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Violent crime redistribution in a city following a substantial increase in the number of off-sale alcohol outlets: A Bayesian analysis

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Abstract

Introduction and Aims.—This study examined whether the introduction of a large number of off-premise alcohol outlets into a city over a brief period of time could affect rates of violent crime.

Design and Methods.—The study analysed annual counts of violent crime across 172 US Census block groups in Lubbock, Texas from 2006 through 2011. Spatial Poisson models related annual violent crime counts within each block group to off-premise and on-premise alcohol outlets active during this time period as well as neighbourhood socio-demographic characteristics. The effects of alcohol outlets were assessed both within block groups and across adjacent block groups.

Results.—On-premise outlets had a small, significant positive association with violence within a given block group. A similar well-supported local effect for off-premise outlets was not found. However, the spatially lagged effect for off-sale premises was well-supported, indicating that greater densities of these outlets were related to greater rates of violent crime in adjacent areas.

Discussion and Conclusions.—While these analyses confirmed a previous time-series analysis in finding no city-wide effect of the increase in off-premise outlets, they do suggest that such outlets in a local area may be related to violence in nearby geographic areas. They indicate the importance of examining neighbourhood-specific effects of alcohol outlets on violence in addition to the city-wide effects. They also present further evidence supporting the need to examine the differential effects of on-sale and off-sale premises.

Keywords

alcohol outlets; Bayesian analysis; off-sale premises; violent crime

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Introduction

While it is frequently claimed that there is a strong relationship between the density of alcohol outlets in a community and the prevalence of alcohol-related harms [1], recent research has shown that the association between the two can be complex and will vary according to the type of alcohol outlet, the type of harm, the type of clientele attracted to an outlet and the broader social context within which outlets are imbedded [2–6]. This is certainly true of the association between off-premise outlets and violent crime, with a number of recent studies reporting weak associations or no statistically significant association between the two [7–10].

A recent policy change presented an unusual opportunity to test the impacts of off-premise alcohol outlets on violence. Before 23 September 2009, Lubbock, Texas allowed off-premise alcohol sales only within a handful of large warehouse-type stores, although alcohol for on-premise consumption was available from more than 200 bars and restaurants city-wide [11]. A licensing law introduced on that date allowed the Texas Alcohol Beverage Commission to issue off-sale licenses to more than 140 stores throughout Lubbock during the following year. A previous time-series analysis of violent crime in Lubbock as a whole failed to identify any relationship between the increase in off-premise outlets and violent crime [12]. More specifically, this earlier analysis showed an increase in violent crimes and assaults relative to a non-stationary decline across the city over time, but the measure of this ‘uptick’ was not significant. This may have been due to two salient limitations of the Lubbock time-series analyses for identifying policy effects. First, these analyses included fewer observations pre- and post-intervention than are typically recommended for efficient timeseries assessments. Second, the implied counterfactual is weak; in the (unobservable) absence of intervention it is assumed that no changes at the city-level would take place, but it is quite possible that the introduction of off-premise outlets into new areas of the city shifted violent crime rates spatially even if it did not necessarily increase risks for the city as a whole.

The current analysis further examines data from the natural experiment that occurred in Lubbock on 23 September 2009, by examining the local effects of the Lubbock licensing change, rather than the citywide effects. The spatial panel approach adopted here offers greater statistical power to identify otherwise undetectable outlet effects. Instead of merely treating the added outlets as an indivisible aggregate, the new approach can accommodate possible associations between the number of outlets in a given location and crime rates in the adjacent areas. The implied counterfactual becomes observable; all other things being equal this is the set of comparable spatial units in which no outlets are introduced. Thus, the research question addressed here is: Will the introduction of a very large number of off-premise outlets into specific city areas increase or redistribute violent crime throughout the city?

