), and patterns of marijuana use (Harper, Strumpf, & Kaufman, 2012; Wall et al., 2011, 2012). In this study, we examine the location of dispensaries in communities, with reference to predictions from economic geography and prior observations of other legal drug markets.

Medical marijuana dispensaries are a new point of supply for a potentially addictive substance. Their location within communities is important because the presence of a dispensary exposes the local population to increased access to marijuana, and possibly to problems related to outlet operations (CPCA, 2009). Availability theory suggests that increased access will lead to increased use among the local population (Stockwell & Gruenewald, 2004), and such an effect has been demonstrated in alcohol markets (Gruenewald, 2011). Wall and colleagues (2011, 2012) found higher proportions of marijuana users in states with medical marijuana laws compared to states without such laws; whereas Harper, Strumpf and Kaufman (2012) found no such relationship in a replication study. A recent study found a cross sectional association where cities with greater density of marijuana dispensaries had more individuals who used marijuana and more frequent use of marijuana by those individuals (Freisthler & Gruenewald, 2013), though causation is unknown.

Regarding problems related to outlet operations, the small body of existing literature contains mixed findings. Crime rates in the immediate vicinity of dispensaries differ according to the security measures implemented by operators (Freisthler, Kepple, Sims, & Martin, 2012). However, there is no association between the density of dispensaries and violent or property crime in Sacramento, California (Kepple & Freisthler, 2012). Opponents of medical marijuana often assume that dispensaries have a detrimental impact on communities in a similar manner to alcohol markets (CPCA, 2009). Longitudinal studies have shown that increased alcohol outlet density is associated with increased assaults (Gruenewald & Remer, 2006; Livingston, 2008), motor vehicle crashes (McMillan, Hanson, & Lapham, 2007; Ponicki, Gruenewald, & Remer, 2013), intimate partner violence (Cunradi, Mair, Ponicki, & Remer, 2012; Livingston, 2011), and child abuse and neglect (Freisthler, Gruenewald, Remer, Lery, & Needell, 2007; Freisthler & Weiss, 2008). To date, no such studies of the neighborhood effects of marijuana dispensaries have been published.

It is unclear if dispensaries have a similar negative impact on communities to alcohol outlets.

Despite these concerns, no studies have attempted to describe the location of dispensaries within communities. Theoretical models from economic geography make clear predictions which fill that void (Aoyama, Murphy, & Hanson, 2011; Hanson, 2005; Harris, 1954). The 2007 National Survey on Drug Use and Health estimated that 40.4% of US residents aged 12 and over had ever used marijuana, and 10.2% had used the drug in the previous 12 months (United States Department of Health and Human Services, 2007). In order to maximize market share and reduce convenience costs for these potential customers, outlets will open in response to demand. Competition will encourage agglomeration (Hotelling, 1929), as will zoning restrictions, local ordinances, and wholesale transportation costs. Therefore, dispensaries should be found concentrated in and near areas of high marijuana demand.

Further theory from urban economics (O'Sullivan, 2007) suggests that income is also likely to be associated with dispensary location. High housing value tends to exclude retail space (DiPasquale & Wheaton, 1992), and outlets with a demonstrable or perceived association with social, environmental or public health problems are excluded from stable neighborhoods that possess the resources to resist their establishment (Skogan, 1990). Thus, dispensaries will likely be located in areas of social disadvantage.

Also of note is the well-documented intersection between the location of drug markets, greater numbers of alcohol outlets, social disadvantage and the presence of other problems (Banerjee et al., 2008; Gruenewald, Millar, Ponicki, & Brinkley, 2000; LaVeist & Wallace Jr, 2000; Livingston, 2012; Romley, Cohen, Ringel, & Sturm, 2007; Zhu, Gorman, & Horel, 2006). However, the potential spatial relationship between marijuana dispensaries and alcohol outlets is unclear. It is possible that dispensaries are excluded by the well-resourced alcohol industry which would seek to protect itself against potential associations with drug markets (Skogan, 1990). Conversely, zoning restrictions and reduced convenience costs for consumers may have the result that alcohol outlets and marijuana dispensaries are co-located within neighborhoods (Aoyama et al., 2011). In either scenario, it is necessary to include alcohol outlets in economic geography models.

The aim of this study was to determine predictors of marijuana dispensary location within communities. Based on the theory presented above, we hypothesized that dispensaries would be located in and near to areas of high marijuana demand and away from high income areas. Given the possible association with alcohol outlets and the influence they may exert on the social ecology of marijuana dispensaries, we also examined the spatial relationship between these two types of businesses. Our results are interpreted in the context of medical marijuana as an emerging legal drug market.

METHODS

This study used two main data sources: (1) person-level data were used to generate estimates of marijuana demand for each Census block group, then (2) Census block-group level data were used to investigate the location of dispensaries according to market potential, socioeconomic indicators, alcohol outlets and other covariates.

Person-Level Data

Study Sample—This study used data from a cross-sectional computer assisted telephone (CATI) survey conducted in 50 moderately sized California cities in 2009. Of the 138 municipalities in the state with between 50,000 and 500,000 residents, a sample of non-contiguous cities was purposively selected based on geography and ecology in order to maximize generalizability to non-sampled cities (Paschall, Grube, Thomas, Cannon, & Treffers, 2012; Thompson, 1992). A response rate of 48.0% was calculated using standard definitions from the American Association for Public Opinion Research (American Association for Public Opinion Research, 2002). There were 8,553 respondents in the original sample, but for the current study, we excluded responses from 1,986 (23.2%) who resided in the eleven study cities without marijuana dispensaries (see Census-Based Data methods, below). Of the remaining 6,567 surveys, a further 627 (9.5%) had incomplete responses for the variables of interest and were omitted from the analyses; of these, 600 (95.7%) were due to non-responses to a single household income item.

