GLOBAL AND LOCALLY-SPECIFIC RELATIONSHIPS BETWEEN ALCOHOL OUTLET DENSITY AND PROPERTY DAMAGE: EVIDENCE FROM NEW ZEALAND

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ABSTRACT: In this paper, we explore the relationship between alcohol outlet density (by type of outlet) and property damage at the local level in New Zealand, controlling for population density and local social deprivation. We employ geographically weighted regression (GWR) to test for spatial heterogeneity in the relationships. We find that alcohol outlet density of all types has statistically significant and positive relationships with property damage events, and that these relationships do not show significant spatial variation. This suggests that approaches to controlling outlet density would have similar effects on property damage, regardless of where they are implemented. (JEL: C21; R52)

KEY WORDS: Alcohol outlet density; Property damage; Geographically-weighted regression; New Zealand

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1. INTRODUCTION

Alcohol is a well-known contributory factor in crime and criminal activity (Babor *et al.*, 2010). The size of its effect on crime depends on the nature of the crime (Felson and Staff, 2010) as well as the social context (Andrews and Bonta, 2010). One extensively researched factor is the relationship between the density of alcohol outlets (measured as the number of outlets per unit population, per unit area, or per roadway mile) and crime. This large, and growing, literature has linked alcohol outlet density to assaultive violence and other violent crime (e.g. Day *et al.*, 2012; Franklin *et al.*, 2010; Livingston, 2008; Pridemore and Grubesic, 2013), domestic violence (e.g. Freisthler *et al.*, 2004; Livingston, 2011), and property and other crime (e.g. Bromley and Nelson, 2002; Cameron *et al.*, 2012c).

Studies examining relationships between alcohol outlet density and social problems have consistently found significant and positive relationships (Cameron *et al.*, 2012a; Livingston *et al.*, 2007; Popova *et al.*, 2009). The literature on alcohol outlet density however focuses mainly on serious violent crime (recent reviews of the literature include Cameron *et al*., (2012a), Livingston *et al*. (2007), Popova *et al*., (2009), and Gmel *et al*. (2015)). Theories from criminology offer potential explanations for these results. For instance, Roncek and Maier (1991) argue that crimes are more likely to occur in areas that attract large numbers of potentially alcohol-impaired victims, as well as alcohol-influenced offenders. This explanation is consistent with 'routine activity theory' (Clarke and Felson, 1993; Cohen and Felson, 1979), wherein the incidence of crime increases when the opportunities available for criminal activity increase. In this way, alcohol outlet density might be observed to be associated with crime and criminal activity, even when it is not associated with significantly increased alcohol consumption. Similarly, Livingston *et al*. (2007) describe 'amenity effects', which can occur where the distribution of 'routine drinking activities' changes in response to changes in outlet density. For example, a large and concentrated entertainment precinct with good transport links might encourage more drinkers to drink in bars as opposed to at home, or may encourage drinkers to drink more (Stockwell and Gruenewald, 2004). Similarly, 'niche theory' suggests that different types of drinkers are attracted to different types of outlets and drinking environments, some of which are more conducive to generating violence (Gruenewald, 2007). Alternatively, the existence of an entertainment precinct may encourage drinkers to pre-load and become intoxicated at home (or elsewhere) before relocating to the entertainment precinct in an intoxicated state (Forsyth, 2010).

Importantly, relationships between outlet density and crime appear to vary significantly, both within and between studies, and depend on the type of outlet, category of crime, and the setting. For instance, studies in Australia have shown that the density of pubs is strongly associated with general assault rates, but that off-licence outlets are more strongly associated with domestic violence rates (Livingston, 2008; 2011). Similarly, studies in the U.S. have found contrasting results, with some observing stronger associations between assault and off-licence outlets rather than bars (Gruenewald *et al*., 2006; Pridemore and Grubesic, 2013), while others have shown the opposite (Franklin *et al*., 2010). This has led some to conclude that the number of outlets may matter less than the type of outlets present in a location and the characteristics of those outlets (Lugo, 2008). The setting appears to matter as well. Recent studies in Australia and the U.S. have demonstrated that the density of alcohol outlets matters more in areas of already high outlet density, and in neighbourhoods with high levels of social deprivation (Livingston, 2008; Mair *et al*., 2013).

Furthermore, the relationship between crime and alcohol outlet density may vary spatially and in non-systematic ways (Cameron *et al*., 2013).

