

# The relationship between electronic gaming machine accessibility and police-recorded domestic violence: A spatio-temporal analysis of 654 postcodes in Victoria, Australia, 2005–2014

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## Abstract

An emerging body of research has documented an association between problem gambling and domestic violence in a range of study populations and locations. Yet little research has analysed this relationship at ecological scales. This study investigates the proposition that gambling accessibility and the incidence of domestic violence might be linked.

The association between police-recorded domestic violence and electronic gaming machine accessibility is described at the postcode level. Police recorded family incidents per 10,000 and domestic-violence related physical assault offenses per 10,000 were used as outcome variables. Electronic gaming machine accessibility was measured as electronic gaming machines per 10,000 and gambling venues per 100,000. Bayesian spatio-temporal mixed-effects models were used to estimate the associations between gambling accessibility and domestic violence, using annual postcode-level data in Victoria, Australia between 2005 and 2014, adjusting for a range of covariates.

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Significant associations of policy-relevant magnitudes were found between all domestic violence and EGM accessibility variables. Postcodes with no electronic gaming machines were associated with 20% (95% credibility interval [C.I.]: 15%, 24%) fewer family incidents per 10,000 and 30% (95% C.I.: 24%, 35%) fewer domestic-violence assaults per 10,000, when compared with postcodes with 75 electronic gaming machine per 10,000. The causal relations underlying these associations are unclear. Quasi-experimental research is required to determine if reducing gambling accessibility is likely to reduce the incidence of domestic violence.

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## Introduction

### Background and Rationale

A multitude of studies clearly demonstrate that domestic violence is an important public health issue (see Krantz, 2002; Vine et al., 2010). Around 30% of women aged 15 or older worldwide are estimated to have been victims of intimate partner violence during their lifetime (Devries et al., 2013). In Australia, rates of domestic violence are above the global average, with 37% of women reporting ever experiencing domestic violence, and an estimated 12-month prevalence rate for intimate partner violence of 2.4% (Australian Bureau of Statistics, 2012). A substantial portion of the global burden of ill health is attributable to domestic violence (Campbell, 2002), with intimate partner violence alone estimated to account for 1%–2% of disability adjusted life years for women globally (Lim et al., 2012).

Despite scholarly debate about the role of gender in domestic violence, it is clear from the overwhelming weight of evidence that domestic violence is almost always perpetrated by men against women (Hamby, 2014). Cross-national evaluations of violence against women suggests that gender inequality is the most important predictor of the prevalence of such violence at the country level (Heise and Kotsadam, 2015). However, an ecological understanding of domestic violence suggests that while male dominance must be at the foundation of any theoretical account, the aetiology of domestic violence is complex and multidimensional, with many factors influencing the probability of violence operating at several geographic and conceptual levels (Heise, 1998).

An emerging body of research has examined the ecological factors that are related to the prevalence or incidence of domestic violence (Beyer et al., 2015; Pinchevsky and Wright,

2012). Disadvantage has most frequently been found to be correlated with an elevated prevalence of domestic violence, whether conceptualised as ‘concentrated disadvantage’ in the framework of social disorganisation theory (e.g. Gracia et al., 2015; Pinchevsky and Wright, 2012) or in terms of relative socioeconomic status (Beyer et al., 2015). Contrary to the expectations of social disorganisation theory, neither residential turnover nor neighbourhood ethnic heterogeneity have been consistently associated with the ecology of domestic violence (Pinchevsky and Wright, 2012). For both of these variables, positive, negative and null correlations have been found. Other neighbourhood-level variables found to be associated with rates of domestic violence include collective efficacy, crime, disorder, gender inequality, rurality and alcohol-outlet density, although the research field is yet to yield a consensus on the importance of many of these contextual risk factors (Beyer et al., 2015).

Gambling is an under-researched contextual factor associated with domestic violence. Although an emerging body of research suggests a strong link between domestic violence and problem gambling at the individual level, domestic violence has too often remained a “hidden” issue for those researching the health and social impacts of gambling (Korn and Shaffer, 1999). To date, the authors are aware of only one nationally-representative study that has examined the association between domestic violence and problem gambling. Re-analysing the US National Comorbidity Survey Replication ( $n = 3334$ ; 18 years and older), Afifi et al. (2010) found that problem gambling was associated with both intimate partner violence perpetration and victimisation. In particular, endorsing five or more DSM-IV criteria for pathological gambling was associated with elevated odds of perpetrating severe marital violence (odds ratio [OR] = 20.4) and severe child abuse (OR = 13.2).

Most studies of the relationship between domestic violence and gambling have investigated convenience samples recruited in clinical contexts or among those undertaking court-mandated programs. Dowling et al. (2014) performed a meta-analysis of 14 studies examining problem gambling among victims and perpetrators of intimate partner violence and found that among problem gamblers, 38.1% report victimisation and 36.5% report perpetrating violence. The prevalence of problem gambling was estimated to be 11.3% among perpetrators of intimate partner violence, compared with general population levels of 0.5%–7.6% (Williams et al., 2012). In these studies, ‘problem gambling’ was measured using validated screening instruments like the Problem Gambling Severity Index or used the accepted diagnostic criteria directly (Dowling et al., 2014). The balance of evidence to date suggests an association between problem gambling and intimate partner violence that persists after adjusting for factors such as poor mental health.

