Title
Examining the role of a retail density ordinance in reducing concentration of tobacco retailers

Authors
Vyas, Priyanka
Sturrock, Hugh
Ling, Pamela M

Publication Date
2020-02-01

DOI
10.1016/j.sste.2019.100307

Peer reviewed

HHS Public Access
Author manuscript
Spat Spatiotemporal Epidemiol. Author manuscript; available in PMC 2021 February 01.

Published in final edited form as:
Spat Spatiotemporal Epidemiol. 2020 February ; 32: 100307. doi:10.1016/j.sste.2019.100307.

Examining the role of a retail density ordinance in reducing concentration of tobacco retailers

Priyanka Vyas, PhD[1], **Hugh Sturrock, PhD**[2] **[Assistant Professor]**, **Pamela Ling, MD, MPH**[3] **[Professor of Medicine, Fellowship Director]**

1. Box 1390, Postdoctoral Fellow Center for Tobacco Control Research and Education, University of California, School of Medicine, 530 Parnassus Avenue, Suite 366, San Francisco, CA, 94143-1390

2. Epidemiology and Biostatistics, Malaria Elimination Initiative, Global Health Group, University of California, San Francisco, Mission Hall, 550 16th St, San Francisco, CA 94158

3. Center for Tobacco Control Research and Education, University of California San Francisco, 530 Parnassus Avenue, Suite 366, San Francisco, CA 94143-1390

Abstract

Neighborhood characteristics and the built environment are important determinants in shaping health inequalities. We evaluate the role of a retail density ordinance in reducing concentration of tobacco stores based on neighborhood characteristics and land use pattern in San Francisco. The study evaluated the spatial distribution of tobacco retailers before and after the ordinance to identify geographic pockets where the most significant reduction had occurred. A generalized additive model was applied to assess the association between the location of the closure of tobacco retailer and socio-demographic characteristics and land use pattern. We did not find a meaningful change in the overall concentration of retailers based on neighborhood income and ethnicity but found a significant association based on patterns of land use. Our findings suggest that future polices must account for the differential distribution of retailers based on land use mix to lower concentration in areas where it is needed the most.

Keywords

tobacco retailers; land use; spatial inequity; neighborhood

Introduction:

Tobacco is the leading preventable cause of disease and deaths in the United States. It is estimated that 480,000 Americans die each year due to cigarette smoking (US Department of Health and Human Services 2014). Neighborhood factors and built environment

Corresponding author: Tel +1-415-476-0813, priyanka.vyas@ucsf.edu.

contribute towards disparities in tobacco use and smoking prevalence (Northridge, Sclar, and Biswas 2003). Neighborhood characteristics such as proximity and density of stores affect access to tobacco products and increases exposure to tobacco marketing and advertising. Prior studies have also shown that tobacco prices vary based on income and racial ethnic composition of the neighborhood, and based on socio-economic characteristics of the schools that are in proximity to tobacco retailers (Dalglish et al. 2013; Henriksen et al. 2017). High density of tobacco retailers has been linked to increased exposure to tobacco advertisements, and increased intention to smoke among never smoking youth (Cantrell et al. 2015; Johns et al. 2013). Retailer density is also linked to changes in attitude towards smoking, and difficulty in quitting among adults (Kirchner et al. 2013; Paul et al. 2010).

Regulating the density of tobacco retailers is, therefore, increasingly recognized as an integral part of tobacco control policy for state and local governments (Cohen and Anglin 2009). Yet, few studies have evaluated the effectiveness of density-based restrictions in reducing spatial concentration of tobacco retailers. A study conducted in Santa Clara county in California described the effect of the retail density ordinance based on the distribution of retailers before and after the ordinance in relation to schools and in proximity to active retailers (Coxe et al. 2014). Two studies that have attempted to evaluate the potential effect of a retail density ordinance prospectively were conducted based on a simulation of scenarios such as complete ban near schools or based on multiple criterion such as proximity from an active retailer and a complete ban near schools and at pharmacies and found an effect in reducing disparities (Ribisl et al. 2016; Myers et al. 2015). In reality, actual density ordinances do not affect existing retailers in many cases and only apply to new retailers. Therefore, examining geographic variation in the closure of retailers and identifying key factors that drive the closure of retailers is important to understand whether or not the ordinance in having an effect in the neighborhoods where it is the most required. This paper fills the gap in the literature by examining the changes in the distribution of tobacco retailers before and after the ordinance based on actual policy implementation in San Francisco and seeks to identify neighborhood factors that are likely to drive this process.

In San Francisco, tobacco retail density is high in low-income and in ethnic-minority neighborhoods, (San Francisco Community Health Improvement Partnership 2016) and smoking rates are also high in these neighborhoods (San Francisco Community Health Improvement Partnership 2016). Widespread availability of tobacco products normalizes uses (Non-Smokers Rights Association 2011) and affects difficulty in quitting, especially for those living in low-income areas. In 2015 San Francisco Board of Supervisors issued an ordinance that set a cap of 45 tobacco licenses per supervisory district which applies to new license applications. In addition, the law prevents new licenses for tobacco from being issued if the store is within 500 feet of an active retailer, or within 500 feet of a school, or at a place that previously did not sell tobacco. However, the law does not apply to existing retailers that continue to remain in business and pay for their fees. We evaluated the spatial distribution of tobacco retailers before and after the ordinance to examine where the change in retailer concentration had occurred and test the association whether reduction was significantly more likely to have occurred in low-income and minority neighborhoods.