In contrast to violent crime, the relationship between alcohol outlet density and property crime such as criminal damage has received much less attention. This is in spite of alcohol being acknowledged as a factor in these types of crime, particularly among young people (Fergusson *et al*., 1996; Ireland and Thommeny, 1993). Previous studies have found small but statistically significant relationships between property damage and alcohol outlet density (Cameron *et al*., 2012c; Stevenson, 1996). Wechsler *et al*. (2002) found that neighbours living near college campuses were more likely to report second-hand effects of heavy alcohol use such as vandalism. In contrast, Donnelly *et al*. (2006) found no significant relationship between alcohol outlet density and the percentage of respondents reporting neighbourhood problems with property damage. However, they did find a significant and positive relationship between these problems and accessibility, measured by the average distance to the nearest five licensed premises. Similarly, Stevenson *et al.* (1999) found no relationship between alcohol outlet density and property damage in New South Wales, after controlling for local alcohol sales. In a recent study, Toomey *et al*. (2012) found a positive association between outlet density (both on-premise and off-premise outlets, measured per roadway mile) and standardized crime ratios for vandalism and nuisance in Minneapolis, with on-premise outlet density found to have larger effects on both vandalism and nuisance than off-premise density.

The theoretical foundation for a relationship between alcohol outlet density and property damage is less developed than that for violent crime. Stevenson (1996, p. vii) notes that "malicious damage to property probably reflects the operation of other contextual variables, such as the close proximity of attractive targets for malicious damage". Amenity effects (Livingston *et al*., 2007) may help to provide a theoretical basis for explaining a relationship between alcohol outlet density and property damage. Areas that have a greater density of alcohol outlets will attract larger numbers of drinkers, including young people, who are more likely to commit criminal damage (Farrington *et al*., 2013).

Bringing together large numbers of young drinkers could lead to increased property damage, as explained by routine activity theory of general deviance (RATGD), an extension of routine activity theory proposed by Osgood *et al*. (1996). RATGD posits that unstructured socializing with peers in the absence of authority is a routine activity through which general deviance, such as property crime, arises. Miller (2013) argues that the RATGD approach can be extended by drawing on the crime facilitator approach of Clarke and Eck (2005). Under Clarke and Eck's categorization, alcohol can be considered a 'chemical facilitator' of crime that provides offenders with a release from moral constraints and inhibitions about risk. Thus, property damage can be expected to increase where there are more alcohol outlets through two intersecting factors. First, the increased availability of alcohol attracts young drinkers. Second, the area surrounding alcohol outlets provides opportunities for property damage in an environment where crime is facilitated by alcohol intoxication. Given an increase in property damage events in areas with more liquor outlets, it is likely that police resources will be increasingly directed towards these areas. Alcohol outlet density can therefore be hypothesized to be positively associated with police activity related to property damage in ecological studies.

We argue that many previous ecological studies on crime and alcohol outlet density are subject to three key limitations, that the present study is able to overcome. First, previous studies have measured non-violent crime such as vandalism as the number of recorded offences in an area in a given period of time (e.g. Toomey *et al.*, 2012) or as self-reported 'neighbourhood problems' (Wechsler *et al.*, 2002; Donnelly *et al.*, 2006; Wilkinson and Livingston, 2012). Vandalism is typically considered a low-level offence, and perpetrators may be let off with warnings by attending police officers. Thus, measuring vandalism or property damage as the number of recorded offences (or arrests, or successful prosecutions) will necessarily bias the estimates of crime downwards. To the extent that police warnings are spatially non-random (e.g. some police precincts may be more inclined to issue warnings than others), this will lead to biases in the estimated relationships between alcohol outlet density and non-violent crime. Although one could argue that crime, by definition, involves a criminal offence, we contend that a better measure is the number of times that police are required to attend a location for that particular offence, regardless of whether an arrest was made.

Second, the geographical scope of most studies is limited to a single urban area (e.g. Franklin *et al.*, 2010; Pridemore and Grubesic, 2013) or a single region or state (e.g. Mair *et al.*, 2013). This approach may lead to 'edge effect' (or boundary effect) problems in spatial models (Anselin, 1988; Haining, 1997; Van Meter *et al.*, 2010). Edge effects arise because the study area is considered as an 'island' and the modelling does not explicitly account for spillover effects, such as when alcohol outlets in neighbouring districts affect property damage in the study area, or when alcohol outlets in the study area affect the level of property damage elsewhere. These edge effects potentially bias coefficient estimates, particularly when there is substantial heterogeneity within the areas neighbouring the study area (e.g. where some neighbouring areas are urban or suburban, while others are rural or uninhabited).