It is plausible that these associations reflect a causal relationship between domestic violence and gambling, a proposition that is supported by victims of violence whose partners have gambling problems (Muelleman et al., 2002; Suomi et al., 2013). For example, in one study of women aged 19–65 years presenting to an emergency department in Nebraska, 24% of victims of intimate partner violence thought that their partner had a gambling problem. Among this subsample, 62% thought that their partners' gambling and violence were related (Muelleman et al., 2002). However victims' understanding of the causal direction of this relationship was not recorded.

Several studies suggest that gambling may increase the risk of violent incidents within families, as gambling may decrease perpetrators feelings of control over their own and their families' lives (Korman et al., 2008; Suomi et al., 2013). For example, some

of the family members of problem gamblers interviewed by Suomi et al. (2013) were assaulted when their partners returned home after a gambling session, angered about lost money. Other victims of violence in the same study reported that their gambling losses triggered a violent response from their partner. Such evidence does not imply that gambling is the ultimate cause of domestic violence. Rather, gambling here may serve as an indirect mediating factor that increases the frequency and severity of aggression in violent relationships.

In the reverse causal direction, gambling may also be used as a coping mechanism by victims and perpetrators to deal with domestic violence. For example, Blaszczynski and Nower (2002) suggest that for some problem gamblers, gambling serves as a method to “modulate affective states and/or meet specific psychological needs.” In other words, for some people, gambling serves as a method for blocking out negative thoughts and memories (Wood and Griffiths, 2007; Woolley and Livingstone, 2010). This mode of gambling is highly prevalent, with around 19% of Australian adults reporting that they use gambling as a method of stress management (Australian Psychological Society, 2015). We expect, therefore, a heightened gambling participation rate among both perpetrators and victims of violence as a result of violence-related stress.

Finally, it is likely that some portion of the correlation between domestic violence and problem gambling in previous studies results from shared risk factors that have not been controlled for. As such, the causal relationships between domestic violence and gambling are likely to be complex and multidirectional.

Given the documented associations between gambling and violence among individuals and their partners, it seems likely that neighbourhoods with highly accessible gambling opportunities will also have elevated rates of

domestic violence. Gambling accessibility is of interest, as limiting venue accessibility is a policy lever that could potentially be used to reduce the incidence rate of domestic violence. Simple availability theory, borrowed from the alcohol research literature (Bruun et al., 1975; Stockwell and Gruenewald, 2003), predicts that increased gambling accessibility will increase the rate of domestic violence, via the following causal chain: (i) as gambling accessibility increases, so too does gambling participation, frequency and intensity (Pearce et al., 2008; Welte et al., 2004b; Young et al., 2012), (ii) as total gambling increases, so too does the prevalence of individuals gambling at a harmful level (Grun and McKeigue, 2000; Lund, 2008; Markham et al., 2014, 2016; Rose and Day, 1990), and (iii) as the number of people gambling more than they can afford in a population increases, so too does the incidence of domestic violence (Dowling et al., 2014). Alternatively, it is plausible that the causal chain may run in the other direction: (i) in areas with elevated rates of domestic violence, people seeking a cognitive escape will gamble more frequently and intensely than might otherwise be the case (Dowling et al., 2014) (ii) as gambling participation, frequency and intensity rise, gambling businesses become more profitable, and (iii) gambling operators will move or trade their licenses to areas with greater incidence of violence in order to profit from violence-induced demand (Marshall and Baker, 2002).

Yet few studies have examined the link between gambling accessibility and domestic violence at the ecological level. Electronic gaming machine (EGM) accessibility is of particular interest, as EGMs are most closely associated with problem gambling (MacLaren, 2015; Productivity Commission, 2010; Welte et al., 2004a) and are responsible for the largest amount of money spent by problem gamblers in Australia (Productivity Commission, 2010). In Australia, three studies have touched on this relationship al-

though none have specifically analysed domestic violence rates as distinct from assault rates more generally. Barratt et al. (2014) conducted a cross-sectional spatial analysis of gambling help and violence in local government areas of Victoria. Their study did not distinguish between domestic violence and other incidents of violence, but did find that violence and access to gambling help were significantly correlated. Similarly, Wheeler et al. (2010) conducted a statistical-local area level cross-sectional spatial analysis of crime in Victoria and found significant relationships between gambling losses and the population rate of non-income generating offenses, a category which includes domestic violence assault. Finally, in a separate study of statistical-local areas in South Australia, Wheeler et al. (2008) found no relationship between gambling losses and the rate of non-income generating offenses.

In the United States, a large and controversial body of econometric literature has examined the relationship between crime and casino accessibility at various ecological scales. These studies, comprehensively reviewed by Walker (2010), have examined crime at county and city scales and have had mixed results, with some finding associations between various offenses and casino availability and others finding no significant relationship. Few of these ecologic studies specifically examined domestic violence with any degree of rigour. Other studies in the United States have been unable to disaggregate domestic violence from other violence due to their reliance on the classification of offenses imposed by the Uniform Crime Reports' standard format (e.g. Evans and Topoleski, 2002; Grinols and Mustard, 2006; Reece, 2010).

In summary, the extant literature has examined the relationship between problem gambling and domestic violence at the individual level only and in general has found significant relationships. Ecological studies of the



impact of gambling accessibility on crime have had mixed results and have rarely focused on domestic violence specifically. This relative scholarly neglect is perhaps unsurprising, as both domestic violence (DeVerteuil, 2015) and gambling (Marshall and Baker, 2001) have been subject to relatively little geographic research.