Methods:

Numerous approaches exist to measure tobacco retailer density. These can be broadly classified into area or zone-based approaches (Schneider et al. 2005; Siahpush et al. 2010) and surface-based approaches (Rodriguez et al. 2013; Cantrell et al. 2015; Shortt et al. 2015). Area-based or zone-based approaches typically aggregate data at political or administrative units whereas surface-based approaches model retailer density as a continuous measure by extrapolating point data from outlet locations and assigning density values at every location over the entire study area. This results into a spatial pattern of continuous phenomenon that is not constrained by boundaries (Kramer et al. 2010; Shortt et al. 2015; Cantrell et al. 2015). Area-based density measures include retailer counts or percentages at census tract level or administrative units (Siahpush et al. 2010), based on road network distances (Yu et al. 2010; Marsh, Doscher, and Robertson 2013), counts within buffer based on straight line distances or Euclidean distance (Henriksen et al. 2008), or retailer counts based on population of 1000 or 10,000 (Chaiton et al. 2013; Lee et al. 2017; Lipperman-Kreda, Grube, and Friend 2012).

A direct problem with area-based measures that aggregate data at political or administrative units is that the administrative units are not of the same geographic area, and the population distribution within these units is not homogenous (Higgs 2004). Retail counts based on population of 1000 or 10,000 can lead to over-concentration in densely populated areas. Besides, it does not account for exposure from adjacent census tracts or countries when the units are small, a concern that has been raised in the context of alcohol outlet density (CDC 2017). Area-based measures do not take into consideration cross-boundary flows or the population distribution and land use types within the area (Higgs 2004; CDC 2017). Due to these limitations, an increasing number of studies are now adopting surface-based methods or approaches that measure retailer density over a continuous surface using fixed or adaptive bandwidths based on distances or population distribution (Rodriguez et al. 2013; Marashi-Pour et al. 2015). Given the limitations of area-based approaches and the availability of retailer data at point-level, we did not aggregate data at census tracts or supervisory districts. Instead, we used statistical approaches suitable for point-level data.

Data:

Outcome variable:

Data on Tobacco Retailers Licenses (TRL) were obtained from the San Francisco Public Health Department, prior to 2015 and until 2017. We geocoded the locations of retailers and classified them into two categories – retailers that existed prior to 2015 and no longer existed in 2017 and those that existed prior to 2015 and continued to remain in business until 2017. This classification was done by comparing the geo-location of retailers based on the two-time period. We modeled our response variable as a binary outcome. Each tobacco retailer that shut down post the ordinance was coded as 1 and 0 if a tobacco retailer existed prior to the density ordinance and continued to remain in business post the ordinance.

Neighborhood measures:

To test whether neighborhood characteristics such as median household income, race, and land use mix predicted closure of retailers, we defined neighborhood based on a 1000 feet buffer around each retailer. While there is no consensus on this matter, it is suggested the size of the buffer and analysis should be based on the health problem and scale (Lovasi et al. 2008). An overlay operation was performed to estimate the socio-demographic characteristics including race and income within the buffer using Maptitude. This procedure uses areal weighting to disaggregate the data from a higher administrative unit to a smaller one (Lovasi et al. 2008; Gabriel et al. 2000; Gregorio and Samociuk 2003). For example, if three census tracts fall within a 1000 feet buffer, then the variable is weighted based on the proportion of the census tract that falls within the buffer. Data on land use for San Francisco were obtained from the Open Data.Gov website. We reduced the classification into residential, commercial, and mixed residential land use and estimated the proportion of each type within a 1000 feet buffer around each retailer.

Spatial analysis:

While limited approaches exist to map spatial variation in a binary response variable, common approaches from spatial epidemiology include using non-parametric methods of smoothing such as bivariate kernel density estimation (Kelsall and Diggle 1995; Davies, Jones, and Hazelton 2016; Prince et al. 2001). However, these methods do not account for the effect of covariates. We, therefore, used a generalized additive model (GAM) with a bivariate locally weighted regression smoother (loess) that was applied on latitude and longitude (Webster et al. 2006; Di Salvo et al. 2015; Chen et al. 2015; Bristow et al. 2014; Vieira et al. 2017; Hoffman et al. 2015). This approach can account for the location while simultaneously adjusting for the covariates and can be used to produce a smoothed map of the odds ratio for the entire study area. This is like a logistic regression, except that it includes a smooth term for latitude and longitude as shown in the equation below:

$$logit[p(x)] = \alpha + \gamma' z + S\left(x_1, x_2\right)$$

Where the left hand side is the log of the odds of a retailer closure at a location x, z is a vector of covariates and $S(x_{1,} x_2)$ denotes a smooth terms for the latitude and the longitude (Webster et al. 2006; Di Salvo et al. 2015). Thus, the smoothed map denotes the spatial odds at each grid point over the entire study area. The smoothing combines the kernel density estimation and nearest neighbor approach by giving more weight to the points that are near each point and as the distance increases the weights decrease. The optimal smoothing is done by choosing a span size that minimizes the Akaike Information Criterion (AIC). The optimal span size is based on the percentage of data that is used for smoothing. A larger span size indicates less overall spatial variability in the data and smaller span size can be used to detect more variability in the data. For example, an optimal span of .85 implies using 85 percent of the data around in both the directions from a point to assign weights (Webster et al. 2006; Di Salvo et al. 2015; Chen et al. 2015; Bristow et al. 2014; Vieira et al. 2017; Hoffman et al. 2015).