Third, most studies assume that the relationship between outlet density and crime is invariant across space. Considering property damage for instance, the association between property damage and alcohol outlets may vary between urban and rural areas, due to different ways in which alcohol outlets may be utilised in different types of neighbourhoods. Thus global models that estimate a mean effect across the entire study area will likely not adequately account for these spatially-varying relationships. New modelling techniques are available that allow coefficient estimates to vary spatially, and studies employing these techniques have demonstrated substantial spatial variation in effects (Cameron *et al*., 2013; Mair *et al*., 2013; Pridemore and Grubesic, 2012). The modelling approach that we employ allows us to explicitly test for spatial heterogeneity of effects.

This paper contributes to the growing literature on the ecological effects of alcohol outlet density. We consider the effects on property damage, an outcome that has thus far not been extensively investigated. Furthermore, we employ a novel method and dataset that allows us to overcome all three of the limitations of previous ecological studies noted above. Specifically, we make use of police resource deployment data to overcome potential non-random bias in apprehension practice between police districts, and we initially use geographically-weighted regression (GWR) to investigate the relationship between outlet density (of different types) and property damage across the North Island of New Zealand. The GWR approach identifies whether the relationship between outlet density and property damage varies spatially, and estimates locally-specific coefficients when significant spatial variation is identified. This provides a more detailed picture of how the relationship varies spatially for each outlet type. GWR techniques are becoming increasingly common in a variety of applications (e.g. see Fraser *et al*., 2012; Siordia *et al*., 2012). We find that, with one exception, there is not statistically significant spatial variation in coefficients. Furthermore, we take advantage of the specific geography of the North Island of New Zealand to overcome any ‘edge effects’, by including all parts of the island in the analysis.

2. DATA AND METHODS

Data Sources and Variables

The study area is the North Island of New Zealand, which covers nearly 44 000 square miles and has a population of about 3.4 million (more than three quarters of the total population of New Zealand). The island contains a number of major population centres, including the cities of Auckland (population 1.4 million), Wellington, (population 400 000), Hamilton (population 210 000), and Tauranga (population 120 000).

Liquor licence data were obtained from the Ministry of Justice, covering all licensed outlets in New Zealand for every quarter between 2006 and 2011. As the address data for many licences were incomplete (missing street address numbers) or inconsistently formatted, an automated geocoding process using an address locator file could not be used. Instead, the licence data for the North Island were geo-coded to the Census Area Unit (CAU) level manually. A CAU is a geographic area with a maximum population of approximately 5 000; in urban areas CAUs are approximately the size of a suburb. The manual geo-coding was performed by searching for each address using a combination of the Statistics New Zealand Interactive Boundary Map, Google Maps, and Google Street View, to ensure accuracy and triangulation. A 10 per cent sample of the addresses was verified by a second separate manual geo-coding, with more than 99 per cent agreement. Overall, all outlets were successfully geocoded.

Liquor licences were then classified by type, using the taxonomy described in Table 1. Following Donnelly *et al*. (2006), some outlet types including catering licences, auctioneers, mail order companies and conveyances, were excluded because the location of the licence is likely to be largely unrelated to the location of drinking, which may occur far from the community in which the licence is located. Vineyards, hospitals, gift stores and florists were similarly excluded because any spatial relationship with property damage was expected to be very weak for these outlet types.

Table 1. Taxonomy of Alcohol Outlet Types.

Code	Main Types	Also includes…
01	Clubs	Off-licenced chartered clubs, off-licenced social clubs
02	Sports Clubs	
11	Bottle Stores	Off-licenced distilleries
12	Grocery Stores	On-licenced grocery stores
13	Supermarkets	
14	Off-licenced hotels	Off-licenced tourist houses
15	Off-licenced taverns	
19	Other off-licences	Off-licenced breweries, locational licences, complementary licences
21	Bars and night clubs	Adult entertainment venues, taverns, TABs, casinos
22	Restaurants and cafés	BYO restaurants, universities, airports
23	Accommodation and function centres	Conference venues, hotels, tourist houses
29	Other on-licences	Theatres, tasting only, gyms, music venues
31	Dual-licenced hotels	Hotels and tourist-houses that hold both an on- and off-licence
32	Dual-licenced bars	Taverns, etc. that hold both an on- and off-licence
33	Dual-licenced restaurants	Restaurants, etc. that hold both an on- and off-licence

Source: the Authors.