## Objectives

In this study, we examine the relationship between domestic violence and EGM accessibility at the neighbourhood level. Specifically, we undertake a spatio-temporal analysis of EGM accessibility in Victoria and annual police-recorded domestic violence between 2005 and 2014 at the postcode level. We estimate the association between the incidence of domestic violence and EGM accessibility, using two measures of EGM accessibility and two measures of police-recorded domestic violence. Because both EGM accessibility and domestic violence are correlated with variables such as socio-economic disadvantage that vary spatially and temporally, we adjust for a range of covariates that differ between postcodes.

## Methods

A Bayesian spatio-temporal Poisson regression approach was used to model the relationship between domestic violence, EGM accessibility and socio-demographic covariates in Victoria, using police-recorded data aggregated by postcode and year between 2005 and 2015. Bayesian spatial or spatio-temporal models are appropriate for investigating ecological correlations between variables under conditions of space-time dependence. While Bayesian methods are widely used in epidemiology, they have rarely been applied to research on domestic violence (Cunradi et al., 2011; Freisthler and Weiss, 2008; Gracia et al., 2014).

## Outcome variables

We used two measures of domestic violence, both derived from the Law Enforcement Assistance Program (LEAP) database used by the Victoria Police to store police records, and provided by the Crime Statistics Agency of Victoria. The first measure was the number of 'family incidents' recorded by police in a postcode in a given calendar year. A family incident is recorded whenever domestic-violence assault, interfamilial sexual offences or child abuse are reported to police, including incidents that do not lead any charges being laid (Victoria Police, 2014). The number of family incidents recorded grew dramatically over the study period, from 28,424 in 2005 to 68,091 in 2014. The increase in recorded family incidents accelerated after 2011 when new police recording guidelines were introduced, moving from an average annual growth rate of 5.7% between 2005 and 2010 to an average of 16.4% between 2011 and 2014.

Due to the dynamism of the family incidents measure, the number of domestic violence assault offenses was used as a secondary outcome variable. Domestic violence assaults were recorded when charges were laid by police for 'assault and related offences' (classification A20) with respect to a family incident as defined above. While this category only covers some types of domestic violence acts and these for only a subset of cases, the category was selected as it was the most numerous family-incident related crime against the person. Additionally, the number of recorded family-incident related physical assaults grew less rapidly over the study period than other family-incident related offenses. Recording of domestic-violence assaults increased by 286% between 2005 and 2014, compared with a 603% growth rate in recording of all other family-incident related

offenses. Counts of police-recorded domestic violence assaults were also aggregated to the postcode level.

Both measures of domestic violence include incidents where the perpetrators are both men and women. In 2014–15, the person identified by police as the ‘primary aggressor’ (Victoria Police, 2014) was a male aged 15 or more in 76% of family incidents. Women and children aged 14 or younger were the victims (or ‘affected family members’) in 78% of incidents.

### Predictor variables

Data on the residential population of each postcode was required to calculate rates of violence. It is worth noting that while much of the American literature reviewed by Walker (2010) is concerned with adjusting for the effect of non-residents visiting in order to gamble at casinos, this issue is unlikely to have relevance in the Victorian context due to the dispersed nature of EGMs across the community. Annual estimated residential populations for Statistical Areas 2 (median 2011 population of 8562) were obtained from the Australian Bureau of Statistics for the study period (Australian Bureau of Statistics, 2015) and were converted postal areas (median population of 2831, see Table 1 below).

The predictor variable of interest was EGM accessibility. Accessibility was measured at the postcode level in two ways: EGMs per 10,000 persons and EGM venues per 100,000 persons, each recorded separately for each postcode during each calendar year. While venue density may be considered a better measure of accessibility as it may be that distance to nearest venue is more important than venue size, EGM density is also of interest as it combines the venue density metric with an indicator of capacity. Data detailing the number of EGMs

in each venue in Victoria during each year of the study period were obtained from the Victorian Commission for Gambling and Liquor Regulation. The postcode of each venue was extracted from its street address. EGM density was calculated by summing the number of EGMs in each postcode for each calendar year, and dividing that by the postcode estimated residential population.

The remaining predictor variables were derived from the Australian Census of Population and Housing, which took place in 2001, 2006 and 2011. Linear interpolation was used to provide estimates of census variable in intercensal years, while 2011 values were carried forward for the years 2012–2014.

Following calls to measure the health effects of gender (e.g. Phillips, 2011), we measured economic gender inequality by calculating the percentage of total personal income in the postcode that accrued to women. We hypothesised that domestic violence rates would be lower in areas where women had relatively more economic autonomy, as measured by the female share of personal income. We estimated the female income share using self-reported personal income data from the census, coding income brackets according to their midpoints and treating the top-coded bracket following Fleming and Measham's (2015) assumption that income is Pareto distributed.

As economic disadvantage is another key variable that is associated with both recorded domestic violence (Beyer et al., 2015; Pinchevsky and Wright, 2012) and EGM density (Marshall and Baker, 2001, 2002), the Socio-Economic Index for Areas (SEIFA) Index of Economic Resources (IER) was included as a postcode-level measure of poverty and prosperity. The IER is a composite measure of various indicators of wealth and income, which means that a more complete picture of economic status can be gained by using a single indicator, without introducing multicollinearity among

predictor variables (Australian Bureau of Statistics, 2008).