Methods

Setting and data

The study setting, as well as the alcohol outlet and crime data, is reported in detail elsewhere [11,12]. Briefly, the city of Lubbock had an estimated population of 233 740 in 2011, plus about 31 000 students at Texas Tech University. Locations of violent crimes (specifically, murder, rape, robbery and aggravated assault) were obtained directly from the Lubbock Police Department for the time period January 2006 through December 2011. In addition to total violent crime, the data analysis was also run separately for aggravated assault (which comprised 73% of the violent crime) and for the other three categories of violent crime (murder, rape and robbery) combined (27% of the violent crimes). This was done as previous studies of alcohol outlet density and violence have separatedout types of violent crime in this manner (e.g. 10) and because studies that use hospital data focus exclusively on assault (e.g. 8).

Locations of off-premise and on-premise outlets active during this same time period were obtained using the Texas Alcohol Beverage Commission online database (and downloaded in January 2013). Both crime and outlet locations were geocoded using Centrus Desktop (with 99% and 100% match rates, respectively) and assigned to the city's 172 Census block groups. Annual violent crimes in the city declined from 1775 in 2006 to 1285 in 2011. Citywide on-premise outlets increased steadily from 154 in 2006 to 215 in 2011, whereas the number of offpremise outlets increased suddenly following the introduction of the new law (rising to 142 by 2011). Analyses related annual counts of violent crime by block group to the number of off- and on-premise outlets per block group for each year.

Because crimes and other outlet related problems may occur at some distance from the location of drinking [13], analyses also controlled for spatial lag effects (that is, average on-premise and off-premise outlets per block group across all adjacent spatial units). In these analyses, block groups that touched in any way, even at only a point on the map, were treated as adjacent. The analyses also controlled for neighbourhood demographic characteristics of the Census block groups. Specifically, annual estimates on the following variables were obtained from GeoLytics Inc. [14]: population density per square mile, inflation-adjusted median household income, percent female-headed households, percentages of owner-occupied and vacant housing, and population percentages aged 15–24 years, Hispanic, Black and male.

Geographic units of analysis

The geographic unit of analysis was the US Census 2000 block group. Census 2000 block group boundaries were used rather than the 2010 Census boundaries since the socio-demographic dataset employed in the analysis (GeoLytics) provided data for Census 2000-defined block groups for five of the six years included in the study (2006–2010). For the year 2011, Geolytics provided data using Census 2010-defined block groups. The shapes of most block group units were the same from 2000 to 2010, but some units were not nested using the different Census area definitions. Accordingly, we mapped the 2011 GeoLytics Census block group demographic estimates into Census 2000 block groups weighting these

estimates by captured year-2000 block populations. This procedure introduced a small amount of noise into the year 2011 GeoLytic estimates used in the analyses.

Statistical analysis

A spatial Poisson panel model was used to assess statistical relationships between independent measures and annual counts of violent crimes across all Census block groups. Prior research using spatial analysis to study the association between alcohol outlet density and violence within small geographic units has shown high levels of spatial autocorrelation [15–18], which can lead to substantial bias if not corrected [19]. Accordingly, we used a Bayesian conditional autoregressive (CAR) specification that accounted for loss of statistical independence among spatial units [13,20]. These models split unexplained block group differences into two random effects: a CAR effect that accounts for similarity among adjacent spatial units, and an unstructured random effect that accounts for block group differences that are not spatially correlated. The Bayesian approach helps to deal with small area problems of measurement unreliability and instability by allowing estimates in each region to borrow strength from those of neighbouring areas, and has also been shown to allow for over-dispersion [21,22]. The model is specified as follows:

$$Y_{i,t} | \mu_{i,t} \sim \text{Poisson}\,(E_{i,t} \exp(\mu_{i,t}))$$

where $Y_{i,t}$ represents the observed count of violent crimes in block group i during year t and $E_{i,t}$ denotes the expected number of the crimes under the assumption that study-wide violent events are distributed in direct proportion to block group population. Hence exp.($\mu_{i,t}$) may be interpreted as the relative crime risk of residing in spatial unit i at time t: regions with exp($\mu_{i,t}$) > 1 will have greater crime counts than expected based on their population, and regions with exp($\mu_{i,t}$) < 1 will have fewer than expected. A specification test assuming that crimes were distributed proportionally to block group land area produced very similar results.