Measures—Marijuana use was collected in the telephone survey as self-reported days of use in the last 12 months (range: 0 to 365). Demographic variables were structured to correspond with US Census data, and were included in the model based on prior demonstrations of an association with marijuana use (Galea, Ahern, Tracy, & Vlahov, 2007; Kerr, Greenfield, Bond, Ye, & Rehm, 2007; Paddock et al., 2012; Tucker, Pollard, de la Haye, Kennedy, & Green, 2013). Variables included gender, race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Hispanic, and Asian), annual household income ($20,000 or less, $20,001 to $60,000, $60,001 to $100,000, ≥ $100,000), age (20 to 29, 30 to 39, 40 to 49, ≥ 50 years) and employment status (full time employed, unemployed or laid off). Highest level of education was coded as high school (or GED), college or technical school, and postgraduate or medical school. We were unable to include a geographic variable (i.e. city of residence) as the low number of marijuana users made the city level estimates imprecise. To avoid multi-colinearity, excluded categories were age 18 to 19, education less than high school or GED, income < $20,000 and other ethnicity.

Census-Based Data

Study Sample—We used Census 2000 block group (BG) data for areas within and around the study cities. We preferred this spatial unit to other Census based geographies (e.g. blocks, tracts) because BGs are the smallest unit for which the demographic data we required are available, and larger units may not capture the hypothesized excluding effect of high local income. Forty-three of the 50 cities had an ordinance prohibiting medical marijuana dispensaries. In order to account for dispensaries located immediately outside these jurisdictions that service the city populations, block groups were included in the sample that had an internal centroid within a 3 mile buffer of the defined city boundaries. Buffers were set at 3 miles as this was considered a reasonable travel distance from the city boundary. Eleven cities did not have any dispensaries within their city boundaries or buffer regions. These cities could not be included in the multi-level model, so were excluded from the sample. In all, the sample contained 7,538 block groups in 39 cities with a total 2009 population of 12,946,683. There were 151 block groups that were in the buffer regions of two study cities, so the total number of block groups included in the models was 7,689. Of the 1,384 BGs in the buffer region, 1,359 (98.2%) were in unincorporated areas (i.e. with local administration performed by the county, rather than a city government).

Measures—The dependent variable of interest was the presence a marijuana dispensary within a block group. Dispensaries were located by a team of trained research assistants by combining seven different online directories of dispensaries and official lists from local jurisdictions. Of the 1,664 active dispensaries identified in California (current at April 23, 2012), 505 were located within the sample region.

Demographic data were extracted at a block group level using 2009 estimates (GeoLytics Inc., 2010), including sex, ethnicity, age, employment status, education, and median household income, population density, and the proportion of residents living under 150% of the poverty line. We preferred these annual estimates to the five-year moving average of the American Community Survey or the Census. There is no evidence of systematic bias in the Geolytics data, so any error would increase background noise, thereby attenuating our results towards the null. Other covariates were an indicator of whether the BG centroid was in a buffer region rather than the city itself and alcohol outlet density. Alcohol outlet data were measured as the density of licensed venues per square mile, based upon 2009 liquor license data from the California Department of Alcoholic Beverage Control. Outlets were categorized as bars/pubs (ABC license types 23, 40, 42, 48, 61, and 75), restaurants (41 and 47) and off-premise outlets (20 and 21). We constructed variables for the proportions alcohol outlets that were (i) bars/pubs and (ii) off premise outlets (i.e. liquor stores) and (iii) restaurants. To avoid colinearity, the third variable of this triplet was omitted, with the effect that the comparison group for the proportion bars/pubs and off-premise variables was the proportion of restaurants.

Statistical Analysis

We used a censored regression model (Tobin, 1958) to predict days of marijuana use per year for individuals according to the demographic independent variables from the telephone survey. The model accounted for left (< 0 days) censoring.

Marijuana Demand—Demand for marijuana per Census block group was approximated by estimating the market potential within each geographical unit (Brakman, Garretsen, & van Marrewijk, 2009). First, in Equation 1, the predicted mean days of marijuana use per block group (y) was calculated by summing the constant term (b_0) plus the proportion of the population with the demographic characteristics included in the TOBIT model (p_c), multiplied by the b-coefficient from the TOBIT model output (b_c).

$$y=b_0+b_1p_1+b_2p_2+b_3p_3\ldots+e \quad (1)$$

Then, for each block group a standard normal distribution (z) was calculated where μ was the block group mean, σ was the censored regression model sigma, and the intercept (x) was zero. The probability that mean days of marijuana use (q) among residents of block group (a) was greater than zero is 1 minus the standard normal Cumulative Density Function (φ) of x.

$$q_a = 1 - \phi(x) \quad (2)$$

We then estimated the mean days of marijuana use (x) among all marijuana users per block group. Where φ(t) is the standard normal Cumulative Density Function, the mean of a truncated standard normal distribution is (Barr & Sherrill, 1999):

$$x_a = \frac{1}{\sqrt{(2\pi(1 - \phi(t_a))}} \times e^{\frac{-t_a{}^2}{2}} \quad (3)$$

Finally, in Equation 4, market potential (d) per block group (expressed as aggregated days of marijuana use per person per year; hereafter, person-days) is equal to the predicted mean days of marijuana use among all marijuana users (x) in that block group, multiplied by the probability that mean days of marijuana use within a block group is greater than zero (q) and the population size of the block group (n):

$$d_a = x_a q_a n_a \quad (4)$$

Multi-level Models—The final step used multi-level Bayesian spatial logit models to determine the likelihood of a dispensary being located within block groups nested within cities. This construction controls for two forms of non-independence among BGs within cities. The multi-level aspect accounts for the expectation that BGs from the same city will be more similar to each other than they are to BGs from other cities, and the conditional autoregressive (CAR) priors allow the possibility that individual BGs will be more similar to their neighbors than they are to distant block groups (i.e. spatial autocorrelation).