Outlet counts per CAU were then aggregated into four categories for analysis:

1. Clubs (Types 01 and 02);
2. Bars and night clubs (Types 21 and 32);
3. Other on-licences (Types 22, 23, 29, 31 and 33);
4. Off-licences (Types 11, 12, 13, 14, 15, 19, 31, 32, and 33)

The split of on-licences into separate categories for bars and night clubs and other on-licence outlets reflects the fundamental difference in purpose between establishments (Cameron *et al*., 2012b). Where drinking is one of the main activities (as in bars and night clubs) the marginal effects are different to on-licence outlets where drinking is incidental to another activity (such as for restaurants and cafés). Clubs were included as a separate category as drinking is typically limited to club members or their guests and not open to the public. Note that dual-licenced outlets (outlets that hold both an on-licence and an off-licence) are included in the counts twice – once as an on-licence, and once as an off-licence.

Counts of the number of outlets within each of the 1316 CAUs in the North Island were obtained. To ensure adequate base population sizes (minimum population size of 300) and contiguity within the spatial dataset, 132 CAUs were amalgamated (merged with a neighbouring CAU), and 12 CAUs (mostly marinas and tidal flats with minimal populations) were excluded from the dataset. Thus 1172 CAUs (including amalgamations) were used in the final analysis.

Data on police activity were obtained from the New Zealand Police Communications and Resource Deployment (CARD) database, covering the period from 2006 to 2011. The data set was first cleaned to remove duplicate events or occurrences, and then restricted to only those subcategories of events related to property damage – (1) Arson; (2) Endangering/Interfering with property; and (3) Wilful damage. The data were geo-coded to the CAU level using an automated process in ArcGIS version 10, and converted to quarterly counts per CAU.

Statistics New Zealand subnational population estimates were used to create population density (persons per square kilometre). Neighbourhood social deprivation was measured by the New Zealand Deprivation Index (NZdep2006), a commonly used index of small area socioeconomic deprivation in New Zealand (Salmond *et al*., 2007). For amalgamated CAUs, deprivation was calculated as a population-weighted average of the component CAUs. While social deprivation is known to be an important variable in models that explain crime and police activity (Day *et al*., 2012; Krivo and Peterson, 1996), the New Zealand Deprivation Index is invariant for this study as it is calculated only for years in which a national Census is conducted (i.e. only for 2006 within the study period). All outlet counts and property damage events per CAU for each quarter were converted into average densities per 10 000 usually resident population for the entire period, using Statistics New Zealand subnational population estimates (at 30 June of each year), and treated as a single cross-section.

Data Analysis

We initially employed geographically weighted regression (GWR) to estimate models of property damage. GWR is a non-parametric regression method that explicitly addresses the problem of spatial heterogeneity that is common to geographically specific analysis (Brunsdon *et al*., 1996). Spatial heterogeneity occurs when the relationship between two variables varies between different locations, e.g. rural and urban. Thus a simple global model, such as that employed in most ecological studies of alcohol outlet density, will fail to capture the underlying diversity of spatial effects across the study area. For instance, highly accessible areas, such as metropolitan areas that include dense road networks and large concentrations of economic activity, will exert stronger effects on their neighbours than do relatively isolated and peripheral regions. Considering the present study, the impact of alcohol outlet density in one area on property damage occurring in surrounding areas may be higher in urban areas and in areas of higher social deprivation. The main distinguishing feature of GWR is that it produces locally linear estimates for every point in space, using a distance weighted sub-sample of observations. Essentially this means that a separate regression equation is fitted for every location in the data set, using data that is weighted to reflect the separation between locations. This highlights a further advantage of GWR in that, because it local area has its own constant term, GWR accounts for local fixed effects (Partridge *et al*., 2008).

Bandwidth is one of the key parameters in GWR, and determines how many surrounding areas have an influence on the locally-specific parameter estimates. Following Fotheringham *et al*. (2002) the optimal bandwidth size was identified using the "golden section" methodology, which attempts to select the bandwidth with the best statistical properties. We used an adaptive Gaussian kernel that minimised the cross-validation score, which resulted in 46 nearest neighbours being used in the model estimation.

Given the multi-period nature of the data, panel data analysis (panel GWR) would usually be the preferred method. However, data issues prevented such an approach here. Specifically, because the social deprivation variable is invariant over the study period, a panel model could not be employed. Since measures of social deprivation are known to be important in quantitative studies of crime and police activity (Krivo and Peterson, 1996; Cameron *et al*., 2012c), a cross-sectional GWR model using annual averages was instead applied. GWR has been rarely applied in the context of alcohol outlet density (see Han and Gorman (2013) for one example).