Other included predictor variables were: the percentage of residents in the postcode who speak only English, a variable relevant to social disorganisation theory; the child-to-woman ratio, selected because the number of children present in the home is an important risk factor for victimisation (Stith et al., 2004), measured as the number of children aged 0–4 divided by the number of women aged 15–45; the percentage of the postcode who identify as Indigenous, selected due to the higher rates of victimisation among Indigenous women in Australia (Al-Yaman et al., 2006; Mouzos and Makkai, 2004); the median age of residents in the postcode, selected because domestic violence risk decreases with age (Stith et al., 2004); and the Open Accessibility and Remoteness Index for Australia (Markham, 2015), a continuous measure of the geographic accessibility of locations in Australia, selected to capture any urban-rural differences in police recording rates or domestic violence rates. The index ranges from 0 in the most urban areas to a maximum of 15 in the most isolated parts of Australia.

During exploratory modelling, each predictor variable was tested in separate Poisson regression models, using no transformation, logarithmic transformation and a second-order polynomial transformation. The variable form that yielded the lowest DIC was retained for the main analysis.

### Spatial units

Due to changes in the configuration of postcodes during the study period, four postcodes were removed from the analysis. In addition, nine postcodes were removed as they represented non-residential areas including university campuses ( $n = 3$ ), military bases ( $n = 3$ ), industrial zones ( $n = 2$ ) or the central business district ( $n = 1$ ). These areas

were excluded for reasons of missing data or to reduce potential bias induced by the high ratio of visitors to residents in the central business district. This left 654 postcodes with 10 years of annual data remaining in the analysis. Postcode boundaries were approximated using the Australian Bureau of Statistics' Postal Areas.

### Statistical methods

Exploratory Poisson regression modelling was undertaken assuming that data were identically and independently distributed. Variance-inflation factors (VIFs) were checked to ensure that multicollinearity was not problematic. Because the logarithmic transformations of venue density and EGM density are highly correlated ( $r = 0.96$ ), they could not be included simultaneously in the same model, leading to the creation of separate models. All other VIFs were in the range 1.2–3.5 (see Online [Supplementary Table 1](#) for pairwise correlations between variables). As expected, Moran's test revealed that significant spatial autocorrelation remained in the models' residuals, while unambiguous temporal trends were also evident in model residuals. Consequently, a spatio-temporal analysis was required in order to incorporate spatial and temporal smoothing into the model.

A Bayesian Poisson mixed effects model was therefore used to estimate the association between domestic violence, EGM density and socio-demographic correlates, taking into account the spatio-temporal autocorrelation non-parametrically. A modelling approach drawing on that of [Knorr-Held \(2000\)](#) was adopted, as it allows for non-separable spatial and temporal autocorrelation structures. As we were interested examining fixed estimates of parameter values rather investigating than the random effects themselves, [Ugarte's et al. \(2012\)](#) simplification that eliminates several nuisance para-



meters from the Knorr-Held specification was adopted. The model used in the spatio-temporal analysis was:

$$\begin{aligned}
 Incidents_{kt} &\sim \text{Poisson}(\mu_{kt}, pop_{kt}) \\
 \log(\mu_{kt}) &= \beta X_{kt} + \log(pop_{kt}) + \phi_t \\
 \beta &\sim N(0, 0.001) \\
 \phi_1 &\sim N(0, \tau^2 Q(W, \rho)^{-1}) \quad t = 1 \\
 \phi_t | \phi_{t-1} &\sim N(\gamma \phi_{t-1}, \tau^2 Q(W, \rho)^{-1}) \quad t = 2, \dots, T \\
 Q(W, \rho) &= \rho [\text{diag}(W1) - W] + (1 - \rho)I \\
 \tau^2 &\sim \text{Inverse Gamma}(0.001, 0.001) \\
 \rho, \gamma &\sim \text{Uniform}(0, 1)
 \end{aligned}$$

where the study site is divided into  $k = 1, \dots, K$  postcodes and  $t = 1, \dots, T$  years;  $Incidents_{kt}$  records the number of recorded family incidents in postcode  $k$  in year  $t$ ;  $pop_{kt}$  records the population of postcode  $k$  in year  $t$ , included as an offset term to account for variations in postcode size;  $X_{kt}$  is a matrix of predictor variables in postcode  $k$  in year  $t$  and  $\beta$  is a commensurate vector of estimated regression coefficients;  $\phi_t$  captures spatio-temporal correlation through a set of random effects. Temporal autocorrelation is modelled through a first order autoregressive term, while spatial autocorrelation enters the model through the random effects precision matrix. The precision matrix is given by  $Q(W, \rho)$  where  $1$  is a vector of ones and  $I$  is the  $K \times K$  identity matrix. The spatial adjacency matrix is given by  $W$ .  $\rho$  and  $\gamma$  vary respectively according to the degree of spatial and temporal autocorrelation in the data, with 0.0 indicating no autocorrelation and 1.0 indicating strong autocorrelation.