The general form of the multilevel model was used where y was the outcome measure of interest (i.e. presence of a dispensary) measured at the block group level:

$$y = (\beta_0 + u_0) + B_a x_a + \theta_a + a \quad (5)$$

β_0 is a city-specific intercept and u_0 is the random city-specific residual component, such that β_0 + u_0 can be thought of as representing adjusted city-level means on the outcome variable. β_a are regression coefficients expressing the associations (slopes) between predictors (x) for block groups (a) and the outcome. θ_a and α are random effects which capture spatially unstructured heterogeneity and CAR spatial dependence respectively.

Four variants of this multilevel model were estimated. Model 1 estimated marijuana demand as the sole level 1 variable (i.e. a basic economic geography model). Model 2 separated demand into its component parts (population size and estimated per capita marijuana use) to determine the main contributors of any relationship between demand and dispensary location. Model 3 further expanded demand into population size and its socio-demographic components (sex, ethnicity, age, employment status, education, and median household income). Model 4 was the final multivariable analysis. Because demand was calculated a function of BG socio-demographics, it was not possible to include both the socio-demographic variables and the demand variable in the same model due to multi-colinearity, so demand replaced its component parts in this model. Besides controlling for demand within a given block group, the model allows for effects of demand averaged over adjacent block groups as well as city-wide demand (calculated as the sum of person-days for BGs within each city). City-specific random effects were included in the models, however in the interest of brevity these were suppressed from the table.

The individual-level censored regression model was performed using STATA v10.1 (StataCorp, 2007). Geoprocessing was completed with ArcGIS v 10.1 (ESRI, 2011), and the block-group multilevel Bayesian models were estimated using WinBUGS v.4.3.1 (Lunn, Thomas, Best, & Spiegelhalter, 2000). Uninformed priors were specified for all random effects. Trace plots showed that all parameters in all four models had stabilized and converged after a 2,000 iteration Markov Chain Monte Carlo (MCMC) burn-in. Two chains with different initial values were used in each model. Posterior estimates were sampled for 20,000 iterations to provide model results.

RESULTS

Characteristics of the survey respondent group are shown in Table 1, and the results of the censored regression model are shown in Table 2. Very few people in the sample reported using marijuana in the last 365 days (5.9%). Whites (= 73.6 [95%CI = 18.4,128.8]), men (70.0 [42.8, 97.2]) and people aged 20 to 29 (82.1 [35.0, 129.2]) used marijuana on more days than the comparison group (i.e. women, aged 18 and 19, “other” ethnicity, household income < $20,000). Older adults (> 50 years) were likely to report less marijuana use, as were Asian/Pacific Islander and Hispanic respondents. McFadden pseudo-R^2 was very low (0.039), indicating that the covariates in the model accounted for very little variance in reported marijuana use.

Of the 7,538 block groups in the sample, 371 (4.9%) contained at least one of the 505 marijuana dispensaries. Table 3 shows the descriptive statistics for the study block groups. Mean demand per block group was 5,628 person-days (SD 5,492), with mean per capita use of 3.2 days (SD=1.3).

Table 4 shows the four multilevel Bayesian conditional autoregressive logit models, including the median estimated effect from the sampled posterior distribution for each variable and a 95% credible interval. The 95% credible interval is the 2.5th and 97.5th percentile of the estimated effect for each variable, and can be interpreted in a similar manner to a 95% confidence interval from a regular logit model (Mair, Gruenewald, Ponicki, & Remer, 2013). Model 1 (the basic economic geographic model) shows that the positive association between marijuana demand and increased odds of having a dispensary is well supported. Model 2 demonstrates that block groups with higher populations were at increased odds of having a dispensary, as were those with higher estimated per capita marijuana use.

Model 3 separated per capita marijuana use into its component predictors from the 2009 Census estimates. Block groups with greater proportions of males were at increased odds of having a dispensary, whereas those with higher median household income were at decreased odds. Specifically, a $10,000 increase in income was associated with 14.5% decreased odds of having a dispensary in a block group.

The relationship between BG level market potential and dispensaries observed in Model 1 remained in Model 4 after adjusting for potential confounders. By linear extrapolation of the log odds, a 10% increase in market potential within a BG was associated with 2.4% increased odds of it having a dispensary. There was no lagged effect of market potential, however a 10% increase in estimated person-days marijuana use across the city was associated with 6.7% increased odds of having a dispensary within any block group within that city. There was a positive, well supported association between the density of alcohol outlets and the location of dispensaries. There was no effect for bars/pubs, but where there was a greater proportion of off-premise outlets there were fewer dispensaries. This finding suggests that dispensaries are less likely to be located near off-premise alcohol outlets compared to restaurants. Model 4 showed a similar effect for socio-economic status to Model 3. Dispensaries tended to be located in BGs with higher proportions of people living under 150% of the poverty line.