To test the association between location and the closure of retailers, we conducted a test of 999 permutations based on the null hypothesis that location is not a significant predictor of the retailer closures. We repeated this test after adjusting for the covariates to assess whether there was a change in the crude map. In other words, we assess whether accounting for predictors based on income, race, and land use pattern would remove the residual autocorrelation in the maps. If the global p-value suggested evidence of a significant association between location and the closure of retailers, then the local point-wise permutation tests were conducted to identify statistically significant areas of increased and decreased odds of retailer closure. This was implemented using the R package MapGAM as it offers convenient method to map binary response variable while adjusting for covariates (Webster et al. 2006; Di Salvo et al. 2015; Chen et al. 2015; Bristow et al. 2014; Vieira et al. 2017; Hoffman et al. 2015).

Results:

Descriptive results

San Francisco is divided into eleven supervisorial districts. It has a population density of 17,179 persons per square mile and spans across an area of 49 square miles. Population ranges between 67,000 to 80,000 in each of the 11 supervisorial districts, yet these districts are very different in their geographic extent and land use pattern.

Figure 1 shows the temporal pattern in the decline of new permits being issued after the ordinance. Figure 2 shows land use pattern by supervisorial district. It can be observed that District Six, Three, and Ten have a larger portion of land parcels designated for commercial land use whereas Districts One, Four, and Seven have the largest residential land use parcels. This inequitable pattern in zoning also reflects in the overall distribution of tobacco retailers as districts which have higher commercial and retail permits have a higher concentration of retailers and districts four, seven, and eleven which are predominantly residential have a smaller number of retailers. Yet in many of the predominantly commercial and mixed residential areas low-income Asian and Hispanic population resides (Figure 3).

Statistical results:

We tested association in location of closure of retailers and neighborhood median income, ethnicity and land use characteristics. Results from generalized additive model without smoothing for location found a positive and significant association between the closure of retailers and the percent of commercial land in the buffer ($p = 0.02$, CI =1.001–1.0144). In mixed residential areas, the reduction was lower ($p = 0.05$, CI=0.964–1.000). There was no significant association between the percent of Hispanic ($p = 0.54$, OR = 0.974–1.013) Asian ($p = 0.66$, CI = (0.983–1.010) or median household income ($p = 0.68$, CI =0.99–1.00) in the neighborhood. To assess whether there was a significant association in the location and the closure of retailers, we repeat the above analysis with and without covariates while smoothing on latitude and longitude. Table 1 shows the results based on the comparison of the crude or the unadjusted model and the adjusted model. The global statistic for the crude model is marginally significant ($p=0.05$), suggesting that location is associated with the closure of the retailers. The adjusted model that accounts for race, and income also indicates a significant geographic variation in the closure of retailers (p=0.02). However, in the fully adjusted model that accounts for race, income, and land use mix, there is no evidence of geographic variation (p=0.23).

In order to visualize statistically significant hot and cold spots, we conducted a test based on 999 permutations based on the null hypothesis that the location was not a significant predictor of the closure of the retailers. We repeated this test for the adjusted model based on race, income, and land use mix. Figure 4(a) shows the unadjusted or crude map without any covariates. Based on the crude map, there is a significant hotspot detected in the commercial district of San Francisco. Figure 4(b) shows the persistence of hotspot even after accounting for race and income in the model. However, the adjusted maps based on income, race, as well as proportion of commercial and mixed residential land use suggests that once land use is accounted for in the model, there is no evidence of unexplained geographic variation in the closure of retailers and and hot spots identified in the earlier figures (Figure 4a–b) no longer persist (Figure 4(c)).

Discussion:

This is the first paper to examine the effect of a local law in reducing spatial concentration of tobacco retailers based on neighborhood characteristics with regard to race, income, and land use patterns. Unlike previous studies conducted in diverse places such as New Jersey, New York, Omaha, Iowa, Ontario, and New South Wales, that have shown association between tobacco retail density and neighborhood income and ethnic composition, (Loomis et al. 2013; Reid et al. 2013; Schneider et al. 2005; Marashi-Pour et al. 2015; Yu et al. 2010; Siahpush et al. 2010; Chaiton et al. 2013), this paper does not find an association between closure of retailers and neighborhood characteristics. Rather we find that land use is a key driver of inequitable concentration of tobacco retailers. This also manifests in inequitable pattern in closure of retailers. We found that the density ordinance did not have a homogenous effect across the city. Instead, our paper demonstrates that land use pattern is highly inequitable in San Francisco due to which some supervisorial districts and census tracts within these districts have a disproportionate share of commercial areas and mixed residential housing while others are predominantly residential. Therefore, the effect of density ordinance was the steepest in the districts that are predominantly commercial and lower in residential and mixed residential neighborhoods. The findings from this paper have practical implications for policies and developing interventions that take into account built environment and its effect on health outcomes (Northridge, Sclar, and Biswas 2003). Policies related to tobacco retail density that do not account for the uneven pattern of land use mix can have a limited effectiveness in reducing concentration in communities and neighborhoods where the most reduction is needed.