GWR typically reports a global model (based on ordinary least squares regression) as well as the locally-specific (GWR) model. The model with the best fit for the data was identified using the adjusted Akaike Information Criterion (AICc) values. Spatial heterogeneity of the GWR coefficient estimates was demonstrated by the interquartile range of local estimates, and spatial non-stationarity (i.e. whether the locally-specific regression coefficients vary significantly across space) was evaluated using the Monte Carlo test specified by Fotheringham *et al.* (2002). The models were estimated using the freely available GWR 4.0 software (http://www.st-andrews.ac.uk/geoinformatics/gwr/gwr-software/). Distance weighting was calculated based on centroid-to-centroid Euclidean distance, i.e. the distance between the centres of the CAU and neighbouring CAUs. The resulting GWR coefficient estimates were mapped in ArcGIS version 10, to enable easy visualization of the spatial relationships.

3. RESULTS

Table 2 presents the results of the global model, along with the AICc of the corresponding GWR model for comparison. The first number in each cell is the coefficient, with the standard error in parentheses below it. Following Cameron *et al*. (2012b; 2012c), as the dependent variable and all of the outlet-related variables are densities measured per 10 000 population, each coefficient may be interpreted as the marginal effect of an additional outlet of that type in a given CAU on the number of property damage events in that CAU in a single year, holding all other factors constant. In the global model, bars and night clubs and licensed clubs have the largest marginal effect on property damage, with an additional bar or night club being associated with 2.8 additional property damage events per year, and an additional licensed club being associated with 1.3 additional property damage events per year. The relationships are smaller, but still statistically significant and positive, for other outlet types. The control variables, population density and social deprivation, are both statistically significant, with more property damage events occurring in areas of high deprivation and high population density, holding all other factors constant. These results are consistent with the hypothesized effects noted earlier.

Table 2. Results of GWR model of Property Damage events.

Variable	Global (OLS) Model	Local (GWR) Model Coefficients			
	Coefficent (SE)	Lower quartile	Median	Upper quartile	Test of stationarity (*p*-value) †
Licensed club density	1.251 (0.210)***	0.856	1.222	1.736	0.873
Bar and night club density	2.834 (0.234)***	1.649	1.829	2.922	0.876
Other on-licence density	0.672 (0.118)***	0.026	0.224	0.718	0.184
Off-licence density	0.998 (0.239)***	-0.396	0.322	1.731	0.375
Social deprivation	0.270 (0.027)***	0.199	0.251	0.344	0.334
Population density	0.346 (0.169)***	-0.398	-0.041	2.123	<0.001***
Intercept	-243.8 (26.54)***	-316.0	-211.1	-156.9	0.161
Adjusted R^2	0.635		0.872		
Akaike Information Criterion (AIC)	13376		12221		

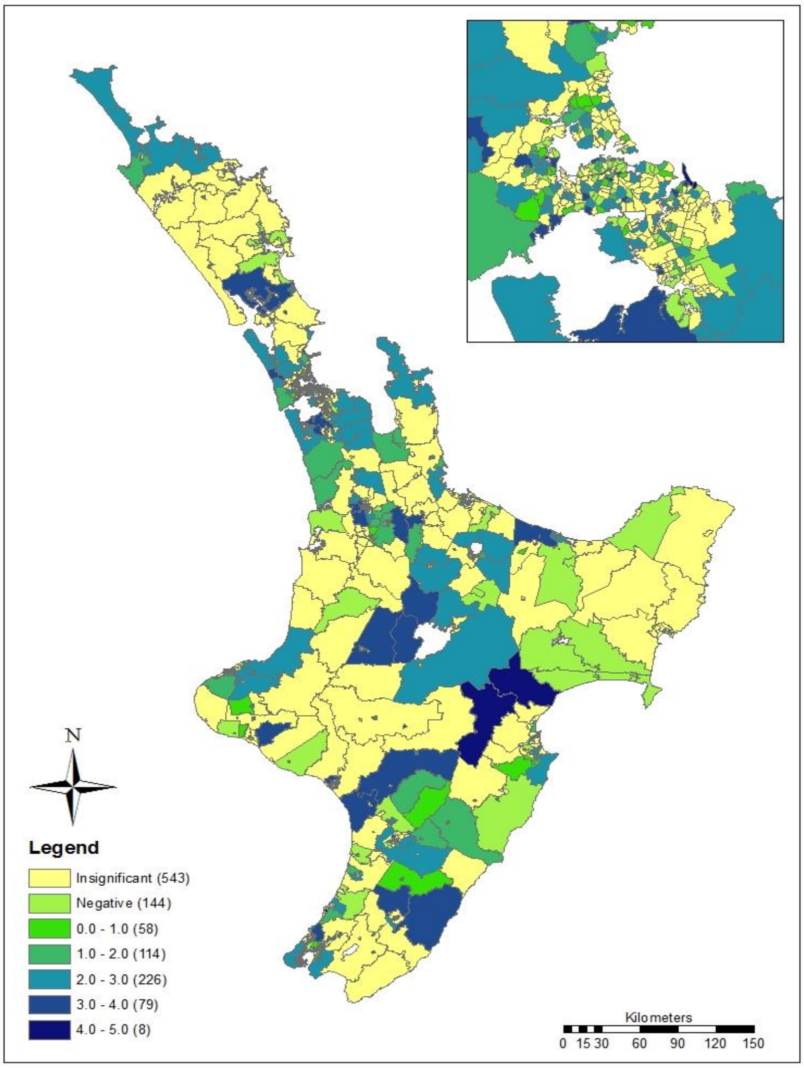
***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level; †Based on Monte Carlo test. Source: Authors Calculations.

