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The impact of changes to liquor licensing policy on violent crime in NSW, 2000-2019

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AIM

To quantify the effects of individual liquor licensing policies introduced in New South Wales (NSW) over the last decade on rates of violent crime.

METHOD

The effects of individual state-wide policies on non-domestic assaults in NSW and additional local policies in the Sydney Central Business District Entertainment Precinct (CBD) and the Kings Cross Entertainment Precinct (KCP) from 2000 to 2019 were quantified using time series intervention models. We used a vector auto regression (VAR) model to create counterfactual datasets. These datasets were derived from proxy data outside the study area and helped predict potential assault outcomes without the policy implementation.

RESULTS

The liquor licensing policies introduced by the NSW Government between 2008 and 2018 contributed to a significant decline in non-domestic assaults, both in Sydney and across NSW. By the end of 2019, non-domestic assaults had reduced by an estimated 19% in NSW, 45% in the Sydney CBD, and 84% in the KCP. Policies restricting late night (or 24-hour) trading of licensed premises and those targeting enforcement toward the highest risk venues contributed most to these declines.

CONCLUSION

This research adds to the mounting evidence that restricting trading hours can substantially reduce the risks associated with acute alcohol intoxication and can be a cost-effective crime reduction strategy when combined with enforcement that targets the small number of premises that account for most of the harm.

KEYWORDS

Alcohol | non-domestic assaults | counterfactual | proxy data | intervention model

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INTRODUCTION

Alcohol plays a significant role in criminal activities and violence. Excessive drinking can lower inhibitions, impair a person's judgement and increase the risk of aggressive behaviours (e.g. Bushman & Cooper, 1990; Exum, 2006). Over the past several decades, extensive research (Babor et al., 2022; Chikritzhs et al., 2007; Escobedo & Ortiz, 2002; Gruenewald et al., 2006; Lipton & Gruenewald, 2002; Wiggers et al., 2016; Zhu et al., 2004) has demonstrated a strong association between alcohol consumption and violent crime, and that engaging in prolonged or binge drinking significantly increases the risk of violent offences being committed. As a result, the issue of alcohol-related violence and, in particular, violence occurring in and around licensed premises, has been at the forefront of debate in New South Wales (NSW) for many years.

Prior research

Regulatory controls on alcohol availability play a crucial role in state efforts to curb alcohol-related harms. These controls can include restrictions on the number of alcohol outlets, trading hours and days, types of beverages sold, and service to intoxicated patrons (Chikritzhs et al., 2007). Despite some methodological limitations, research generally suggests that such policy levers can effectively reduce alcohol-related violent crime and injury (Fitterer et al., 2015).

Studies consistently show that restrictions on trading hours and days can help curb violence (Nepal et al., 2020; Sanchez-Ramirez & Voaklander, 2018; Wilkinson et al., 2016). Evidence also indicates that a higher concentration of liquor outlets in an area is associated with increased alcohol consumption and violence (Gordon et al., 2015; Gorman et al., 2001; Gruenewald & Remer, 2006; Kearns et al., 2015; Livingston, 2011; McKinney et al., 2009; Nordstrom, 2000), although some methodological limitations have been noted in relation to this literature (Gmel, Holmes & Studer, 2015).

Other initiatives, such as restrictions on serving alcohol to intoxicated patrons and the implementation of liquor accords,[1] have less conclusive evidence supporting their effectiveness (Chikritzhs et al., 2007; Miller et al., 2014; Siegfried & Parry, 2019). The same applies to policing interventions; however, proactive policing supporting community partnerships (Liu et al., 2016) and enforcement targeting higher risk venues (Menendez et al., 2015; Moffatt & Weatherburn, 2011) has shown some promise. Further research is required to confirm the effectiveness of lockouts and patron bans (Farmer et al., 2023; Livingston et al., 2010; Taylor et al., 2018). Lockouts combined with other alcohol restrictions show some benefits (Donnelly et al., 2017; Fulde et al., 2015; Jones et al., 2011), but their unique impact on crime remains uncertain (Kypri et al., 2011; Mazerolle et al., 2011).

One challenge faced is that alcohol restrictions are often introduced as part of wider intervention packages, making it difficult to determine causal relationships between specific components and observed changes in outcomes (Taylor et al., 2018). Improved understanding of specific regulatory strategies is essential for formulating effective policies and avoiding potentially harmful ones.

1 Liquor accords are partnerships among licensed venues, community members, local businesses, local councils, police and government departments that work together to develop practical solutions to address alcohol-related issues, anti-social behaviour and violence in local areas (see Liquor & Gaming NSW website www.liquorandgaming.nsw.gov.au).