Our paper highlights the spatial process by which retail density ordinances have an effect in reducing concentration. The San Francisco Retail Density Ordinance applies a combination of criterion such as density-based caps and proximity-based measures to assess whether or not to grant new permits to tobacco retailers. Density-based caps prevent new licenses from being issued in administrative units where the existing number of licenses exceed beyond the threshold set by the density ordinance whereas proximity-based restrictions prevent new permits from being issued based on proximity of retailer to another retailer or near school within a specific distance. At the time the ordinance was implemented no supervisory district was below the cap of 45 except for District 7 due to which no new permits can be granted in most districts. Since the law does not apply to existing retailers but only new retailers, the process by which retailer concentration gets reduced is mainly through attrition or when existing stores decide to give up their permit. This analysis finds that proximity-based measures will have the most impact in smaller geographic area that have the highest concentration of retailers due to retailer attrition, but these policies may not have the same effect in low-income and minority areas if the market is not highly concentrated and retailers do not give up their permits. The empirical findings from this paper support previous studies that have argued from a legal perspective that the law must be applied to existing retailers after a specific time period. This would ensure the most effectiveness of the ordinance and reduce concentration (Ackerman et al. 2017).

In the light of legalization of recreational cannabis (Berg et al. 2018), the need to monitor tobacco and marijuana retailers concentration based on land use pattern is even greater as the areas with high concentration of tobacco retailers may also attract cannabis outlets due to zoning restrictions that govern the location of these outlets. A study comparing spatial equity in the distribution of cannabis stores in four large cities in United States found that zoning policies contributed towards a disproportionate share of cannabis stores in certain census tracts of the city (Németh and Ross 2014). Our paper is timely and relevant as we argue that public health departments and urban planning department must examine the differential distribution of tobacco and cannabis stores based on land use pattern and zoning regulations to prevent geographic concentration. In many of these commercial neighborhoods, poverty, income, homelessness and violence already contribute to worse health indicators and outcomes in these neighborhoods (San Francisco Community Health Improvement Partnership 2016). Without taking into consideration the differential pattern based on zoning, a blanket policy based on “one size fits all” approach may not be the most effective in reducing concentration across the city.

By increasing the level of awareness among the health officials on the role of land use policy in influencing health, health departments can develop policies aimed at improving population health by integrating them with urban planning policies. Ultimately, efforts to reduce inequity in tobacco availability and excess supply in specific neighborhoods will need to be linked to health promoting infrastructure, developing capacity within community-based organizations to engage with land use planning and policy, and fostering cross-government collaboration in order to integrate health and health equity into land use decisions.

Strengths and Limitations:

This research demonstrates a novel approach to assess spatial variation in exposure or risk that can be applied in the context of health outcomes such as obesity, substance-abuse and those related non-communicable diseases. Unlike some of the studies that have attempted to model the impact of density ordinances based on simulation (Myers et al. 2015; Ribisl et al. 2016), our paper is based on changes in the retailer licensing data based on an actual law and grounded in reality. Therefore, the findings from this study can be useful as more cities consider similar laws.

A limitation of this study is that it is geographically limited to San Francisco and the findings may be limited to larger cities of similar nature such as New York, Philadelphia, or Boston. However, it still provides useful context to other cities and counties that may be considering a retail density ordinance. The study could also not account for gentrification and changes in rents in residential and commercial areas, which could also have a role in retailer attrition. In commercial districts where tobacco retailer density is high, changes in commercial rents could affect the choice of retailers to remain in business. In predominantly residential areas where corner store or a convenience store primarily sell tobacco, competition from retail chains could affect the viability of the business. Increased gentrification can have implications on driving retailer concentration from one area to another and should be addressed in future studies.

Conclusion:

We found a significant geographic variation in the closure of the tobacco retailers. However, once we accounted for race, income, and land use mix there was no spatial variation in the reduction of tobacco retailers. Our results indicate an increased odd of the closure of retailers in the commercial areas. Policies related to tobacco retail density that do not account for the uneven pattern of land use mix can have a limited effectiveness in reducing concentration in communities and neighborhoods where the most reduction is needed.

Acknowledgments

This research was supported in part by National Institute of Health T32 CA113710. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References

Ackerman Amy, Etow Alexis, Bartel Sara, and Ribisl Kurt M. 2017 ‘Reducing the density and number of tobacco retailers: policy solutions and legal issues’, Nicotine & Tobacco Research, 19: 133–40. [PubMed: 27127232]

Berg Carla J, Lisa Henriksen, Patricia Cavazos-Rehg, Regine Haardoerfer, and Bridget Freisthler. 2018 ‘The emerging marijuana retail environment: Key lessons learned from tobacco and alcohol retail research’, Addictive behaviors.

Bristow Robert E, Jenny Chang, Argyrios Ziogas, Hoda Anton-Culver, and Vieira Veronica M. 2014 ‘Spatial analysis of adherence to treatment guidelines for advanced-stage ovarian cancer and the impact of race and socioeconomic status’, Gynecologic oncology, 134: 60–67. [PubMed: 24680770]

Cantrell Jennifer, Anesetti-Rothermel Andrew, Pearson Jennifer L, Haijun Xiao, Donna Vallone, and Kirchner Thomas R. 2015 ‘The impact of the tobacco retail outlet environment on adult cessation and differences by neighborhood poverty’, Addiction, 110: 152–61. [PubMed: 25171184]

CDC. 2017 “Guide for measuring alcohol outlet density” In. Atlanta: Centers for Disease Control and Prevention, US Department of Health and Human Services.