Following standard generalised linear models, the log-relative risk, $\mu_{i,t}$, is modelled linearly as:

$$\mu_{i,t} = \alpha + \lambda \bullet t + X'_{i,t}\beta + \theta_i + \varphi_i + \xi_i \bullet t$$

This is a linear combination of fixed covariate effects and random effects which may take account of spatial correlation. Parameter α is an intercept, and $\lambda \bullet t$ is a city-wide linear time trend. Matrix $X'_{i,t}$ contains spaceand time-specific covariates and β is a vector of fixedeffects estimates of the impacts of those covariates. θ_i and $\varnothing_i$ denote the pair of random effects capturing spatially unstructured heterogeneity and CAR spatial dependence, respectively. Finally, ξ_i is a separate CAR random effect allowing for spatial variation in growth rate centred around the city-wide time trend λ.

Model parameters were estimated using WinBUGS 1.4.3 software [23]. Non-informative priors were specified for all fixed and random effects. Simulations were allowed to burn-in for 10 000 Markov Chain Monte Carlo (MCMC) iterations (using the WinBUGS default

Gibbs sampling method), which in our study were sufficient for all parameter estimates to stabilise and converge between two chains with different initial values. Posterior estimates were then sampled for an additional 40 000 iterations.

Results

Descriptive statistics

Table 1 presents the summary statistics of neighbourhood demographic and population variables included in the model, as well as violent crime and on- and offpremise alcohol outlets within the study area during the time period between 2006 and 2011. There were 172 Census block groups, and their populations ranged from 38 to 8379, with a mean of 1148.6 and standard deviation of 604.0. Over 1032 space–time observation units (172 spatial units over 6 years), there was an average of 8.6 violent crimes per block group per year. There was an average of 1.07 on-premise outlets and 0.34 off-premise outlets per block group. The average number of on-premise outlets in adjacent block groups was 1.25, and the average number of offpremise outlets 0.41.

Figure 1 shows the ranges of outlet counts in 2008 (before the change in the law and expansion of offpremise outlets) and 2009 (after the law and expansion). The top pair of maps is for off-premise outlets, and shows a large discontinuous increase. The bottom pair is for on-premise outlets, which appear stable over this period of time.

Within and across block group estimates for all violent crime

Table 2 presents the results of Bayesian space–time analyses of violent crime. The posterior median of each parameter represents the model's predicted log-relative risk, and is accompanied by its 95% credible interval from the posterior distribution. The table also presents the median expressed as a relative risk. The relative risk presented in the final column of the table can be interpreted as the proportional increase (or decrease) related to an unit increase in each covariate. For example, the relative risk of 1.0402 for on-premise outlets indicates adding an on-premise outlet to a block group would entail a 4% increase in violent crime in that block group. In contrast, neither the effect for off-premise outlets nor the spatially lagged effect for on-sale premises was well-supported. However, the spatially lagged effect for off-premise outlets was well-supported and fairly large (1.1463), indicating that greater offpremise densities were associated with greater rates of violent crime in adjacent residential areas over time. Specifically, adding an average of one off-premise outlet to the block groups that are immediate neighbours to another block group was associated with a 14.6% increase in violent crime within the latter.

With regard to the neighbourhood socioeconomic characteristics, median household income, percent owner-occupied home, percent population aged 15–24 years and population density were each inversely related to violence. The associations were all fairly strong (ranging from an 11% to 30% decrease). The other two neighbourhood demographic variables that were well-supported in the analysis were percent Hispanic (28% increase) and percent female-headed households (12% increase). The time trend effect was negative, suggesting that crime

rates were declining by 13% per year during this period after controlling for changes in other variables.

Analyses of types of violent crime

The results from the analyses run separately for aggravated assault and for the other three categories of violent crime (murder, rape and robbery) combined were very similar to those for total violent crimes. Specifically, on-premise outlets had positive well-supported effects on local crime (relative risk = 1.0395 for aggravated assault and 1.0598 for the other three crimes), while the local effects of off-premise outlets and the adjacent effect of on-premise outlets were not wellsupported for either crime category. Only in the case of the adjacent effects of off-premise outlets was there a difference across the two categories of violent crime: while the effects were always positive, they were only well-supported for the combined murder/rape/robbery category (relative risk = 1.3153) but not for aggravated assault (relative risk = 1.0735).