Liquor licensing reforms in NSW

Between 2008 and 2018, the NSW Government implemented a series of reforms to reduce violence related to licensed premises, including both state-wide and local area strategies. Several studies have examined the effectiveness of these measures in reducing alcohol-related crime. Menéndez et al. (2015) found that the 2008 legislative reforms, which introduced a freeze on new 24-hour liquor licensing trading permits, mandatory six-hour closure periods for licensed venues, and the "declared-premises" scheme,[2] reduced police-recorded serious assaults, and that subsequent policy changes in 2011 and 2012[3] enhanced these effects. The 2014 Sydney CBD Entertainment Plan of Management, known as the "lockout laws", also led to a significant decrease in assault incidences in the Kings Cross and Sydney CBD Entertainment Precincts (Athanasopoulos et al., 2022; Donnelly et al., 2017; Kypri & Livingston, 2020; Menendez, Kypri & Weatherburn, 2015). However, these reforms were heavily criticized for negatively affecting Sydney's night-time economy and city vibrancy.

In response to the criticism of the lockout laws, the NSW Government commissioned a review in 2016, which led to minor changes in trading hours of live entertainment venues and small bars, and increased small bar patron capacity in the Sydney CBD and Kings Cross areas. A joint select parliamentary committee in 2019 made a further 48 recommendations, including the removal of lockout laws in all areas except Kings Cross. In 2020, the lockout laws were scrapped in Sydney's CBD and Oxford Street, and further changes were made to small bar patron capacity and bottle shop opening hours.[4] Only one study to date has considered the impact of the easing of these restrictions. Wang et al. (2022) found that the one-hour extension of trading hours for takeaway alcohol sales and home delivery services in 2016 led to a small increase in late-night domestic violence-related assaults but no significant change in non-domestic assaults.

The current study

One of the recommendations from the 2019 parliamentary select committee on Sydney's night-time economy was "that further analysis and research be undertaken to ascertain which of the suite of public safety measures introduced in the last decade have contributed most to the decline in non-domestic assaults both in Sydney and across the state" (pp. xii, Parliament of NSW, 2019). The NSW Bureau of Crime Statistics and Research was nominated to lead this work and identify a methodology to quantify the effects of individual liquor licensing policies on rates of violent crime in NSW.

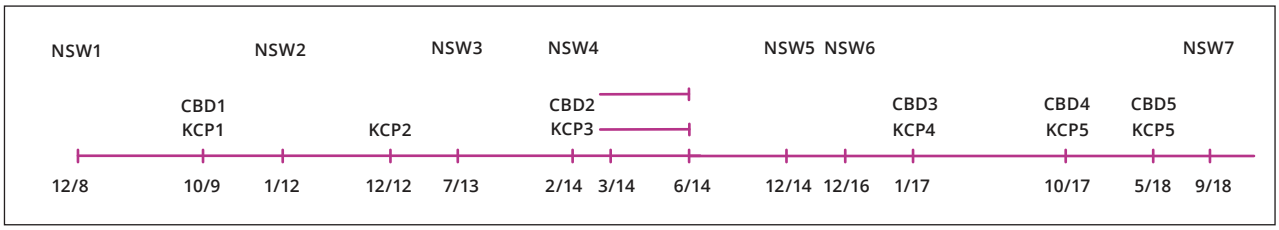
Figure 1 and Tables 1 and 2 show the timeline of changes to NSW liquor licensing policy since 2008. Table 1 lists the state-wide policies (NSW) introduced during this period and Table 2 lists those that were in effect only for CBD and KCP areas.[5] This study aims to quantify the effect of each of these policy changes on reported non-domestic assaults. Given that the liquor licensing policies were applied to different geographical areas, we first quantify the effects of each individual statewide alcohol policy for the rest of New South Wales (RNSW; defined as all of NSW excluding the Sydney Local Government Area (Sydney LGA)), and then the effects of each localised set of additional policies in the CBD and KCP.

2 The "declared-premises" scheme imposed special conditions on the 48 highest risk venues in NSW.
3 In August 2011 a new RSA photo competency card and database were introduced to verify staff's responsible service of alcohol training, and in January 2012 a new "three strikes" disciplinary scheme for licensed premises was introduced.
4 These policy changes post 2018 are out of scope of the current study.
5 This timeline was compiled from Roth and Angus (2015) and the NSW Legislation website, and verified by officers from the Liquor & Gaming NSW.

This study utilises related time series data from Victoria[6] (VIC; and areas near the CBD and KCP) to guide understanding on what assaults may have been reported in NSW if the liquor licensing policies had not been introduced. This allows the effect of potential latent factors influencing alcohol consumption and violent behaviour over the past decade, such as alcohol consumption patterns, public sentiment, and economic conditions, to be accounted for and removed in the analysis. We then identify and quantify the effect of those state-wide and area-specific policies that had a statistically significant impact on reported assaults, both instantaneous and gradually over time, both individually and as a cumulation of all previous policies. Results are reported separately for the CBD, the KCP and RNSW.

For many of the policies, the promulgation time between consecutive policies is short; of the order of a few months. For example, for statewide policy, the promulgation time interval between the Violence Venues Scheme (01/12/2008) and the Six-Hour Closure Period (03/12/2008) is less than one week. This makes it challenging to determine the effect of each of the interventions separately when modelling weekly aggregate data. Accordingly, for such policies, we group them into a single composite policy dated at the promulgation time of the earliest individual policy in each group. In this way, the statewide Periodic Licence Fee Scheme (05/02/2014) and take-away alcohol restrictions (24/02/2014) policies are combined into a single group, dated 05/02/2014. The resulting seven statewide (composite) policies, five CBD policies and six KCP policies are shown in Tables 1 and 2.