Chaiton Michael O, Mecredy Graham C, Cohen Joanna E, and Tilson Melodie L. 2013 ‘Tobacco retail outlets and vulnerable populations in Ontario, Canada’, International journal of environmental research and public health, 10: 7299–309. [PubMed: 24351748]

Chen Kai, Huang Lei, Zhou Lian, Ma Zongwei, Bi Jun, and Li Tiantian. 2015 'Spatial analysis of the effect of the 2010 heat wave on stroke mortality in Nanjing, China', Scientific reports, 5: 10816. [PubMed: 26034864]

Cohen Joanna E, and Lise Anglin. 2009 'Outlet density: a new frontier for tobacco control', Addiction, 104: 2–3. [PubMed: 19133881]

Coxe Nicole, Webber Whitney, Burkhart Janie, Broderick Bonnie, Yeager Ken, Jones Laura, and Fenstersheib Marty. 2014 'Use of tobacco retail permitting to reduce youth access and exposure to tobacco in Santa Clara County, California', Preventive medicine, 67: S46–S50. [PubMed: 24513170]

Dalglish Emma, Deirdre McLaughlin Annette Dobson, and Gartner Coral. 2013 'Cigarette availability and price in low and high socioeconomic areas', Australian and New Zealand journal of public health, 37: 371–76. [PubMed: 23895481]

Davies Tilman M, Jones Khair, and Hazelton Martin L. 2016 'Symmetric adaptive smoothing regimens for estimation of the spatial relative risk function', Computational Statistics & Data Analysis, 101: 12–28.

Di Salvo Francesca, Meneghini Elisabetta, Vieira Veronica, Baili Paolo, Mariottini Mauro, Baldini Marco, Micheli Andrea, and Sant Milena. 2015 'Spatial variation in mortality risk for hematological malignancies near a petrochemical refinery: A population-based case-control study', Environmental research, 140: 641–48. [PubMed: 26073202]

Gabriel Roy M, Mondeaux Frank P, Laws Katherine E, Hahn Karen J, and Weaver David. 2000 'Reducing births of drug-affected babies: a retrospective analysis of archival data and a community wide effort', Evaluation and Program Planning, 23: 347–53.

Gregorio David I, and Samociuk Holly. 2003 'Breast cancer surveillance using gridded population units, Connecticut, 1992 to 1995', Annals of epidemiology, 13: 42–49. [PubMed: 12547484]

Henriksen Lisa, Andersen-Rodgers Elizabeth Xueying Zhang, Roeseler April, Sun Dennis L, Johnson Trent O, and Schleicher Nina C. 2017 'Neighborhood variation in the price of cheap tobacco products in California: Results from Healthy Stores for a Healthy Community', Nicotine & Tobacco Research, 19: 1330–37. [PubMed: 28444233]

Henriksen Lisa, Feighery Ellen C, Schleicher Nina C, Cowling David W, Kline Randolph S, and Fortmann Stephen P. 2008 'Is adolescent smoking related to the density and proximity of tobacco outlets and retail cigarette advertising near schools?', Preventive medicine, 47: 210–14. [PubMed: 18544462]

Higgs Gary. 2004 'A literature review of the use of GIS-based measures of access to health care services', Health Services and Outcomes Research Methodology, 5: 119–39.

Hoffman Kate, Aschengrau Ann, Webster Thomas F, Bartell Scott M, and Vieira Verónica M. 2015 'Associations between residence at birth and mental health disorders: a spatial analysis of retrospective cohort data', BMC Public Health, 15: 688. [PubMed: 26195105]

Johns Michael, Sacks Rachel, Rane Madhura, and Kansagra Susan M. 2013 'Exposure to tobacco retail outlets and smoking initiation among New York City adolescents', Journal of Urban Health, 90: 1091–101. [PubMed: 23700202]

Kelsall Julia E, and Diggle Peter J. 1995 'Non-parametric estimation of spatial variation in relative risk', Statistics in medicine, 14: 2335–42. [PubMed: 8711273]

Kirchner Thomas R, Cantrell Jennifer, Anesetti-Rothermel Andrew, Ganz Ollie, Vallone Donna M, and Abrams David B. 2013 'Geospatial exposure to point-of-sale tobacco: real-time craving and smoking-cessation outcomes', American journal of preventive medicine, 45: 379–85. [PubMed: 24050412]

Kramer Michael R, Cooper Hannah L, Drews-Botsch Carolyn D, Waller Lance A, and Hogue Carol R. 2010 'Do measures matter? Comparing surface-density-derived and census-tract-derived measures of racial residential segregation', International Journal of Health Geographics, 9: 29. [PubMed: 20540797]

Lee Joseph GL, Sun Dennis L, Schleicher Nina M, Ribisl Kurt M, Luke Douglas A, and Henriksen Lisa. 2017 'Inequalities in tobacco outlet density by race, ethnicity and socioeconomic status, 2012, USA: results from the ASPiRE Study', J Epidemiol Community Health: jech-2016-208475.