With regard to the socio-demographic variables, a higher percent female-headed households and a higher percent Hispanics were associated with higher rates of all three crime categories (total; assault; murder/rape/ robbery). Population density and percent aged 15–24 were negatively related to all three crime categories. However, there were some differences across the three crime categories: median household income was always a negative parameter but was not wellsupported for non-assault violence and percent owneroccupied was always a negative parameter but not well-supported for aggravated assault.

Sensitivity analyses

Finally, in order to test the robustness of our findings we conducted two additional sensitivity analyses. First, we adjusted for the spatial lags of all covariates in the analyses that examined the spatially lagged effects of alcohol outlets. All well-supported effects related to on- and off-premise outlet densities observed in the original analyses continued to be well-supported. In addition, all unsupported effects continued to be unsupported. There were well-supported spatial lag effects for a number of covariates in these new models (e.g. household income). However, while these are of some general interest, they did not affect the primary results pertaining to alcohol outlets of the original analysis.

Second, since we mapped the 2011 GeoLytics Census block group demographic estimates into Census 2000 block groups, we deleted data from 2011 and repeated all analyses presented above. All effects related to on-premise and off-premise outlet densities observed using the full dataset (well-supported or not, and lagged or not) were replicated.

Discussion and Conclusions

The current analyses show a positive spatially lagged (i.e. adjacent) association of off-premise alcohol outlets with total violent crime, at a time when the overall crime rate in Lubbock was declining. Further analyses showed that this adjacent effect was stronger for more serious crimes (i.e. the combined murder/rape/robbery category) than for aggravated assault. As noted above, the results of the earlier time-series analysis showed an increase in violent crimes and assaults relative to a non-stationary decline across the city over time, but

the measure of this up-tick was not significant. The current panel design is more powerful in that it looks at the effects of changes in outlet counts over place and time, enabling a comparison of block group years that have greatly different retail exposures and providing more power to identify significant outlet effects. Again, continuous declines in crime rates were observed across the city over time despite the influx of new off-premise outlets, but against this background there was a positive well-supported coefficient relating off-premise outlet counts to crime rates in immediately adjacent areas. On average, each additional off-premise outlet in a block group was associated with close to a 15% increase in violent crime within its neighbour. We found that some areas continued to exhibit declining crime rates while others exhibited increased crime related to outlets in adjacent areas; some of the spatial change in crime rates may be due to the displacement of offences, and some to the criminogenic effects of outlets. However, we were unable to differentiate the two kinds of changes in crime rates using data available to the present study.

It is also possible that the Lubbock alcohol market was more or less saturated prior to September of 2009, with residents able to purchase alcohol from existing on-premise locations or drive to the few existing warehouse-style off-premise locations. In explaining this, Han and Gorman [12] speculated that to the extent the new off-premise licenses might have an effect on violence, this would be through a mechanism that Livingston *et al.* [24] refer to as a ‘proximity effect’ (also known as ‘convenience costs’ in the economics literature, Gruenewald [25]), that is by making alcohol more readily available and easier to consume in private settings such as the home. The current findings concerning the effects of off-premise outlets on total violent crime lend support to this view, in that they show that the greater availability of alcohol throughout the city after September of 2009 was associated with a redistribution of crime within the city.