The adjacency matrix was calculated using queen's contiguity in R using the *spdep* package (Bivand et al., 2008) with a tolerance of 10 m. The model was fitted us-

ing the *CARBayesST* package (Lee et al., 2015). Model parameters were estimated using Markov-Chain Monte Carlo (MCMC) simulations. A burn in period of 40,000 iterations was used, after which 200,000 samples were made. A thinning factor of five was used to reduce correlation among the simulations, meaning that parameters were effectively estimated from 40,000 simulations. Convergence was assessed by examining trace plots, with estimates of all the parameters of interest converging well.

## Results

### Descriptive statistics

After excluding ineligible postcodes, 4,970,000 persons were resident in the study area in 2005, rising to 5,800,000 in 2014. The exclusion of ineligible postcodes removed less than 1% of the Victorian population from the analysis.

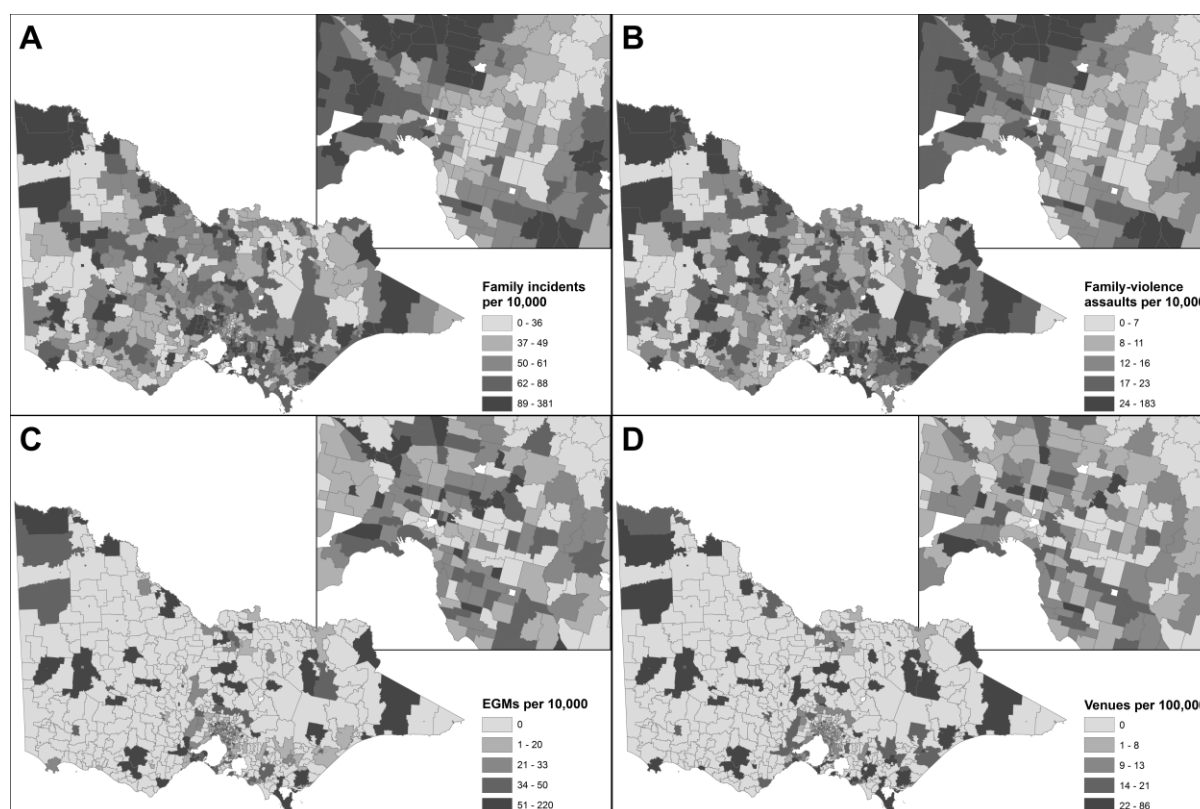
Among Victorian postcodes in 2005–2014, the median rate of family incidents and domestic-violence assaults per 10,000 were 52 and 10 respectively (see Table 1). However, the distribution of incidents was highly positively skewed, with the mean rate of family incidents and domestic-violence assaults much higher at 65 and 17 respectively. The distribution of EGM accessibility variables were similarly positively skewed.

Police-recorded domestic violence was highly concentrated in particular regions of Victoria (see Fig. 1). In particular, high rates of violence were recorded in the northern, western and far south-eastern suburbs of Melbourne. Similarly, EGMs are concentrated in particular regions, particularly Melbourne's western, north-western and south-eastern fringes

**Table 1.** Summary statistics recorded domestic violence, electronic gaming machine density and socio-demographic covariates in 654 Victorian postcodes, each year between 2005 and 2014.

	Mean	Median	SD	Min	Max
Total population	8220.4	2831.3	11422.6	123.3	93875.6
Family incidents per year per 10,000	65.1	52.2	57.5	0.0	754.0
Domestic-violence assaults per year per 10,000	16.5	10.3	23.1	0.0	475.1
Venues per 100,000	6.0	0.0	11.2	0.0	91.7
EGMs per 10,000	15.5	0.0	28.7	0.0	232.5
Index of economic resources	1004.1	999.1	65.0	811.1	1213.0
Female income share	37.8	37.8	4.7	13.7	77.8
Per cent only speak English	84.9	91.6	15.4	16.6	100.0
Child-to-woman ratio	0.3	0.3	0.1	0.0	1.6
Per cent Indigenous	0.9	0.5	1.2	0.0	18.1
Median age	41.1	40.6	5.8	20.0	65.0
Accessibility and remoteness index for Australia	0.4	0.3	0.4	0.0	2.1

*Notes:* Summary statistics presented in this table were not weighted by postcode population and therefore should be interpreted as representing averages among postcodes rather than the population average at state level.