Lipperman-Kreda Sharon, Grube Joel W, and Friend Karen B. 2012 ‘Local tobacco policy and tobacco outlet density: associations with youth smoking’, Journal of Adolescent Health, 50: 547–52. [PubMed: 22626479]

Loomis BR, Kim AE Goetz JL, and Juster HR. 2013 ‘Density of tobacco retailers and its association with sociodemographic characteristics of communities across New York’, Public Health, 127: 333–38. [PubMed: 23515009]

Lovasi Gina S, Moudon Anne Vernez, Smith Nicholas L, Lumley Thomas, Larson Eric B, Sohn Dong W, Siscovick David S, and Psaty Bruce M. 2008 ‘Evaluating options for measurement of neighborhood socioeconomic context: evidence from a myocardial infarction case–control study’, Health & place, 14: 453–67. [PubMed: 17950024]

Marashi-Pour Sadaf, Cretikos Michelle, Lyons Claudine, Rose Nick, Jalaludin Bin, and Smith Joanne. 2015 ‘The association between the density of retail tobacco outlets, individual smoking status, neighbourhood socioeconomic status and school locations in New South Wales, Australia’, Spatial and spatio-temporal epidemiology, 12: 1–7. [PubMed: 25779904]

Marsh Louise, Doscher Crile, and Robertson Lindsay A. 2013 ‘Characteristics of tobacco retailers in New Zealand’, Health & place, 23: 165–70. [PubMed: 23933446]

Myers Allison E, Hall Marissa G, Isgett Lisa F, and Ribisl Kurt M. 2015 ‘A comparison of three policy approaches for tobacco retailer reduction’, Preventive medicine, 74: 67–73. [PubMed: 25689540]

Németh Jeremy, and Ross Eric. 2014 ‘Planning for marijuana: The cannabis conundrum’, Journal of the American Planning Association, 80: 6–20.

Non-Smokers Rights Association. 2011 “Reducing the availability of tobacco products at retail: Policy Analysis.” In.

Northridge Mary E, Sclar Elliot D, and Biswas Padmini. 2003 ‘Sorting out the connections between the built environment and health: a conceptual framework for navigating pathways and planning healthy cities’, Journal of Urban Health, 80: 556–68. [PubMed: 14709705]

Paul Christine L, Mee Kathleen J, Judd Tanya M, Walsh Raoul A, Tang Anita, Penman Andrew, and Girgis Afaf. 2010 ‘Anywhere, anytime: retail access to tobacco in New South Wales and its potential impact on consumption and quitting’, Social Science & Medicine, 71: 799–806. [PubMed: 20554363]

Prince Martin I, Chetwynd Amanda, Diggle Peter, Jarner Mikala, Metcalf Jane V, and James Oliver FW. 2001 ‘The geographical distribution of primary biliary cirrhosis in a well-defined cohort’, Hepatology, 34: 1083–88. [PubMed: 11731995]

Reid Robert J, Morton Cory M, Garcia-Reid Pauline, Peterson N Andrew, and Yu Danlin. 2013 ‘Examining tobacco outlet concentration in New Jersey: does income and ethnicity matter?’, Journal of ethnicity in substance abuse, 12: 197–209. [PubMed: 23967882]

Ribisl Kurt M, Luke Douglas A, Bohannon Doneisha L, Sorg Amy A, and Moreland-Russell Sarah. 2016 ‘Reducing disparities in tobacco retailer density by banning tobacco product sales near schools’, Nicotine & Tobacco Research, 19: 239–44. [PubMed: 27613900]

Rodriguez Daniel, Carlos Heather A, Adachi-Mejia Anna M, Berke Ethan M, and Sargent James D. 2013 ‘Predictors of tobacco outlet density nationwide: a geographic analysis’, Tobacco Control, 22: 349–55. [PubMed: 22491038]

San Francisco Community Health Improvement Partnership. 2016 “San Francisco Community Health Improvement Partnership.” In.

Schneider John E, Reid Robert J, Peterson N Andrew, Lowe John B, and Hughey Joseph. 2005 ‘Tobacco outlet density and demographics at the tract level of analysis in Iowa: implications for environmentally based prevention initiatives’, Prevention Science, 6: 319–25. [PubMed: 16163568]

Shortt Niamh K, Tisch Catherine, Pearce Jamie, Mitchell Richard, Richardson Elizabeth A, Hill Sarah, and Collin Jeff. 2015 ‘A cross-sectional analysis of the relationship between tobacco and alcohol outlet density and neighbourhood deprivation’, BMC Public Health, 15: 1014. [PubMed: 26437967]

Siahpush M, Jones PR, Singh GK, Timsina LR, and Martin J. 2010 ‘Association of availability of tobacco products with socio-economic and racial/ethnic characteristics of neighbourhoods’, Public Health, 124: 525–29. [PubMed: 20723950]

US Department of Health and Human Services. 2014 “The Health Consequences of Smoking: 50 Years of Progress: A Report of the Surgeon General.” In.: US Department of Health and Human Services.