Figure 1. Timeline of Statewide, CBD, and KCP liquor licensing policies



6 A comparison with Queensland (QLD) was also considered. However, domestic and non-domestic assaults are indistinguishable in QLD police recorded offence data.

Table 1. Timeline of state-wide liquor licensing policy introduced in NSW between 2008 and 2018, and policy grouping for this study

Grouping	Implementation	Policy	Details of policy
NSW Policy 1	1/12/2008	Violent Venues Scheme	Introduction of special licence conditions on the 48 licensed premises with the highest numbers of violent incidents reported to or detected by police. The special conditions included: a mandatory 2am lock out; no glass containers after midnight, no shots after midnight and drink limits; 10-minute alcohol sales time out every hour after midnight; cessation of alcohol service 30 minutes prior to close.
	3/12/2008	Six-hour closure period for licensed premises	Freeze on granting of 24-hour liquor licences in NSW. A special condition was placed on all new licences granted on or after 30 October 2008, specifying that liquor must not be sold on the licensed premises for a continuous period of 6 hours during each consecutive period of 24 hours. The default closure period was 4am to 10am unless another period was approved by the Independent Liquor and Gaming Authority (ILGA).
NSW Policy 2	1/1/2012	Three Strikes Scheme	Under this scheme, "strikes" could be imposed on a licence when a licensee or approved manager was convicted of one or more serious offences under the NSW liquor laws. Different disciplinary action could be taken depending on the number of strikes accrued: one strike could result in special conditions (e.g., incident registers and management plans) being imposed on the licence; additional conditions could be applied if two strikes were incurred including security measures and banning alcohol sales after 1pm; and three strikes could result in 12 months suspension of the licence or cancellation.
NSW Policy 3	1/7/2013	Small Bar Licence	Introduction of a new liquor licence for bars that do not operate gaming machines or sell takeaway alcohol and hold up to 60 patrons (initial patron limit).
NSW Policy 4	5/2/2014	Periodic Licence Fee Scheme	Requires licensees to pay an annual base fee plus a risk loading that reflects location risk, trading hours and compliance history, with higher fees levied for premises trading late in high-risk areas and for premises where infringements have been detected.
	24/2/2014	State-wide take-away alcohol restrictions	Introduction of a ban on takeaway alcohol sales after 10pm across NSW (reduced from 11pm).
NSW Policy 5	15/12/2014	Minors Sanctions Scheme	This scheme introduced an escalating sanctions regime that applied significant penalties for selling alcohol to minors. The sanctions included licence suspension and cancellation and may be triggered if any person is convicted of an offence of selling liquor to a minor on licensed premises.
NSW Policy 6	16/12/2016	Updated Small Bar Licence	Patron capacity for small bar licences increased to 100.
	16/12/2016	Take-away liquor trading hours extension	Trading hours of bottle shops extended from 10pm to 11pm on Monday to Saturday.
NSW Policy 7	1/9/2018	Tiered Industry Training Framework	Responsible service of alcohol (RSA) training requirements in NSW overhauled to ensure that frontline staff, licensees, and approved managers are trained at a level appropriate for their roles. RSA training in NSW was aligned with the national minimum standard with a separate NSW module delivered. New Licensee Training and Advanced Licensee Training was also introduced.

Table 2. Timeline of liquor licensing policy for the CBD & KCP between 2008 and 2018, and policy grouping for each area