**Fig. 1.** Map of the unsmoothed spatial distribution of postcodes in Victoria showing (A) family incidents per 10,000; (B) family-violence assaults per 10,000; (C) EGMs per 10,000, and (D) EGM venues per 100,000. Inset maps show Greater Melbourne. All maps show the mean of annual postcode rates.

## Main results

Both venue density and EGM density were significantly associated with family incidents and domestic-violence assaults (Table 2). The model fitting process revealed the relationship to be best modelled as a logarithmic curve, indicating that the association increases rapidly with the first EGM venue in a postcode, followed by marginally smaller increases in domestic violence as accessibility increases thereafter. This correlation held both when controlling for other variables in multiple regression (Table 2) and in bivariate models (Online Supplementary Table 2).

The association between EGM density and domestic violence is presented in terms of absolute risk in Fig. 2. It is clear that while EGM accessibility is associated with violence in all four models, it explains only a small fraction of the inter-postcode variation in domestic violence rates. Table 2 shows that alternating between venues per 100,000 and EGMs per 10,000 has little substantive effect on the estimated association between EGM accessibility and domestic violence, although the DICs reported in Table 2 suggest that use of venues per 100,000 marginally improves model fit.

The index of economic resources was negatively correlated with both measures of domestic violence, meaning that there were more incidents of police-recorded violence per capita in poorer areas. Contrary to our expectations, the female income share was positively correlated with the rate of domestic violence, meaning that in postcodes where women have gained relatively more economic power, recorded violence rates are higher, not lower. The percentage of people only speaking English was negatively correlated with family incidents but was not correlated with domestic-violence assaults. The

accessibility and remoteness index was negatively correlated with violence rates, meaning that police recorded a greater rate of family incidents in more urban areas.

Both  $\rho$  and  $\gamma$  were estimated to be relatively close to 1.0. This indicates a great degree of both spatial and temporal autocorrelation among the data. Because recording of family incidents increased during the study period much more rapidly than domestic-violence assaults,  $\gamma$  is correspondingly higher for family incidents.

## Discussion and conclusions

### Key results

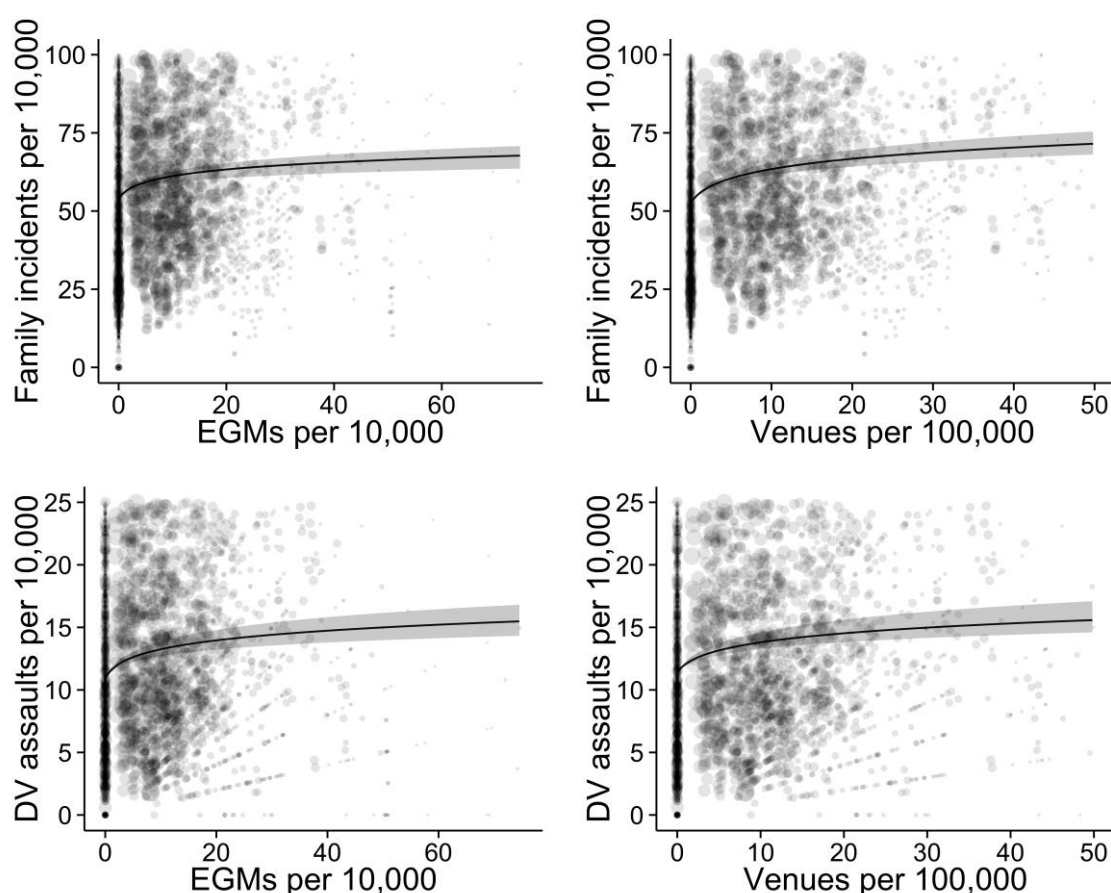
EGM density was significantly associated with both the rate of family incidents and the rate of domestic-violence assaults (Table 2). As Fig. 2 shows, EGM-free postcodes were associated with a mean incidence rate of 54 family incidents per 10,000 and 11 domestic-violence assaults per 10,000. The mean incidence rate for postcodes with 75 EGMs per 10,000 (approximately 2 SDs above the mean), was 68 family incidents per 10,000 (95% credibility interval [C.I.]: 64, 71) and 16 domestic-violence assaults per 10,000 (95% C.I.: 14, 17). Similar patterns were evident when venue density was used as the predictor variable. In terms of relative risk, postcodes with no EGMs were associated with 20% (95% C.I.: 15%, 24%) fewer family incidents per 10,000 and 30% (95% C.I.: 24%, 35%) fewer domestic-violence assaults per 10,000, when compared with postcodes with 75 EGMs per 10,000.