This is a fundamentally different effect than that described by Livingston *et al.* [24] as an ‘amenity effect’, which posits the negative impact of licensed premises on the communities in which they operate arises primarily through the types of individuals they attract to buy and consume alcohol (see Gruenewald *et al.* [26] for a discussion of a history of these concepts). Since many of the new off-premise licenses were issued to stores that were already in operation selling other goods, and since the alcohol sold would not be consumed on these premises, it is unlikely that they would serve to attract intoxicated individuals who would be interacting with one another. However, such an influx of off-premise outlets into the city would serve to facilitate the ability of individuals to drink at home or other private settings (e.g. parties), and the fact that close to 80% of these new outlets were located on or within one-third of a mile of major roadways would mean that it was easier after September, 2009 for the residents of Lubbock to purchase alcohol as part of their routine activities (e.g. returning from work or buying groceries). If consumption of alcohol is associated with violent behaviour, but the market for alcohol is basically saturated, then the effects of the new off-premise outlets will be to change the locations at which violence occurs rather than increase the total incidence of crime.

The results are also consistent with the idea of diffusion bias recently proposed by Cameron *et al.* [27,28] as an explanation of the differential effects of onpremise and off-premise alcohol outlets on alcoholrelated harms such as violence. This refers to the observation that

with on-sale premises the location of the purchase of alcohol and that of consumption will be spatially tied to a specific venue (e.g. a bar), whereas with off-sale premises the location of purchase and that of consumption will be separated by some distance. Furthermore, any violence associated with consumption of alcohol purchased from off-sale outlets will also be separated from the point of purchase (see Gruenewald *et al.* [13] for an analysis of such diffusion effects regarding alcohol-related traffic crashes). The present analysis found a spatially lagged association between the number of off-premise outlets in block groups and violent crime committed in the adjacent block group. It must be noted, however, that while this spatially lagged effect suggests that the private settings in which alcohol was consumed were adjacent to those in which the alcohol was purchased from the new offsale outlets, our analysis does not allow the identification of such a specific proximity effect as it does not include consumption data. The effect exists in the form of making it easier to consume alcohol in private settings in Lubbock following the introduction of the new premises, but whether the alcohol sold was consumed close to these or at a distance cannot be determined from our data. Likewise, we cannot specifically link the locations of violent crimes in our data to the new off-sale outlets that appeared in adjacent geographic units.

It should be noted that the coefficients for two covariates that appear in our results are against general predictions in criminology, which might lead one to believe the model specification suffered from some important omission of variables. With regard to the age variable, there is a body of criminological research showing that ages 15 to 24 years are the peak time for commission of violent crime [29], whereas our results show that block groups with a higher proportion of residents in this age group have lower violent crime rates. Similarly, there is an established literature showing that recent immigrants from countries such as Mexico fare better on a range of health indicators (including violence) than their socioeconomic position would lead one to expect [30,31], while we found an association between percent Hispanic and increased violence. When interpreting our findings, it is important to recognise that these pertain to geographic units and not individuals and that inferences about the latter cannot be drawn from them (this would constitute an ecological fallacy; [32]). Accordingly, it is likely that areas with greater proportions of children represent more stable residential, and hence less crime prone, areas of the city. Also, previous areal studies of cities in the southwest and California have also found an association between the concentration of Hispanics and elevated levels of violence [8,16,18], supporting the view that individual and ecological effects can look quite different and that the social mechanisms underlying crime may differ in cities in the southwest USA from those in operation in older urban areas in the mid-west and north-east such as Chicago [33].

We have already noted a number of limitations in the interpretations that can be made concerning the association between alcohol outlets and violence due to the data used in the present study. Specifically, the data presented do not allow us to identify the mechanisms whereby the effects of off-premise outlets on violent crime occur across block group boundaries and not within them. A second limitation is that the data reported come from one geographically isolated city in north-west Texas in which a fairly unusual policy change occurred. This policy involved the dramatic increase in off-premise outlets, not their introduction into an environment where they did not previously exist at all. What is interesting about the policy is that it allowed outlets into sections of the city in which they