Vieira Verónica M, Villanueva Carolina, Chang Jenny, Ziogas Argyrios, and Bristow Robert E. 2017 ‘Impact of community disadvantage and air pollution burden on geographic disparities of ovarian cancer survival in California’, Environmental research, 156: 388–93. [PubMed: 28395243]

Webster Thomas, Vieira Verónica, Weinberg Janice, and Aschengrau Ann. 2006 ‘Method for mapping population-based case-control studies: an application using generalized additive models’, International Journal of Health Geographics, 5: 26. [PubMed: 16764727]

Yu D, Peterson NA, Sheffer MA, Reid RJ, and Schnieder JE. 2010 ‘Tobacco outlet density and demographics: analysing the relationships with a spatial regression approach’, Public Health, 124: 412–16. [PubMed: 20541232]

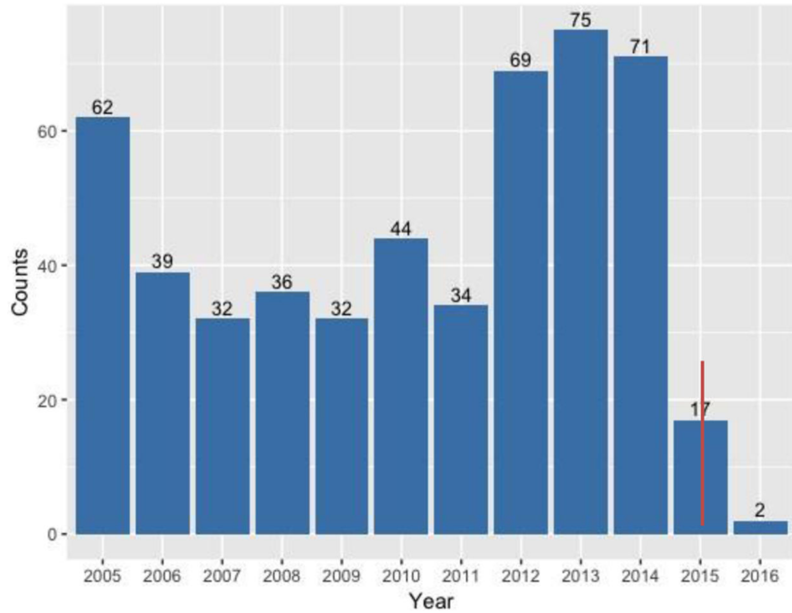

Figure 1:

New permits issued to retailers for selling tobacco in San Francisco since 2005. The red vertical line indicates the year when the ordinance came into effect.

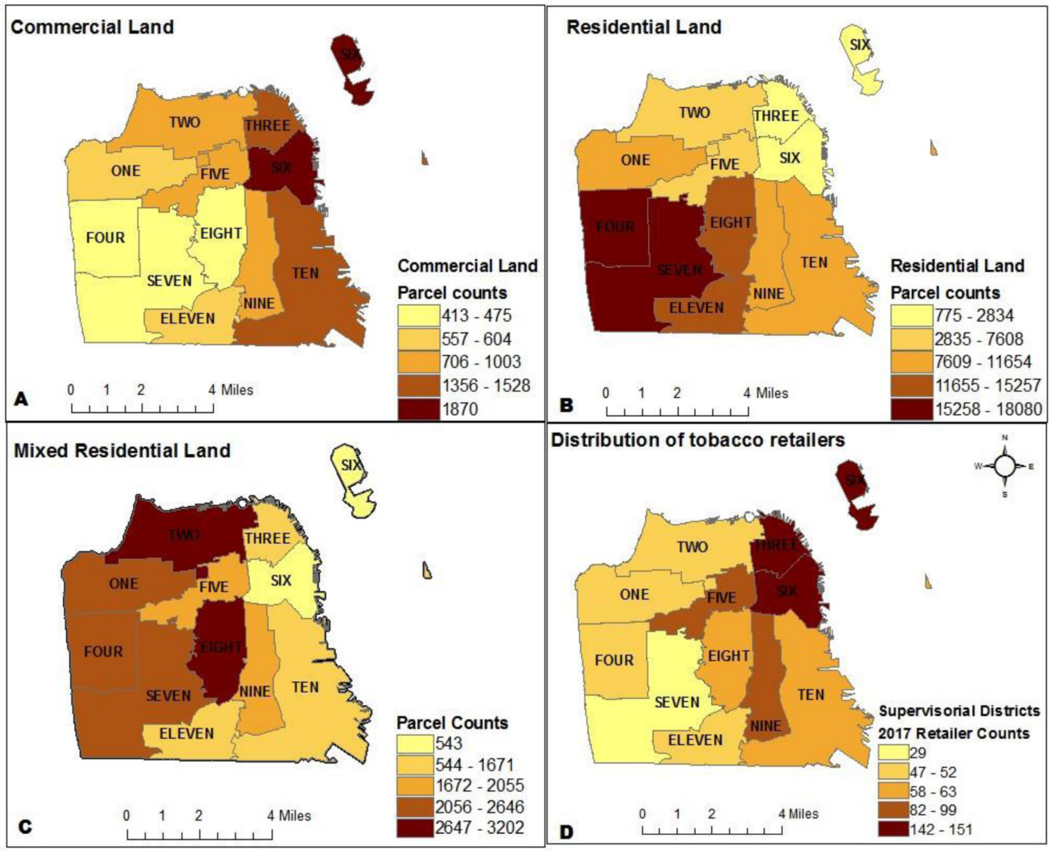

Figure 2:
Land Use Pattern in San Francisco and Distribution of Tobacco Retailers by Supervisory District. The number highlighted within the district are the official supervisory district number.