Other postcode-level covariates such as economic disadvantage, female income share, the percentage of households only speaking English, the number of children per woman, the proportion of Indigenous residents and urbanicity were also found to be correlated with the increased incidence of police-recorded domestic violence.

**Table 2.** Associations between domestic violence, EGM accessibility and socio-demographic characteristics from Bayesian spatio-temporal analysis

	$\beta$ coefficients							
	Family incidents				Domestic-violence assaults			
	Model 1		Model 2		Model 3		Model 4	
	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
Intercept	<b>-8.3</b>	<b>[-9.3, -7.3]</b>	<b>-8.2</b>	<b>[-9.2, -7.2]</b>	<b>-9.6</b>	<b>[-11.0, -7.9]</b>	<b>-9.6</b>	<b>[-11.1, -8.0]</b>
$\ln$ (Venues per 100,000 + 1) $\times 10^1$	<b>0.8</b>	<b>[0.6, 0.9]</b>			<b>0.9</b>	<b>[0.6, 1.1]</b>		
$\ln$ (EGMs per 10,000 + 1) $\times 10^1$			<b>0.5</b>	<b>[0.4, 0.6]</b>			<b>0.8</b>	<b>[0.6, 1.1]</b>
IER $\times 10^3$	<b>-5.5</b>	<b>[-6.0, -5.0]</b>	<b>-5.6</b>	<b>[-6.1, -5.1]</b>	<b>-5.8</b>	<b>[-6.6, -5.0]</b>	<b>-5.9</b>	<b>[-6.6, -5.3]</b>
IER <sup>2</sup> $\times 10^1$	-0.5	[-4.0, 2.9]	-0.5	[-4.2, 3.4]	4.1	[-1.3, 9.2]	4.2	[-1.1, 9.3]
$\ln$ Fem. income share	<b>0.6</b>	<b>[0.3, 0.8]</b>	<b>0.5</b>	<b>[0.3, 0.8]</b>	<b>0.6</b>	<b>[0.3, 0.9]</b>	<b>0.6</b>	<b>[0.3, 0.9]</b>
$\ln$ % English only $\times 10^1$	<b>2.0</b>	<b>[0.5, 3.2]</b>	<b>1.9</b>	<b>[0.6, 3.2]</b>	0.9	[-1.0, 2.7]	0.9	[-0.9, 2.6]
Child-to-woman ratio $\times 10^1$	<b>4.7</b>	<b>[1.3, 7.7]</b>	<b>4.4</b>	<b>[1.6, 7.6]</b>	<b>4.9</b>	<b>[0.5, 9.4]</b>	4.7	[-0.3, 9.2]
$\ln$ (% Indigenous + 1) $\times 10^1$	<b>2.2</b>	<b>[1.6, 2.8]</b>	<b>2.2</b>	<b>[1.6, 2.9]</b>	<b>1.9</b>	<b>[0.9, 2.9]</b>	<b>1.8</b>	<b>[0.9, 2.7]</b>
Median age $\times 10^2$	-0.4	[-0.9, 0.4]	-0.4	[-0.9, 0.2]	-0.5	[-1.5, 0.3]	-0.5	[-1.4, 0.3]
Median age <sup>2</sup>	2.4	[-1.8, 7.5]	1.4	[-3.6, 6.7]	4.5	[-2.0, 12.0]	4.7	[-2.3, 11.7]
$\ln$ (OARIA + 1) $\times 10^1$	<b>-6.6</b>	<b>[-10.3, -3.1]</b>	<b>-7.6</b>	<b>[-11.0, -4.9]</b>	-3.4	[-7.9, 0.8]	-3.5	[-7.0, 0.4]
$\tau^2$	.11	[.11, .12]	.12	[.11, .13]	.23	[.20, .25]	.23	[.20, .25]
$\rho$	.95	[.92, .97]	.95	[.92, .97]	.97	[.94, .98]	.97	[.94, .98]
$\gamma$	.98	[.96, 1.00]	.98	[.97, 1.00]	.89	[.87, .92]	.89	[.87, .92]
DIC	39352		39347		28705		28705	

Notes: Est. = estimate; CI = credibility interval;  $\ln$  = natural logarithm; EGM = electronic gaming machine; IER = Index of economic resources; Fem. = female; OARIA = Open Accessibility and Remoteness Index; DIC = Deviance information criterion. Bold type indicates coefficients for which the 95% C.I. does not contain zero. Model coefficients are estimated simultaneously from a multivariate spatio-temporal model containing all the parameters for which coefficients were listed.