Posterior spatial random effects ( ) from Model 4 were used to calculate a Moran's I of 0.828, indicating a very strong tendency for BGs with dispensaries to agglomerate, and block groups with no dispensaries to be located adjacent to other block groups with no dispensaries (see Figure 1). The CAR spatial random effects explained over 99% of the overall error variance in each of the four models. Had we not corrected for these CAR effects, the likelihood of a type I error would have been high.

DISCUSSION

This study demonstrated that medical marijuana dispensaries are found in areas with high market potential and low income; thus the two *a priori* hypotheses were supported. We also found that dispensaries are more likely to be co-located in block groups with alcohol outlets and to be located in buffer areas around the study cities (which are mostly unincorporated).

In the absence of prior research into medical marijuana markets, we based our analyses on predictions from economic geography and prior observations from alcohol markets. The effects we observed were as expected, however, the interpretation for marijuana should differ from that for alcohol. The latter has been legally sold in the United States since prohibition ended in 1933 and markets are typically mature and saturated (Gruenewald, 2008). By comparison, California's medical marijuana industry is in its infancy. In that context, the theoretical models make clear predictions regarding the future of this emerging industry. Dispensaries will continue to open to meet demand until the market is saturated, at which point they will diversify to appeal to specific market segments (Gruenewald, 2008). The development of new dispensaries will be greater in low income areas and in communities that lack the social and economic resources to resist their establishment. It is possible that in the sparse medical marijuana market, the few establishments that exist are located where they attract the least resistance and can service demand from both their immediate neighbors (within block groups) and cross-town customers (within cities). Therefore, jurisdictions that do not prohibit marijuana dispensaries will attract them in relative abundance, due to the opportunity to service demand from both the local and neighboring communities.

Our findings and the predictions that follow emphasize the need to determine the true effect of dispensaries on marijuana use and problems in local communities. At present, the link between dispensaries and crime is unclear (Freisthler et al., 2012; Kepple & Freisthler, 2012), and there is an association of unknown directionality between dispensaries and increased marijuana use in California (Freisthler & Gruenewald, 2013). Prior studies of alcohol outlets may provide some indication as to the neighborhood effects of marijuana dispensaries. However, alcohol and marijuana have substantially different psychoactive properties, risks, and business models. The extent to which they have similar detrimental effects on local populations is uncertain, as is the effect of new medical marijuana dispensaries on the illegal marijuana market. This is an important area for future study. Availability theory suggests that marijuana dispensaries will cause increased use among local populations beyond the illegal sales they may replace (Stockwell & Gruenewald, 2004). If this is the case, or if dispensaries cause increased problems for the communities in which they are located, our findings point to a form of environmental injustice in which the socially disadvantaged are disproportionately exposed to problems (Romley et al., 2007). Limited evidence also suggests that patients may travel between cities to access dispensaries (Freisthler, 2013). Future research may consider effects outside the immediate study city.

This study is the first to consider the location of medical marijuana dispensaries in communities. The primary limitation is the cross-sectional study design, which prohibits observation of temporal trends. Small differences in the proportions of African-Americans, whites and Hispanics in the telephone survey compared to the city populations are unlikely to have materially affected the key findings as the market potential estimate was driven primarily by population size (r = 0.86), rather than proportion black (r = 0.01), white (r = 0.09) or Hispanic (r = 0.04). The spatial sample permits generalization to other California cities of comparable size, but similar studies in other communities would be prudent. Replication of the current analysis with different spatial unit configurations and smaller spatial scales could assess the extent to which our results are affected by the modifiable area unit problem (Openshaw, 1984) and aggregation bias (Hodgson, Shmulevitz, & Körkel, 1997). Our exclusion of the most populous California cities meant we omitted the areas with the greatest numbers of dispensaries (e.g. the City of Los Angeles). The associations we observed between dispensaries and higher alcohol outlet density and lower population density may be artifacts of zoning restrictions, which we were not able to adjust for in our analyses.

Despite these limitations, our findings have implications for policy. Marijuana dispensaries are spatially related to market potential. Jurisdictions that wish to avoid having new dispensaries (and therefore minimize any possible adverse effects associated with their operations) should actively prevent their establishment. If dispensaries are found to cause problems for local populations, the state, county and city regulators should ensure that communities with fewer resources (e.g. those with low incomes, unincorporated areas) are not burdened with disproportionately large numbers that service demand from both local and neighboring areas. Nevertheless, the uncertain regulatory environment and competition with a parallel black market means the industry will likely be in a constant state of change, and the consequences of such intervention should be carefully considered. One clear example (and a limitation of the current study) is the recent emergence of home delivery services: an innovative means of circumventing city ordinances that prohibit marijuana dispensaries from operating from shop-front stores. Future longitudinal research would permit investigation of such social, political and economic dynamics as medical marijuana markets mature, and should clarify whether dispensaries indeed cause problems for the communities in which they are located.

Acknowledgments

This research was supported by National Institute on Drug Abuse (NIDA) Grant R01-DA-032715 and National Institute on Alcohol Abuse and Alcoholism Center Grant P60-AA006282

REFERENCES

American Association for Public Opinion Research. Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys. Author; Ann Arbor, MI: 2002.

Aoyama, Y.; Murphy, JT.; Hanson, S. Key Concepts in Economic Geography. Sage Publications; Thousand Oaks, California: 2011.