CBD	KCP	Implementation	Policy	Details of policy
CBD Policy 1	KCP Policy 1	1/10/2009	Liquor Licence Freeze	12 months freeze on the issuing of new liquor licences in Kings Cross, the Oxford Street/Darlinghurst precinct, and parts of the southern CBD. During the freeze period no new licences (or extended trading authorisations) were to be granted if it were likely to result in an increase in the number of persons who enter the precinct principally to consume alcohol. Licensed restaurants/cafes and small bars were generally exempted from the freeze. The 12-month freeze was extended a number of times.
	KCP Policy 2	7/12/2012	Kings Cross Plan of Management	Special conditions introduced for licensed premises located in the newly defined Kings Cross Precinct. These included restrictions on Friday and Saturday nights which prohibited shots, limited the number of drinks that may be sold to the same person to 4, mandated 2 responsible service of alcohol marshals on duty at the venue, required alcohol service to cease 1 hour before close (if trading past 2am). After midnight venues were also required to operate a CCTV system and not use glasses or glass jugs. Licensees were also required to keep an incident register, not admit any person displaying the name or colours of a listed motorcycle gang, and promote late night transport options.
CBD Policy 2	KCP Policy 3	5/2/2014	Sydney CBD Entertainment Plan of Management	A range of measures introduced to reduce alcohol-related violence; including 1:30am lockouts at hotels, clubs and karaoke bars across the Sydney CBD Entertainment and Kings Cross precincts; 3am cessation of alcohol service in those venues across the Sydney CBD and Kings Cross precincts; and a freeze on new liquor licences and approvals for existing licences across the Sydney CBD Entertainment precinct. Also, known as the "lockout laws".
		15/3/2014	Long-term banning orders	Police given the power to issue a person with a temporary (up to 48 hours) banning order prohibiting the person from entering or remaining in licensed premises in the Sydney CBD Entertainment Precinct. Applications could also be made the ILGA to issue a long-term (up to 12 months) banning order prohibiting entry into "high-risk" venues.
		13/6/2014	ID scanners in high-risk venues in Kings Cross	Requirement that all "high-risk" venues in the Kings Cross precinct scan a patron's ID with a scanner linked to the Kings Cross precinct ID scanner system before admitting entry to the premises.
CBD Policy 3	KCP Policy 4	16/1/2017	30-min relaxation of lockout laws for live entertainment venues (by application)	1:30am lockouts relaxed by 30 minutes (to 2am) and last drinks to 3:30am for small bars and venues providing live entertainment. First application for extension was approved on 16/01/2017.
CBD Policy 4	KCP Policy 5	1/10/2017	Late night drinks restrictions lifted on CBD and Kings Cross small bars	Drinks restrictions on small bars in the Sydney CBD and Kings Cross precincts that trade after midnight removed, allowing these venues to sell shots, spirits neat or on the rocks and bespoke cocktails.
CBD Policy 5	KCP Policy 6	25/5/2018	Liquor licence freeze lifted for entertainment and arts venues	Freeze on new liquor licences in Kings Cross and Sydney CBD lifted for venues with a focus on live entertainment, performing arts or other cultural events.

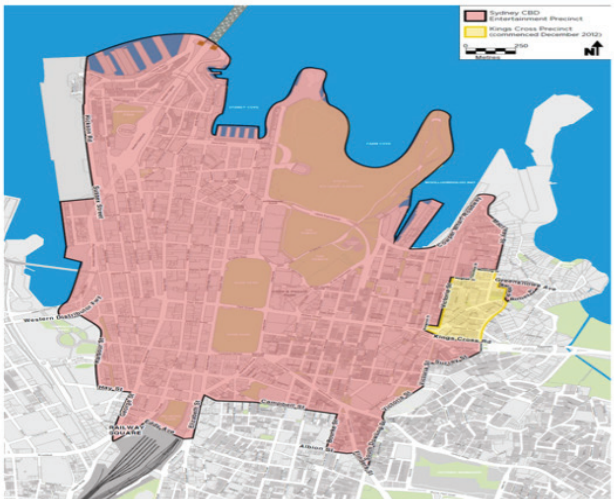
METHOD

Data

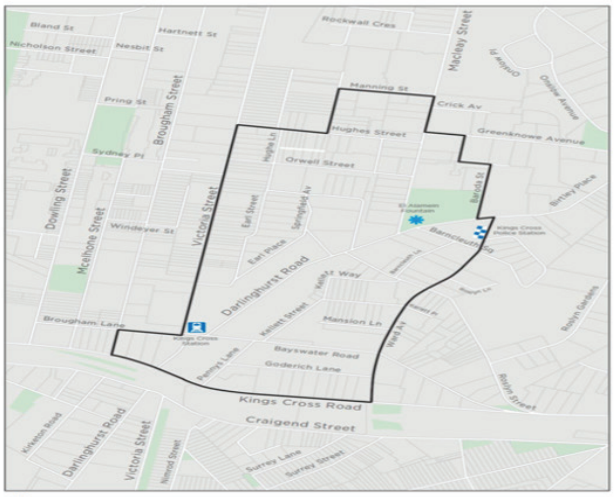
Data on all assaults recorded by the NSW police between 1st January 2000 and 31st December 2019 were extracted from the NSW Police Force's Computerised Operational Policing System. Assaults were categorised as domestic violence or non-domestic violence. This analysis focuses on the 749,576 non-domestic violence-related assaults in NSW from 2000–2019. Due to the varying geographical scope of liquor licensing policies, the assault data were partitioned[7] into those occurring in the CBD (Figure 2(a)), the KCP (Figure 2(b)), and RNSW, with weekly aggregate time series counts for each of these geographical areas shown in Figures 3-5 (black lines).

Data on the weekly number of non-domestic assaults recorded by Victorian Police between 1st January 2000 and 31st December 2019 were also obtained from the Victorian Crime Statistics Agency to use as a counterfactual (Figure 3; grey line).

Figure 2. Map of Sydney CBD Entertainment Precinct and Kings Cross Precinct (KCP), NSW, Australia



(a) Sydney CBD Entertainment Precinct



(b) Kings Cross Precinct

7 Incidents were assigned to particular geographical areas based on the geocode or address recorded by NSW police. In a small proportion of cases only the street and/or suburb was recorded. In these cases, a series of decision rules were applied to decide whether the incident occurred in the CBD, KCP or PASYD. These displacement areas were previously used by Menéndez et al. (2015), Donnelly & Poynton (2019) and Athanasopoulos et al. (2022) when examining the impact of the NSW Lockout Laws.