Considering the GWR estimation, the larger adjusted R^2 and smaller AICc demonstrate that the GWR model is a better fit for the data than the global model. In the GWR, none of the outlet density variables demonstrate significantly spatially-varying relationships with property damage, as shown in the final column. Only population density appears to demonstrate significant spatial heterogeneity.

Figure 1 maps the locally-specific coefficient estimates for the relationship between population density and property damage, showing the spatial distribution of the relationship. Areas that are classified within the lowest interval on the map are not statistically significant (at the 10 per cent level of significance). The global effect (Table 1) masks substantial and statistically significant spatial variation – point coefficient estimates vary from -1.1 to +4.2. When the spatial variation is mapped, it is clear that there is no systematic spatial pattern for the marginal effects between population density and property damage. Much of the island exhibits a statistically insignificant relationship between population density and property damage, with 534 of the 1172 Census Area Units having a statistically insignificant relationship at the 10 per cent level. The statistically significant relationships are distributed across the island, and across urban areas (see inset for Auckland City) with no discernible pattern. However, there are clusters where the size of the relationship is largest, in some rural areas surrounding Auckland, and in the central high country.

Having used GWR to explore spatial heterogeneity, and finding little heterogeneity in the relationships for our key variables of interest (i.e. alcohol outlet density), we turn now to considering a global model addressing spatial spill-overs between areas. The mechanisms underlying such spill-overs are relatively straight forward and intuitive in the case of alcohol related property damage. Individuals might purchase alcohol in one area and consume it in a neighbouring area with any attendant harms occurring at the place of consumption rather than at the location of purchase. Alternatively, intoxicated people leaving a bar might damage property that lies on their route home, but which is at some distance from where they consumed the alcohol.

The modelling of such spill-overs, however, is not straightforward as the very nature of spill-overs violates one of the key assumptions of standard techniques (such as OLS), that each observation is independent of other observations in the analysis; hence more specialised techniques are required. As a consequence there has in recent years been a proliferation of approaches proposed in the spatial econometric literature; maximum likelihood, quasi-maximum likelihood, GMM, IV, Bayesian, maximum entropy, robust GMM, robust Bayesian, semiparametric, along with static and dynamic panel extensions, and variants for dealing with count data, truncated and limited dependent variables amongst others (LeSage, 2014). We argue that any spillover effects are likely to be local rather than global, and adopt a spatial Durbin error model (SDEM), following LeSage (2014). The data are the same as those in the previous analysis, and the spatial weights matrix used to generate the spatial lags for the SDEM model is based on inverse squared Euclidean distance.



Source: the Authors.

Figure 1. Locally-specific point parameter estimates for the relationship between Population Density and Property Damage events in the North Island, 2006-2011.

The results of the SDEM model are presented in Table 3. All of the explanatory variables are positively signed and, with the exception of population density, highly statistically significant. The sizes of the coefficients are similar to those in the global (OLS) model reported in Table 2. Considering the outlet densities, the parameter estimates range from a low of 0.69 for other on-licences to 2.61 for bar and night club density while social deprivation continues to have a large impact (recall that the Index of Social deprivation has a mean of 1000 and a standard deviation of 100). For the spatially lagged variables only the lags on bar and night club density (positively signed) and off-licence density (negatively signed) are significant. The parameter on the lag of off-licence density is negative, opposite to that on the variable itself, suggesting that while higher levels of property damage are associated with areas of high off-licence density they are also associated with lower levels in surrounding areas. The spatial parameter lambda is large (lambda can range from 0 to 1) and highly significant indicating that spatial effects play an important role in understanding the observed pattern of alcohol related property damage.