Banerjee, A.; LaScala, E.; Gruenewald, P.; Freisthler, B.; Treno, A.; Remer, L. Social Disorganization, Alcohol and Drug Markets, and Violence.. In: Thomas, YF.; Richardson, D.; Cheung, I., editors. Geography and Drug Addiction. Springer; Netherlands: 2008.

Barr DR, Sherrill ET. Mean and variance of truncated normal distributions. The American Statistician. 1999; 53(4):357–361.

Brakman, S.; Garretsen, H.; van Marrewijk, C. The New Introduction to Geographical Economics. Cambridge University Press; Cambridge: 2009.

California Police Chiefs' Association. White Paper On Marijuana Dispensaries. Author; Sacramento: 2009.

Cunradi CB, Mair C, Ponicki W, Remer L. Alcohol outlet density and intimate partner violence-related emergency department visits. Alcoholism: Clinical and Experimental Research. 2012; 36(5):847–853.

DiPasquale D, Wheaton WC. The markets for real estate assets and space: a conceptual framework. Journal of the American Real Estate and Urban Economics Association. 1992; 1:181–197.

Drug Enforcement Agency. The DEA Position on Marijuana. Author; Washington, DC: 2011.

ESRI. ArcGIS Desktop: Release 10. Environmental Systems Research Institute; Redlands, CA: 2011.

Freisthler B. Medical marijuana dispensaries and the local ecology. Paper presented at The Social Ecology of Substance Use: Theories, Models, Methods and Applications satellite meeting of the Research Society on Alcoholism. 2012

Fresithler, B.; Gruenewald, PJ. Paper presented at the College on Problems of Drug Dependence annual meeting; June 15 - June 20; 2013.

Freisthler B, Gruenewald PJ, Remer LG, Lery B, Needell B. Exploring the spatial dynamics of alcohol outlets and Child Protective Services referrals, substantiations, and foster care entries. Child Maltreatment. 2007; 12:114–124. [PubMed: 17446565]

Freisthler B, Kepple N, Sims R, Martin S. Evaluating medical marijuana dispensary policies: spatial methods for the study of environmentally-based interventions. Am J Community Psychol. 2012 Epub ahead of print.

Freisthler B, Weiss RE. Using Bayesian space-time models to understand the substance use environment and risk for being referred to Child Protective Services. Substance Use & Misuse Special Issue. 2008; 43(2):239–251.

Galea S, Ahern J, Tracy M, Vlahov D. Neighborhood income and income distribution and the use of cigarettes, alcohol, and marijuana. American Journal of Preventive Medicine. 2007; 32(6 Suppl):S192–S202.

GeoLytics, Inc. Annual Estimates 2001-2010. GeoLytics, Inc.; East Brunswick, NJ: 2010.

Gruenewald PJ. Why do alcohol outlets matter anyway? Addiction. 2008; 103:1585–1587. [PubMed: 18821868]

Gruenewald PJ. Regulating availability: how access to alcohol affects drinking and problems in youth and adults. Alcohol Research & Health. 2011; 34(2):250–259.

Gruenewald PJ, Millar A, Ponicki WR, Brinkley G. Wilson R, DuFour M. Physical and economic access to alcohol: the application of geostatistical methods to small area analysis in community settings. NIAAA Research Monograph - 36, Small Area Analysis and the Epidemiology of Alcohol Problems. 2000:163–212.

Gruenewald PJ, Remer L. Changes in outlet densities affect violence rates. Alcoholism: Clinical & Experimental Research. 2006; 30(7):1184–1193.

Hanson GH. Market potential, increasing returns and geographic concentration. Journal of International Economics. 2005; 67(1):1–24.

Harper S, Strumpf EC, Kaufman JS. Do medical marijuana laws increase marijuana use? replication study and extension. Annals of Epidemiology. 2012; 22(3):207–212. [PubMed: 22285867]

Harris CD. The market as a factor in the localization of industry in the United States. Annals of the Association of American Geographers. 1954; 44(4):315–348.

Hodgson MJ, Shmulevitz F, Körkel M. Aggregation error effects on the discrete- space p-median model: The case of Edmonton, Canada. Canadian Geographer. 1997; 41(4):415–428.

Hotelling H. Stability in competition. The Economic Journal. 1929; 39(153):41–57.

Kepple N, Freisthler B. Exploring the ecological association between crime and medical marijuana dispensaries. Journal of Studies on Alcohol and Drugs. 2012; 73(4):523–530. [PubMed: 22630790]

Kerr WC, Greenfield TK, Bond J, Ye Y, Rehm J. Age–period–cohort influences on trends in past year marijuana use in the US from the 1984, 1990, 1995 and 2000 National Alcohol Surveys. Drug and Alcohol Dependence. 2007; 86(2–3):132–138. [PubMed: 16806739]

LaVeist TA, Wallace JM Jr. Health risk and inequitable distribution of liquor stores in African American neighborhood. Social Science & Medicine. 2000; 51(4):613–617. [PubMed: 10868674]

Linthicum, K.; Blankstein, A. U.S. raids L.A. marijuana shops. Los Angeles Times; 2012. from: http://articles.latimes.com/2012/sep/26/local/la-me-medical-marijuana-20120926 [January 10, 2013]

Livingston M. A longitudinal analysis of alcohol outlet density and assault. Alcoholism: Clinical and Experimental Research. 2008; 32(6):1074–1079.