Figure 3. Aggregated weekly counts of reported non-domestic assaults in RNSW (black line) and Victoria (VIC; grey line) between 1st January 2000 and 31st December 2019. Vertical lines indicate the promulgation times of the 7 statewide policy interventions in Table 1

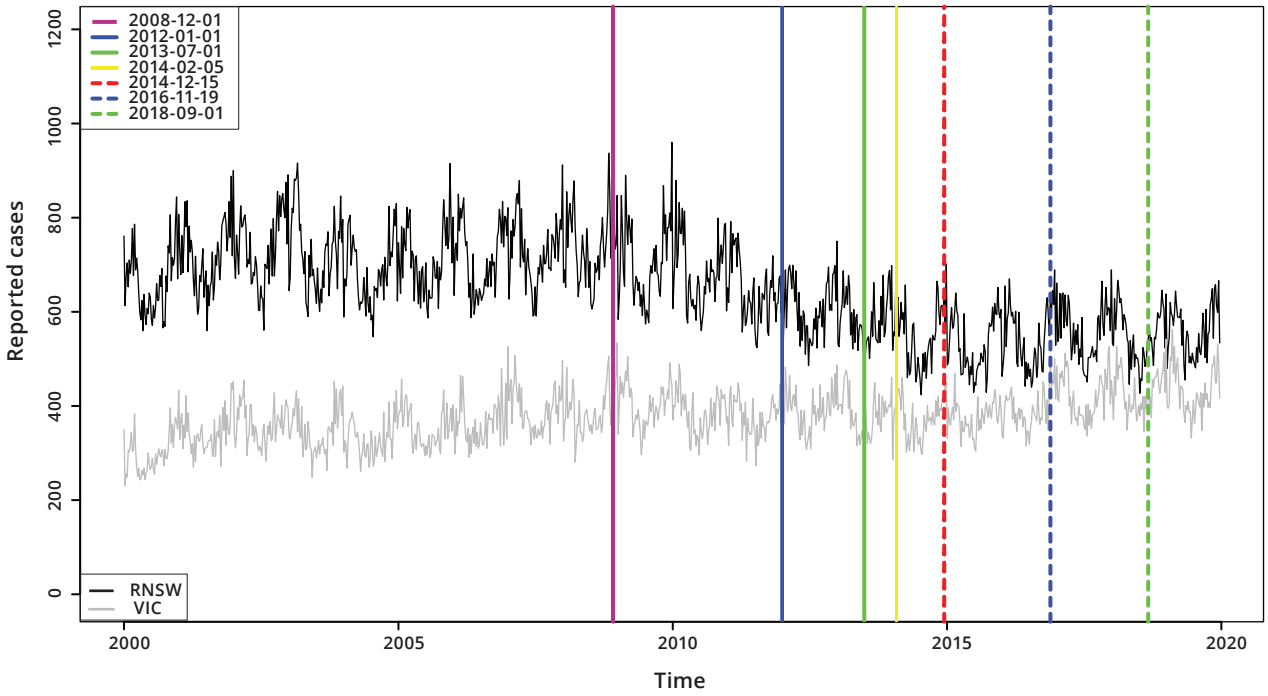


Figure 4. Aggregated weekly counts of reported non-domestic assaults in the CBD (black line) and PASYD (grey line) between 1st January 2000 and 31st December 2019. Vertical lines indicate the promulgation times of the 5 CBD policy interventions in Table 2