Table 3. Results of SDEM model of Property Damage events.

Variable	Coefficent (SE)
Licensed club density	1.097 (0.197)***
Bar and night club density	2.607 (0.217)***
Other on-licence density	0.691 (0.110)***
Off-licence density	1.253 (0.227)***
Social deprivation	0.260 (0.031)***
Population density	0.037 (0.237)
Lag of licensed club density	0.142 (0.742)
Lag of bar and night club density	3.656 (0.956)***
Lag of other on-licence density	-0.343 (0.420)
Lag of off-licence density	-4.895 (0.839)***
Lag of social deprivation	0.110 (0.085)
Lag of population density	0.917 (0.591)
Intercept	-345.9 (80.78)***
Lambda	0.603 (0.040)***

***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level. Source: Authors calculations.

4. DISCUSSION

The global model demonstrated a number of statistically significant effects that occur *on average* across the North Island of New Zealand. These include statistically significant and positive associations between alcohol outlet density of all types and property damage events. These marginal effects were largest for bars and night clubs, and licensed clubs, and smallest for other on-licence outlets (such as restaurants and cafés). Moreover, social deprivation is one of the most significant factors associated with property damage in our study, similar to past ecological studies of crime in New Zealand (Cameron *et al*., 2012b, 2012c; Day *et al*., 2012). However, with the exception of population density, our results demonstrate that the marginal effects of alcohol outlets on property damage do not vary spatially. Stevenson *et al*. (1999) provide a possible explanation for the spatial heterogeneity of the effects of population density on property damage, suggesting that country areas (with low population density) have greater social and demographic heterogeneity and hence different relationships between population and crime.

However, the lack of spatial variation in the effects of outlets on property damage is somewhat surprising, although similar to the lack of spatial variation observed by Han and Gorman (2013) for violent rather than non-violent crime. Other studies of violent and other crime have shown that the context and the type of outlet appears to matter greatly (Cameron *et al*., 2012c; Lugo, 2008; Mair *et al*., 2013). However, the mechanisms that relate alcohol outlet density (particularly on-licence density, such as bars) to violence are likely to be quite different from those that may relate density to property damage. For instance, Gruenewald's (2007) niche theory suggests that an increased number of outlets increases the number of drinkers in the area, leading to stratification among drinkers, with some bars catering to strata of drinkers with greater propensity for violence. Thus, greater density of outlets leads to more stratification and more violence as violent groups become concentrated together. However, in the case of property damage, as we noted in the introduction increased availability of alcohol attracts young drinkers, and the area surrounding outlets provides opportunities for property damage. These conditions don't necessarily vary when the outlets are located in different places. Thus bars or night clubs (or licensed clubs), being venues that attract young drinkers, may also attract property damage to a similar level regardless of where they are located. This also sets these venues apart from restaurants and cafés, which tend not to attract young drinkers (and in our model restaurants and cafés were shown to have much smaller effects on property damage).

Of the outlet density measures, bar and night club density had the largest effects on property damage, with an additional bar or night club associated with 2.6 additional property damage events per year. This effect was nearly three times larger than off-licence outlet density (1.0 additional property damage events per year). These results contrast with those of Wilkinson and Livingston (2012), who found that self-reported problems with property damage were related to distance from off-licence outlets, but not on-licence outlets. We note that our results are not based on self-reports, and that the size of these effects is similar to those reported in earlier research for Manukau City in New Zealand by Cameron *et al*. (2012c), who used a similar categorization of police resource deployment events.

These results suggest that bars and night clubs are a more significant factor in property damage events than other outlet types, regardless of their location. However, this simple conclusion ignores a potential bias that occurs when the spatial effects of on-licence outlets (such as bars, night clubs, licensed clubs, or other on-licence outlets such as restaurants) are compared with the spatial effects of off-licence outlets. The impacts of alcohol outlet density in terms of property damage are likely to be more spatially distributed for off-licence outlets than for on-licence outlets, leading to a 'diffusion bias'. This bias arises because of differences in the relationship between the location of purchase and the location of consumption between on-licence outlets and off-licence outlets. For on-licence outlets, alcohol is both purchased and consumed at the same location, while for off-licence outlets the location of consumption (and related property damage) is more likely to be spatially separated from the location of purchase. The latter also follows from research that suggests the 'journey to crime' is short (Capone and Nichols, 1976), i.e. that people commit crimes close to their homes. This leads to larger numbers of alcohol-affected people congregating in the vicinity of on-licence outlets than off-licence outlets. Following RATGD, property damage that arises from consumption of alcohol in an on-licence outlet is likely to be concentrated in close proximity to that outlet. In contrast, the separation between location of purchase and location of consumption leads to lower global and local estimates of the size of the relationship between property damage and alcohol outlet density for off-licence outlets, when the spatial scale used in estimating both relationships is the same.