Livingston M. A longitudinal analysis of alcohol outlet density and domestic violence. Addiction. 2011; 106:919–925. [PubMed: 21205052]

Livingston M. The social gradient of alcohol availability in Victoria, Australia. Australian & New Zealand Journal of Public Health. 2012; 36(1):41–47. [PubMed: 22313705]

Lunn DJ, Thomas A, Best N, Spiegelhalter D. WinBUGS - A Bayesian modelling framework: Concepts, structure, and extensibility. Statistics and Computing. 2000; 10:325–337.

Mair C, Gruenewald PJ, Ponicki WR, Remer L. Varying impacts of alcohol outlet densities on violent assaults: Explaining differences across neighborhoods. Journal of Studies on Alcohol and Drugs. 2013; 74(1):50–58. [PubMed: 23200150]

McMillan GP, Hanson TE, Lapham SC. Geographic variability in alcohol- related crashes in response to legalized Sunday packaged alcohol sales in New Mexico. Accident Analysis & Prevention. 2007; 39(2):252–257. [PubMed: 16999927]

Openshaw, S. The Modifiable Areal Unit Problem. Geobooks; Norwich, England: 1984.

O'Sullivan, A. Urban Economics. 6th Ed.. McGraw-Hill Irwin; Boston: 2007.

Paddock SM, Kilmer B, Caulkins JP, Booth MJ, Pacula RL, Liccardo R. An epidemiological model for examining marijuana use over the life course. Epidemiology Research International. 20122012

Paschall MJ, Grube JW, Thomas S, Cannon C, Treffers R. Relationships between local enforcement, alcohol availability, drinking norms, and adolescent alcohol use in 50 California cities. Journal of Studies on Alcohol and Drugs. 2012; 73(4):657–665. [PubMed: 22630804]

Ponicki WR, Gruenewald PJ, Remer LG. Spatial panel analyses of alcohol outlets and motor vehicle crashes in California: 1999-2008. Accident Analysis and Prevention. 2013; 55:135–143. [PubMed: 23537623]

Romley J, Cohen D, Ringel J, Sturm R. Alcohol and environmental justice: The density of liquor stores and bars in urban neighborhoods in the United States. Journal of Studies on Alcohol and Drugs. 2007; 68:48–55. [PubMed: 17149517]

Skogan, WG. Disorder and Decline: Crime and the Spiral of Decay in American Neighborhoods. University of California Press; Berkeley, CA: 1990.

StataCorp. Stata Statistical Software: Release 10. StataCorp LP; College Station, TX: 2007.

Stockwell, T.; Gruenewald, PJ. Controls on the Physical Availability of Alcohol.. In: Heather, N.; Stockwell, T., editors. The Essential Handbook of Treatment and Prevention of Alcohol Problems. John Wiley; New York: 2004. p. 213-234.

Thompson, SK. Sampling. Wiley; New York: 1992.

Tobin J. Estimation of relationships for limited dependent variables. Econometrica. 1958; 26(1):24–36.

Tucker JS, Pollard MS, de la Haye K, Kennedy DP, Green HD Jr. Neighborhood characteristics and the initiation of marijuana use and binge drinking. Drug and Alcohol Dependence. 2013; 128(1–2):83–89. [PubMed: 22938829]

United States Department of Health and Human Services. National Survey on Drug Use and Health 2007. Inter-University Consortium for Political and Social Research; Ann Arbor, MI: 2007. distributor

Wall MM, Poh E, Cerdá M, Keyes KM, Galea S, Hasin DS. Adolescent marijuana use from 2002 to 2008: Higher in states with medical marijuana laws, cause still unclear. Annals of Epidemiology. 2011; 21(9):714–716. [PubMed: 21820632]

Wall MM, Poh E, Cerdá M, Keyes KM, Galea S, Hasin DS. Commentary on Harper S, Strumpf EC, Kaufman JS. Do medical marijuana laws increase marijuana use? Replication study and extension. Annals of Epidemiology. 2012; 22(7):536–537. [PubMed: 22534177]

Zhu L, Gorman DM, Horel S. Hierarchical Bayesian spatial models for alcohol availability, drug "hot spots" and violent crime. International Journal of Health Geographics. 2006; 5(54)