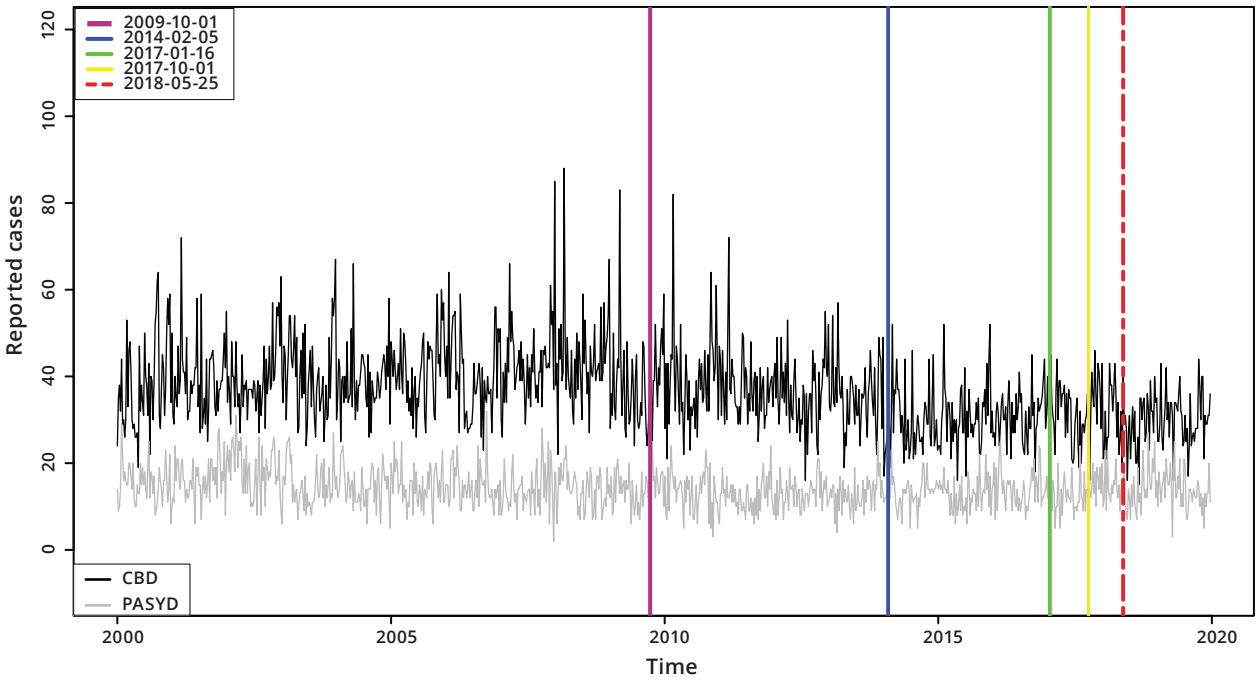
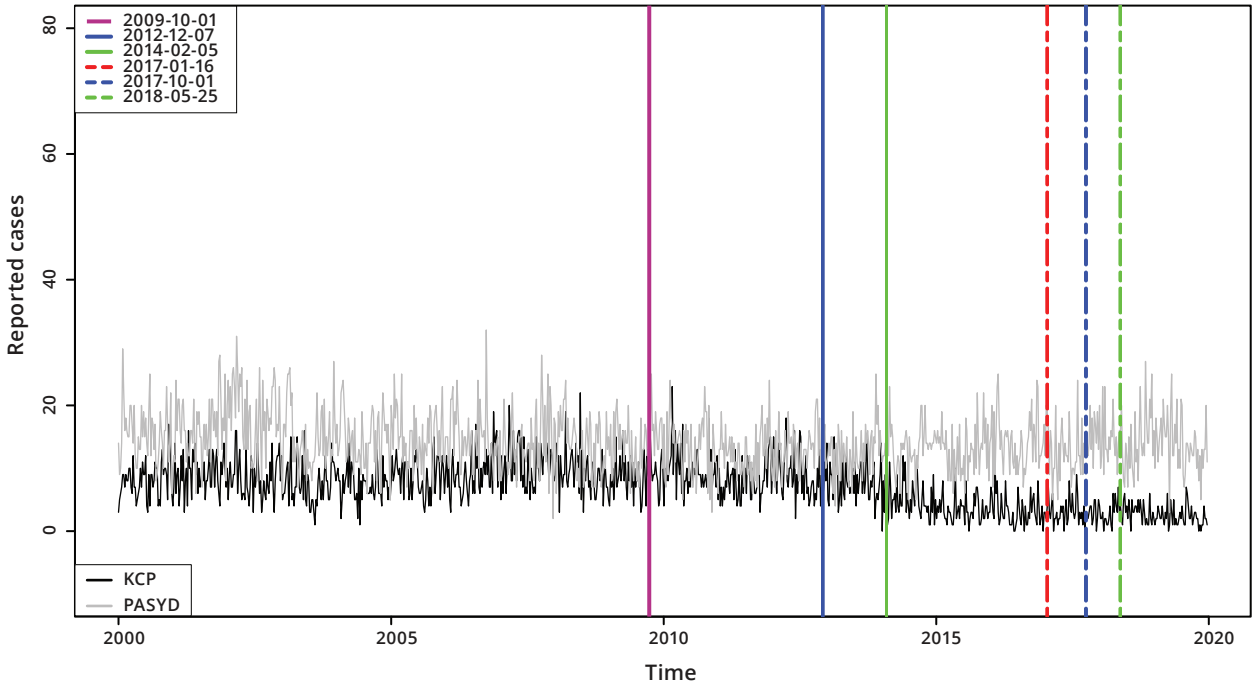


Figure 5. Aggregated weekly counts of reported non-domestic assault in the KCP (black line) and PASYD (grey line) between 1st January 2000 and 31st December 2019. Vertical lines indicate the promulgation times of the 6 KCP policy interventions in Table 2



Statistical analysis

To estimate the impact of liquor licensing policy changes on non-domestic assaults, we analyse the weekly count series $\{y_t\}$ for each region (RNSW, CBD, and KCP). Our approach is to build a model to construct a counterfactual dataset $\{y_t^*\}$, which is the dataset we would have observed if the liquor licensing policies in each region had not been introduced. With the assumption of additive policy effects, the resulting difference dataset $\{D_t = y_t^* - y_t\}$ will have trend, seasonality, and other (unknown) latent factors removed, with the remaining process mean being directly attributed to the legislative changes in each region. Prior to the first policy in each region $y_t^* = y_t$, with the series diverging from this point.