Our results appear to support this idea of diffusion bias; similarly, Toomey *et al*. (2012) find that the coefficients in the relationship between on-licence outlets and non-violent crime are larger than those for off-licence outlets. The problems associated with spatial scales in estimates of the effects of alcohol outlet density on violence have only recently been acknowledged (Mair *et al.*, 2013). However, this bias can be mitigated somewhat by employing larger geographical units in the analysis, or using higher-order spatial weights matrices that will take into account observations and effects that occur at greater distances from the spatial unit of interest. In this paper, we used geographically weighted regression to account for observations in surrounding areas as well as local areas. However, a hybridized approach that combines geographically weighted regression with spatial lag variables may lead to even better estimates in future studies.

Spatial variability in the relationships between alcohol outlet densities and measures of social harm is particularly pertinent given the current development of Local Alcohol Policies by many local authorities in New Zealand. The *Sale and Supply of Alcohol Act 2012* has given local authorities the ability to develop and adopt policies that differ from the national defaults in terms of outlet density and location, hours of sale, and other conditions of liquor licences within their boundaries. Our results suggest that the relationship between property damage and alcohol outlet density does not vary substantially between different areas, for all outlet types. Overall, our results imply that policies that restrict these alcohol outlets of various types would likely have similar effects on the incidence of property damage wherever they are implemented. These results contrast findings from previous studies (e.g. Mair *et al.*, 2013; Pridemore and Grubesic, 2012). We suggest that further research is necessary to test the robustness of our findings in other contexts and using alternative modelling approaches.

Limitations

Geographically weighted regressions such as those reported in this paper are useful in identifying spatially-varying effects. However, there are a number of limitations to our analysis. First, despite the concordance between these results and other research on the relationships between alcohol outlet density and crime, we are unable to definitively establish causality. We cannot say for certain that alcohol outlet density causes higher (or lower) numbers of property damage events. However, our results are consistent with much of the past literature and consistent with a causal story as laid out in the introduction, i.e. that the combination of increased availability of alcohol and opportunities for property damage leads to more property damage events. Second, this paper concentrated on the spatial variation in the relationships, without consideration of any temporal variation. It is likely that the relationships between outlet densities and alcohol-related harms vary not just across space, but also across time. Panel data models could deal with this variation explicitly – however, the properties of panel GWR estimators are not well known (Yu, 2010). Third, because the GWR method uses a subset of data, the locally-specific regression models can be under-powered to identify statistically significant effects compared with a global model. However, as shown in Table 2 all of our variables were statistically significant so presumably this is not an issue in our analysis. Fourth, GWR can be somewhat unreliable in its estimates and subject to false positives (Wheeler and Tiefelsdorf, 2005). Our sample size of 1172 is large though, and Paez *et al*. (2011) have demonstrated that the unreliability of GWR estimates is less problematic for large samples. Finally, we used a bandwidth that was limited to 30 nearest neighbours in the estimate of each location-specific relationship. A smaller bandwidth may have identified more local variation in parameter estimates – however, estimation with a smaller bandwidth comes at a cost of lower precision of each estimate. The SDEM model results that we report do not suffer from the same limitations as the GWR model results – however, they assume that the coefficient on population density does not vary spatially, which the GWR model demonstrates is unlikely to hold.

5. CONCLUSION

There has been little published research to date on the relationship between alcohol outlet density and property damage. We found that property damage events are related to alcohol outlet density of all types, and that bar and night club density has the largest effect. The relationships between alcohol outlet density of all types and property damage do not vary spatially. However, significant spatial variation is observed for the relationship between population density and property damage, although there is no discernible pattern to this relationship. When included in a model that does not allow for spatially varying coefficients, population density appears to be statistically insignificant. Overall, these results suggest that policies to intercede in this relationship would have similar effects regardless of where they are implemented. Future research should build on the methodological developments discussed in this report, especially to further consider the issue of potential diffusion bias.

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