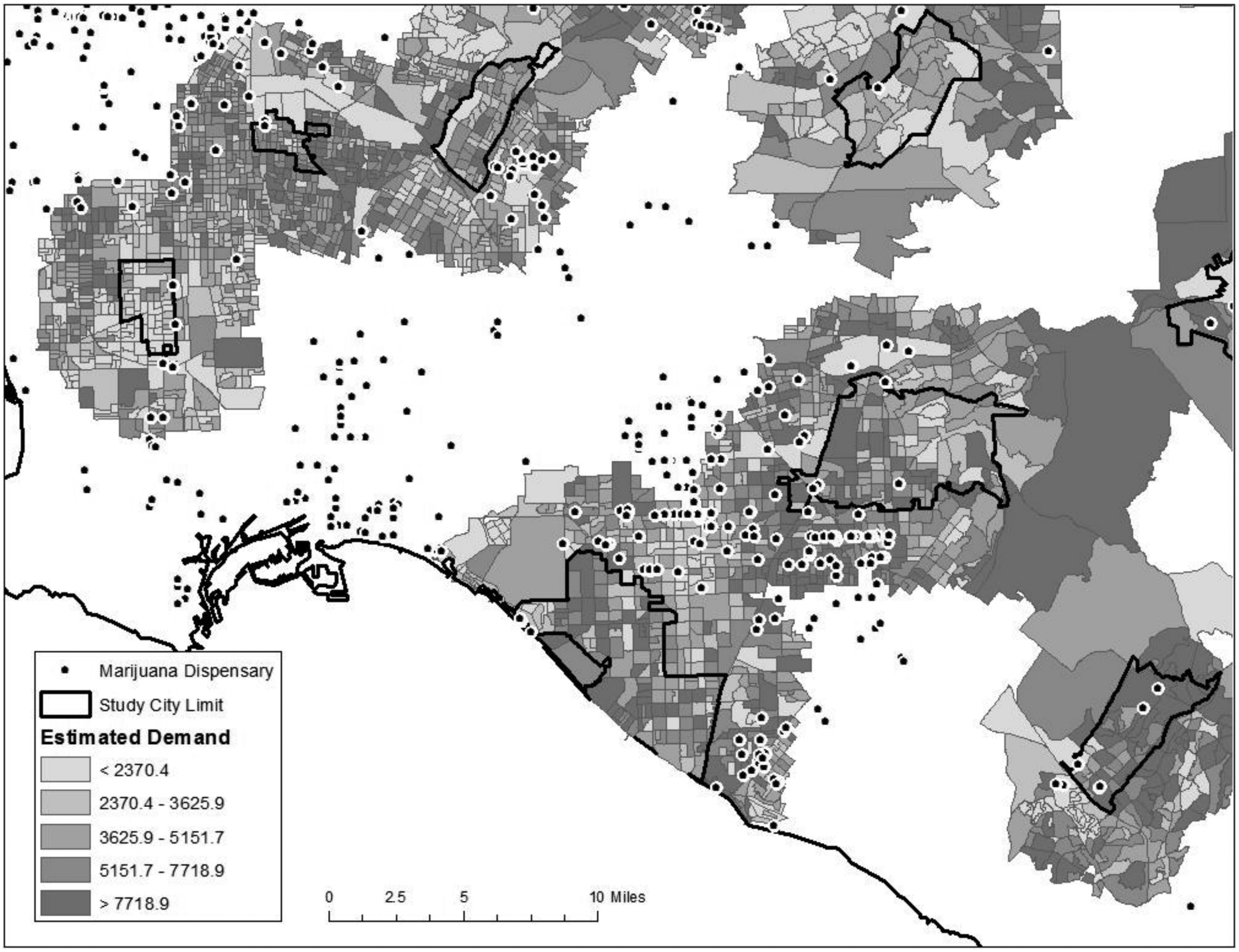

Figure 1.

Estimated marijuana demand (aggregated person-days) by quintile per census block group for study cities plus buffer regions in the Los Angeles basin area

Table 1

Characteristics of telephone survey respondents (n = 5,940)

Variable	**n**	**(%)**
Male	2,626	(44.2)
Ethnicity:		
African American	268	(4.5)
White	3,507	(59.0)
Hispanic	1,836	(30.9)
Asian/Pacific Islander	356	(6.0)
Age:		
20 to 29 years	439	(7.4)
30 to 39 years	891	(15.0)
40 to 49 years	941	(15.8)
≥ 50 years	2,352	(39.6)
Highest Educational Achievement:		
High School/GED	2,392	(40.3)
Undergraduate	1,494	(25.2)
Postgraduate/Medical School	1,235	(20.8)
Employment Status:		
Full Time Employed	2,175	(36.6)
Unemployed	447	(7.5)
Household Income per Year:		
< $20,000	1,361	(22.9)
$20,000 to $60,000	2,198	(37.0)
$60,000 to $100,000	1,241	(20.9)
> $100,000	1,140	(19.2)
Any marijuana use in last 365 days	350	(5.9)
	Mean	SD
Days marijuana use	5.0	[37.0]

Table 2

Censored regression model for self-reported days of marijuana use in the last year (n = 5,940)

Variable	B-Coefficient	(95% CI)		p-value
Male	69.99	42.77	97.21	<0.001
Ethnicity:				
African American	10.18	−65.60	85.97	0.792
White	73.59	18.39	128.80	0.009
Hispanic	−88.71	−146.65	−30.77	0.003
Asian/Pacific Islander	−121.74	−208.55	−34.93	0.006
Age:				
Age 20 to 29 years	82.10	34.96	129.23	0.001
Age 30 to 39 years	−11.60	−55.63	32.43	0.606
Age 40 to 49 years	15.58	−22.69	53.85	0.425
Age ≥ 50 years	−160.36	−199.86	−120.86	<0.001
Highest Educational Achievement:				
High School/GED	83.55	26.53	140.57	0.004
Undergraduate	72.64	10.91	134.37	0.021
Postgraduate/Medical School	42.53	−23.23	108.30	0.205
Employment Status:				
Full Time Employed	−31.82	−63.63	0.00	0.050
Unemployed	36.10	−9.28	81.48	0.119
Household Income per Year:				
$20,000 to $60,000	−18.14	−56.65	20.37	0.356
$60,000 to $100,000	−27.35	−72.00	17.30	0.230
> $100,000	−29.47	−77.10	18.16	0.225
Constant	−435.95	−526.26	−345.65	<0.001
Sigma	242.67			

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 3

Descriptive statistics for block groups in study region (n = 7,538)