To construct $\{y_t^*\}$ we suppose that a proxy dataset $\{p_t\}$ is available for the full study period which displays the same pre-intervention behaviours as $\{y_t\}$, but which is not subject to subsequent policy exposure. For the proxy data for NSW statewide policies, the grey line in Figure 3 shows the equivalent weekly counts of non-domestic assault from the state of Victoria (VIC), which is similar in population and urbanization to NSW, but which did not enact significant liquor licensing policy changes.[8] Prior to the enactment of the first policy, there is a clear visual correspondence of assault behaviour between the two states. The continuation of the Victorian series beyond 2008 gives some indication of how the counterfactual RNSW series $\{y_t^*\}$ would behave after this point. We note that the population for NSW and Victoria has increased at a very similar rate over the study period, and so accounting for changes in population trends is not necessary. Regarding the proxy data for CBD and KCP policies, the grey line in Figures 4 and 5 shows the equivalent weekly counts of non-domestic assault from a subset of the Sydney LGA (Proximal Areas in the Sydney LGA; PASYD). The PASYD excludes the CBD, KCP, a group of entertainment areas not far from the KCP or CBD termed the distal displacement area (DDA; including Bondi Beach, Coogee, Double Bay and Newtown), and an area contiguous with the CBD and KCP termed the Proximal Displacement Area[5] (PDA; including Surry Hills, Chippendale, Ultimo, Pyrmont and Elizabeth Bay, and also

8 Four noteworthy 'interventions' were implemented in Victoria during this period but none of them were found to have any impact on assaults. These are (1) a 3-month trial of 2am lockouts in Melbourne in 2008 but this was only taken up by around 60% of venues; (2) introduction of risk-based licensing; (3) provision of 24-hour public transport; and (4) a freeze on late night licences in 2008 (after the lockouts were abandoned). For evaluations of these initiatives see Curtis et al. (2019a), Curtis et al. (2019b), Nepal et al. (2019) and Miller et al. (2020).

The Star casino).[9] In this manner, we hypothesize that the assaults in the PASYD will reasonably resemble those in the CBD and KCP due to spatial proximity, and similar suburb lifestyles, but without the impact of the CBD- or KCP-specific policies that suburbs directly bordering these areas may exhibit. An alternative proxy could be to use the RNSW, however, although it is subject to the same state policies, it is likely unsuitable because of different behaviours due to regional variations. While the PASYD proxy dataset is less visibly related to the observed pre-policy assaults (Figures 4 & 5), its method of construction is reasonable based on the data that was available for this task.

We model the joint distribution of $\{(y_t, p_t)\}$ via a vector autoregression (VAR) model using the pre-intervention data in each region (see Appendix). We then forecast the unobserved y_t^* from the conditional (normal) distribution of $y_t^* | \{p_{1:t}\}, \{y^*_{1:(t-1)}\}$ for the rest of the observation period, noting that $y_t^* = y_t$ up to the introduction of the first policy. To account for forecast variability, we generate 1,000 replicate counterfactual datasets $\{y_t^*\}$, and as a result, 1,000 difference datasets $\{D_t\}$ for subsequent analysis.

An intervention model (see Appendix) is used to analyse the structure of the difference datasets $\{D_t\}$ and attribute it to the relevant liquor policy laws. The model is a piecewise linear spline with knots at each policy promulgation time, and with policy-specific intercepts. Accordingly, the full model incorporates both instantaneous policy effects (change of intercept, c_k) and gradual over time effects (change of slope, β_k) for each policy k. "Instantaneous" effects can either be interpreted as a genuine instantaneous change due to a given policy, or as an average change in the level of assaults in the following period after accounting for over time effects. Residuals are modelled as an ARMA(p, q) model, with p and q determined by minimizing AIC scores for each difference dataset. For each region, stepwise backward selection is used to identify a reduced model (see Appendix), retaining only significant instantaneous or over time policy effects. While we recognize the potential influence of lagged effects, our methodology primarily focused on immediate and collective impacts due to the proximity of policy introductions and the scope of our study's objective.