were previously prohibited; nevertheless the findings may not be generalisable beyond this setting and this type of policy change. This is especially important for the discussion of the potential effects of the rapid influx of the new off-premise outlets on the convenience costs of purchasing alcohol for consumption at home or in some other private setting. Lubbock is a geographically isolated city within a county spread over 896.6 mile^2 [34], and it has an average yearly temperature of 23.5 Celsius [35]. In 2015, close to 98% of the population owned a car, with more than 70% of households having between two and four cars [36]. A mere 3% of the working population walked to work or used public transportation (the City's bus service runs between 5:30 a.m. and 8:00 p.m., Monday through Saturday [37]). In such a city in which the predominant mode of transportation is the automobile, driving to purchase alcohol will be the norm and whether one drives five or six miles to buy alcohol (before the change in the law) or half a mile (after the change in the law) might not represent much of a convenience cost, especially if one spends a lot of time driving anyway. In cities where the convenience cost would be greatly reduced by an influx of 140 offpremise outlets in the space of 1 year (e.g. places in which the geography, temperature and transportation system result in people walking more to buy goods), the effects of the licensing change introduced in Lubbock might be quite different.

A third noteworthy limitation is that the lagged effect reported for off-sale premises refers to adding an *average* of one outlet in surrounding areas and this resulting in a 15% increase in violent crime. Since the mean number of off-sale premises per block group in Lubbock over the period examined in the study was small and fractional (0.34), adding one off-sale premise per neighbour would amount to a large increase of nearly 300%. While there can be a fractional increase in the number of outlets in surrounding areas, the adjacent effects are interpreted in terms of the addition of an average of one outlet per surrounding area to make them consistent with that of the within block group effect for which a fractional increase is not possible.

A final limitation of the study is that we only used one source of data, police department records, pertaining to the occurrence of violence. While very serious violent crimes such as murder are likely to come to the attention of the police irrespective of whether they occur in a public (e.g. outside a bar) or a private setting (e.g. inside a house), the same is unlikely to be true of assaults. The current study would therefore be stronger had additional sources of data pertaining to assault also been used, such as hospital records or child and youth services records. In relation to this, it is notable that our results pertaining to the adjacent effects of off-premise outlets were much stronger for murder, rape and robbery than for aggregated assault.

These limitations should be taken into account when drawing conclusions from the results reported. On the one hand, our results support the earlier time-series analyses showing that an increase in violent crime, as reflected in police department data, did not occur after the large increase in off-premise outlets in the city. On the other hand, these more sophisticated time–space analyses show that the introduction of the outlets has likely altered the pattern and distribution of violent crime (especially severe violent crime) within the city. This, plus the fact that the study did not include data sources that might better capture assaultive violence that occurs within private settings and that Lubbock is something of an unusual

setting, leads us to be cautious in stating that the type of policy change that occurred in Lubbock can have just a limited public health impact.

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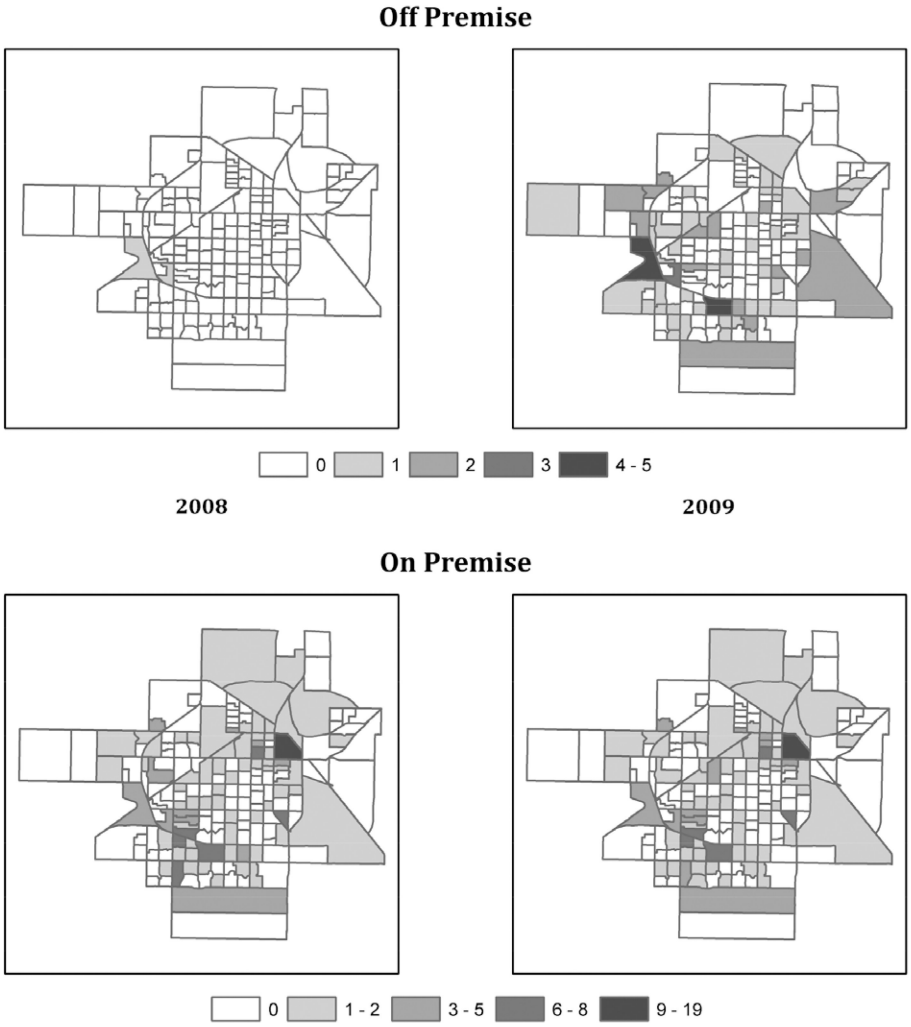