Variable	Mean	(SD)
Population (× 10^3)	1.72	(1.26)
Area (miles^2)	0.65	(2.50)
Population density (× 1,000/mile^2)	9.53	(9.98)
Marijuana demand:*		
Block group (× 10^3 person-days)	0.56	(0.55)
Per capita (days)	3.20	(1.27)
Lagged block group (× 10^3 person-days)	0.58	(0.35)
City level (× 10^6 person-days)	1.53	(0.78)
Alcohol outlet density (per mile^2)	13.62	(25.56)
Portion of alcohol outlets that are bars/pubs (%)	6.42	(12.44)
Portion of alcohol outlets that are off premise (%)	58.15	(26.80)
Male (%)	49.32	(4.61)
Ethnicity:		
African American (%)	7.83	(13.11)
White (%)	76.05	(19.31)
Hispanic (%)	38.12	(28.08)
Asian/Pacific Islander (%)	12.01	(14.34)
Age:		
Age 20 to 29 years (%)	14.20	(3.28)
Age 30 to 39 years (%)	13.41	(3.45)
Age 40 to 49 years (%)	14.29	(2.77)
Age ≥ 50 years (%)	58.04	(22.61)
Employment Status:		
Full time employed (%)	44.13	(12.91)
Unemployed (%)	5.11	(5.12)
Highest educational achievement:		
High school/GED (%)	42.45	(13.42)
Undergraduate (%)	21.63	(13.47)
Postgraduate/Medical school (%)	8.00	(8.93)
Household income per year:		
< $20,000 (%)	20.14	(15.29)
$20,000 to $60,000 (%)	41.33	(13.86)
$60,000 to $100,000 (%)	21.41	(11.45)
> $100,000 (%)	14.69	(15.09)
Living Under 150% Poverty Line (× 10%)	2.40	(1.89)
Median Household Income (× $10,000/year)	5.09	(2.50)

*Marijuana demand estimates are calculated using the B-coefficients from Table 2 and the demographic profile of Census block groups.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 4

Odds Ratios (OR) [95% credible intervals] from multilevel Bayesian conditional autoregressive logit models, for medical marijuana dispensary location according to estimated marijuana demand and covariates (n = 7,538).

	Model 1		Model 2		Model 3		Model 4	
Variable	***OR***	***[95% CI]***	***OR***	***[95% CI]***	***OR***	***[95% CI]***	***OR***	***[95% CI]***
Market potential for marijuana:								
Block group (× 10^3 person-days)	**1.375**	**[1.160 1.628]**					**1.537**	**[1.289 1.838]**
Per capita (days)			**1.158**	**[1.069 1.252]**				
Lagged block group (× 10^3 person-days)							0.986	[0.632 1.499]
City level (× 10^6 person-days)							**1.530**	**[1.028 2.309]**
Population (× 10^3)			**1.133**	**[1.021 1.249]**	**1.185**	**[1.091 1.287]**		
Male (%)					**1.063**	**[1.017 1.111]**		
Ethnicity:								
African American (%)					0.988	[0.951 1.022]		
White (%)					1.009	[0.974 1.042]		
Hispanic (%)					0.999	[0.987 1.012]		
Asian/Pacific Islander (%)					**0.858**	**[0.776 0.953]**		
Age:								
Age 20 to 29 years (%)					1.073	[0.997 1.154]		
Age 30 to 39 years (%)					**0.885**	**[0.799 0.980]**		
Age 40 to 49 years (%)					0.989	[0.970 1.009]		
Age ≥ 50 years (%)					1.001	[0.964 1.035]		
Employment Status:								
Full time employed (%)					1.001	[0.984 1.020]		
Unemployed (%)					1.019	[0.991 1.048]		
Highest educational achievement:								
High school/GED (%)					1.006	[0.992 1.021]		
Undergraduate (%)					0.999	[0.977 1.020]		

	Model 1		Model 2		Model 3		Model 4	
Variable	***OR***	***[95% CI]***	***OR***	***[95% CI]***	***OR***	***[95% CI]***	***OR***	***[95% CI]***
Postgraduate/Medical school (%)					0.978	[0.947 1.009]		
Median Household Income (× $10,000/year)					**0.855**	**[0.759 0.957]**		
Population density (× 1,000/mile^2)							**0.919**	**[0.897 0.940]**
Living Under 150% Poverty Line (× 10%)							**1.295**	**[1.195 1.403]**
Buffer area							**1.592**	**[1.113 2.271]**
Alcohol outlet density (per mile^2)							**1.010**	**[1.006 1.013]**
Portion of alcohol outlets that are bars/pubs (%)							0.688	[0.263 1.690]
Portion alcohol outlets that are off premise (%)							**0.412**	**[0.254 0.671]**

Random Effects	***Median***	***[95% CI]***	***Median***	***[95% CI]***	***Median***	***[95% CI]***	***Median***	***[95% CI]***
Proportion of total error variance explained by city random effects	0.281	[0.175 0.412]	0.275	[0.174 0.404]	0.289	[0.176 0.430]	0.243	[0.140 0.378]
Proportion of BG variance explained by spatial random effect	0.999	[0.770 1.000]	0.999	[0.940 1.000]	0.999	[0.969 1.000]	0.999	[0.931 1.000]
S.D. of city random effect	0.747	[0.581 0.945]	0.730	[0.563 0.927]	0.737	[0.553 0.953]	0.724	[0.537 0.942]
S.D. of CAR spatial random effect	1.179	[0.935 1.453]	1.181	[0.942 1.437]	1.155	[0.911 1.428]	1.277	[1.014 1.567]
S.D. of noise random effect	0.044	[0.014 0.644]	0.034	[0.013 0.296]	0.036	[0.012 0.200]	0.035	[0.014 0.349]

Note: β intercept suppressed from table; bolded odds ratios denote a 95% credible interval that does not include 1.000, thereby indicating support of a significant association between the corresponding independent variable and the presence of dispensaries.