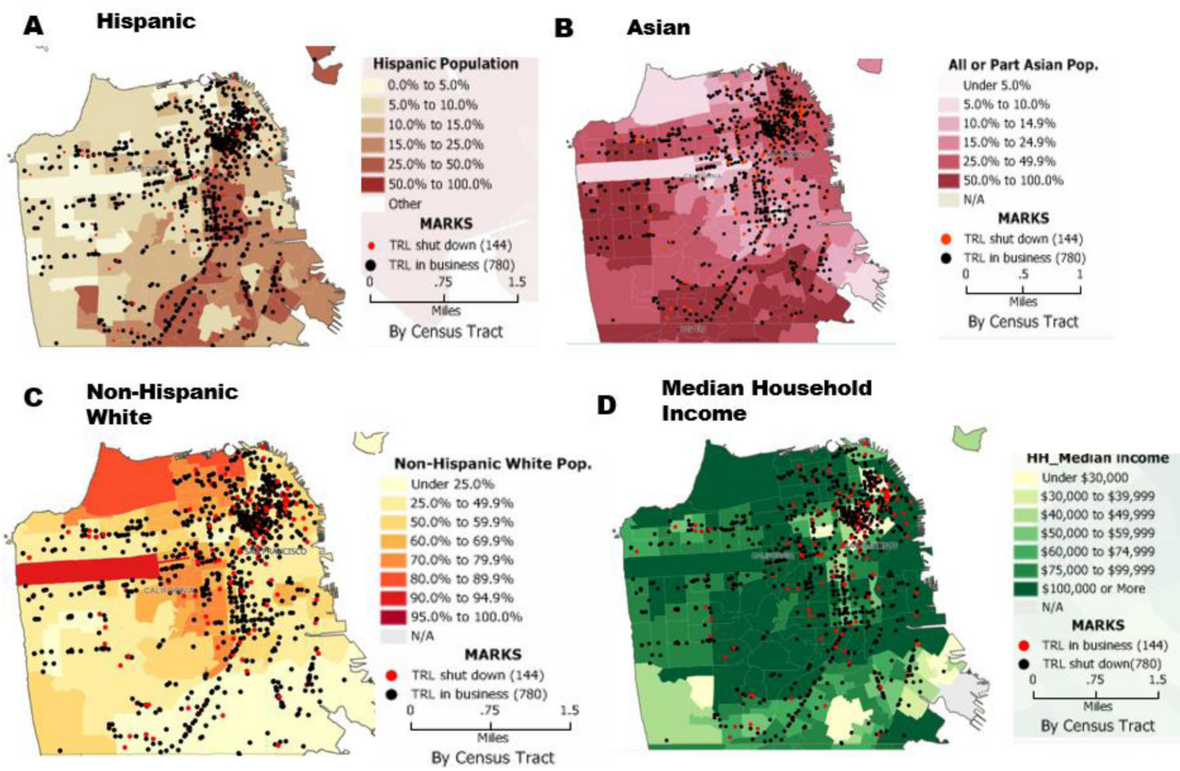

Figure 3:

Distribution of tobacco outlets and the socio-demographic profile of the census tracts in San Francisco. Darker color indicates a higher percentage. Locations of retailers no longer in business are in red and the ones that continued to remain in business are in black

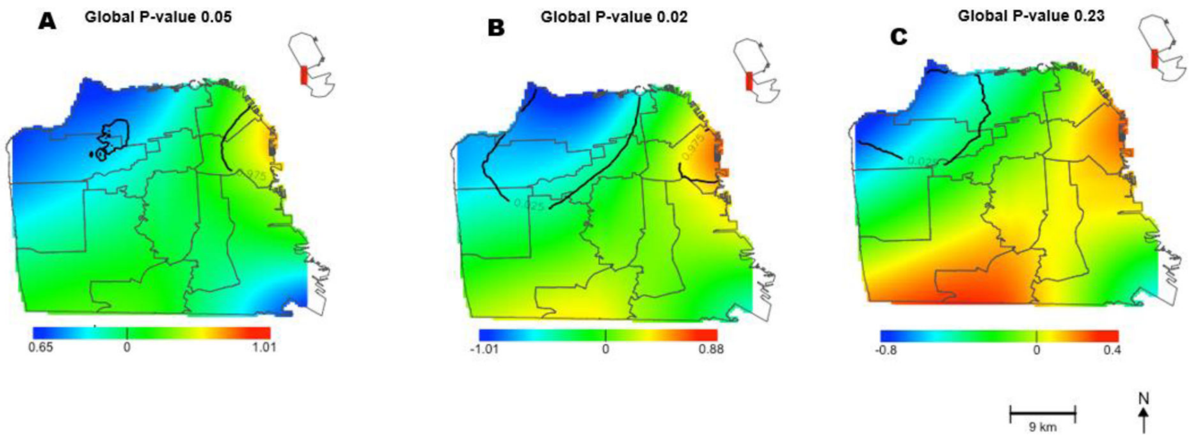

Figure 4:

Spatial variation in the reduction of tobacco retailers in San Francisco after the density ordinance. The map shows the significant hotspots based on 999 permutations A) Crude map without adjusting for any covariates B) Adjusted map based on race and income C) Adjusted map based on race, income, and land.

Table 1:

Results from generalized additive model testing the significance of location of closure of retailers with and without covariates.

	Global P-value	Adjusted Odds Ratio Range	Optimal span size
Crude	0.05	0.52 −2.73	0.85
Adjusted for race and income	0.02	0.36–2.42	0.80
Adjusted for race, income, and land use	0.23	0.44–1.49	0.95