Figure 1.

Map showing the geographic distributions of off-premise and on-premise outlets in Lubbock, Texas in the year before (2008) and the year after (2009) the licensing policy change.

Table 1.

Descriptive summary statistics for violent crime, alcohol outlets and neighbourhood demographic variables, 2006–2011, Lubbock, Texas[a]

	Mean	SD
Neighbourhood demographics		
% Hispanic	32.99	24.64
% Black	10.03	15.69
% female-headed households	8.35	6.74
% owner-occupied	54.95	25.28
% vacant homes	7.32	7.34
Population density per square mile	4258.4	2443.9
% population male	48.72	3.47
% population aged 15–24	14.74	3.34
Median household income (2011 $)	38 927	23 219
Violent crime (total)	8.60	9.05
Aggravated assault	6.26	6.69
Murder/rape/robbery	2.34	3.06
Alcohol outlets	1.42	2.32
On-premise	1.07	2.01
Off-premise	0.34	0.73
Adjacent on-premise	1.25	1.08
Adjacent off-premise	0.41	0.52
Population	1148.6	604.0
Square miles	0.54	0.92

[a] $N = 172$ block groups over $T = 6$ years, resulting in $N * T = 1032$ space–time unit.

Table 2.

Association between alcohol outlets and violent crime in Lubbock, Texas

	Log-relative risks			
	2.5%	**Median**	**97.5%**	**Relative risk**
Constant	−0.0765	0.0529	0.1796	1.0543
Time trend	−0.1753	−0.1440	−0.1138	0.8659[a]
On-premise outlets	0.0087	0.0394	0.0704	1.0402[a]
Off-premise outlets	−0.0217	0.0247	0.0708	1.0250
Adjacent on-premise outlets	−0.0979	−0.0146	0.0735	0.9855
Adjacent off-premise outlets	0.0285	0.1365	0.2434	1.1463[a]
Median household income	−0.3426	−0.2279	−0.1148	0.7962[a]
% female-headed households	0.0467	0.1135	0.1812	1.1202[a]
% Black	−0.0575	0.0777	0.2052	1.0808
% Hispanic	0.1155	0.2438	0.3610	1.2761[a]
% owner-occupied	−0.1758	−0.1136	−0.0514	0.8926[a]
% vacant homes	−0.0401	0.0038	0.0476	1.0038
% population aged 15–24	−0.3454	−0.2651	−0.1875	0.7671[a]
% population male	−0.0745	−0.0198	0.0352	0.9804
Population density	−0.4408	−0.3545	−0.2728	0.7015[a]

[a]Credible interval that indicates a well-supported finding.