**Fig. 2.** Associations between domestic violence outcomes and EGM accessibility in Victoria postcodes, 2005–2014, after adjusting for socio-demographic characteristics from Bayesian spatial analysis. The trendline shows the estimated association between EGM accessibility and domestic violence, with the shaded grey area representing the 95% credibility interval. Each circle represents a single postcode in a single year, with the area of circles sized proportionate to the population of the postcode.



## Limitations and generalisability

These findings are subject to several limitations. First, police records routinely undercount domestic violence (Felson et al., 2002), with recorded cases sometimes likened to the tip of an “iceberg” of statistically-invisible, unrecorded cases (Gracia, 2004). This is likely to downward bias the estimated incidence of domestic violence and thus the magnitude of the estimates of absolute risk. However, our estimates of relative risk will only be biased if recording rates are spatially correlated with EGM density. We cautiously suggest that there is little *a priori* reason to expect that this would be the case. Second, our research is subject to the modifiable areal unit problem (MAUP: Openshaw, 1984). Postcodes are not the ideal spatial units for conducting this kind of analysis. Future research could use geocoded police data to analyse the relationship between EGM accessibility and domestic violence at fine spatial scales using frame-invariant statistics (Tobler, 1990), thereby mitigating the MAUP. Analysis of geocoded police data would also enable the use of more sophisticated sub-zonal measures of EGM accessibility. Third, our estimates are associations only, limiting any causal inferences that can be made about the relationship between EGM density and domestic violence. Fourth, we did not set out to specifically investigate interactions between EGM density and other predictors of domestic violence but have instead estimated the average association between EGM density and violence across social space. Future research might investigate the potential socio-spatial non-stationarity of these relationships.

We see little *prima facie* reason to doubt that our results are generalizable to other jurisdictions in high income countries where EGMs are accessible throughout the community. While the incidence rates are highly dependent on police recording protocols, we

expect that the underlying relationship will be present in other jurisdictions.

## Interpretation

There is an association between EGM density and domestic violence rates among postcodes, above and beyond that explained by the geography of contextual factors like disadvantage. That is to say, once the effect of disadvantage and other covariates are controlled for, a correlation between EGM density and violence remains. The logarithmic shape of the relationship suggests that the first few EGM venues added to an area have the greatest impact on domestic violence rates.

Gambling is likely to be both a cause and effect of domestic violence. Furthermore, despite our efforts to find neighbourhood-level proxies for domestic violence risk factors, it is likely that the correlation between EGM accessibility and domestic violence results partly from the correlation of both these variables with other unobserved variables like alcohol-outlet density. We expect that all three of these causal pathways contribute to some extent to the association we have documented, although their relative importance is unclear.

The magnitude of these estimated associations is larger than we anticipated and suggests that the relationship between EGM accessibility and domestic violence is policy relevant. If all of this association results from gambling-caused domestic violence (rather than the other two causal pathways mentioned above), we would expect that reducing the accessibility of EGMs or removing them entirely would result in a substantially reduced incidence of domestic violence. A more plausible interpretation is that only a fraction of the estimated association is



attributable to gambling-caused domestic violence. Further study using strong quasi-experimental designs is needed to disentangle the multiple causal pathways to this association and to estimate the magnitude of potential reductions in the domestic violence incidence rate that may occur if EGM accessibility were decreased.

As Fig. 2 demonstrates, EGM accessibility only explains a small portion of the variation in the rate of police-recorded domestic violence between postcodes. This implies that reducing EGM density is unlikely to be a policy priority for those seeking to reduce rates of domestic violence. However, domestic violence should be considered as a relevant social impact by authorities licensing EGMs.

Consistent with the broader literature and social disorganisation theory, economically disadvantaged postcodes have an elevated rate of police-recorded domestic violence (Beyer et al., 2015; Pinchevsky and Wright, 2012), although it is possible that this correlation is due to more intensive policing of poorer areas. Our finding that postcodes with greater linguistic diversity experience lower rates of police-recorded domestic violence is contrary to the expectations of social disorganisation theory, but consistent with non-ecological surveys in Australia (Mouzos and Makkai, 2004; O'Donnell et al., 2002). Contrary to our expectations, postcodes with a greater female income share also had elevated rates of violence. Jewkes (2002), writing about similar relationships between intimate partner violence and female education in the United States and South Africa, suggests that as women gain more power they pose a greater challenge to patriarchal authority, a challenge that may be met with violence. Finally, the finding that police-recorded violence rates are higher in urban areas when urbanicity is measured using a

continuous measure of remoteness and accessibility is novel in the research literature, which has rarely measured the urban-rural continuum using non-binary measures in developed countries (Beyer et al., 2015).

## Conclusions

EGM accessibility is associated with police-recorded domestic violence incidence in postcodes in Victoria. Reducing EGM accessibility may potentially provide an avenue for reducing the incidence of domestic violence. Further research utilising strong quasi-experimental designs should be undertaken to disentangle the causal relations underlying this association.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.socscimed.2016.06.008>.

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