RESULTS

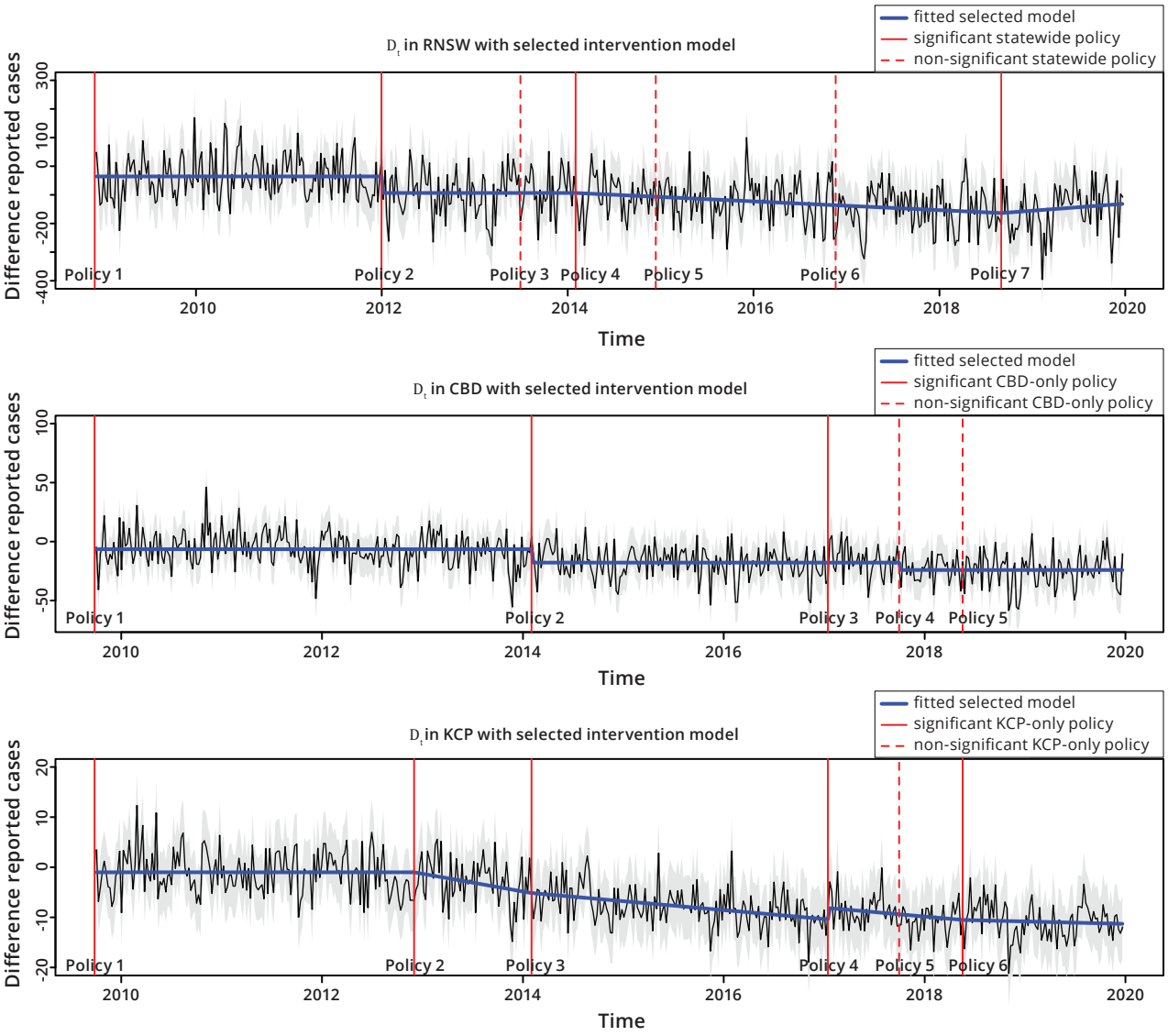
Constructing the difference datasets

The fitted VAR models produced R^2 values of (0.68, 0.60), (0.29, 0.27), and (0.18, 0.28) for RNSW, the CBD, and the KCP, respectively. These values indicate the proportion of variability in $\{(y_t, p_t)\}$ prior to the first policy, explained by the model. The relationship between $\{y_t\}$ and $\{p_t\}$ is strongest for RNSW. Because, the relationship is not perfect, especially for the CBD and KCP, some uncertainty propagates into the forecast counterfactual datasets. VAR model diagnostics, including the portmanteau test for autocorrelation, quantile-quantile plots for marginal normality, and the Henze-Zirkler multivariate normality test, all suggest reasonable fits for the models. By generating 1,000 counterfactual series for each region, 1,000 difference datasets $\{D_t\}$ are created for further analysis.

Figure 6 summarises the resulting difference datasets $\{D_t = y_t - y_t^*\}$ between the observed and counterfactual time series during the post-intervention period (2009–2019). The black solid lines represent the mean forecast at each time point, and the shaded areas indicate the central 95% simulation envelope. Visually it appears that there may be a reduction in assaults in RNSW, CBD and KCP. The difference datasets don't appear to have any remaining trend or seasonality, though there appears to be some stochastic temporal dependence. Our intended construction is that the only remaining signal in these series is attributable to the policy interventions.

9 The PDA and DDA are excluded because the alcohol restrictions operating in the CBD and KCP may displace some of the assault-related activity to this nearby area. These displacement areas have been used in previous studies examining the impact of the NSW Lockout Laws (see Menéndez et al., (2015), Donnelly and Poynton (2019) and Athanasopoulos et al., (2022)).

Figure 6. Summary of the difference time series datasets during the post-intervention period (2009-2019), for RNSW (top), the CBD (middle) and KCP (bottom). Black solid lines indicate the mean forecast value and shading the 95% simulation envelope; vertical red lines indicate the activation times of the respective areas policy interventions; blue solid lines indicate respective the fitted reduced intervention models



Policy effect estimates

For each geographical area, the full intervention model is initially fit for each of the replicated difference datasets, producing maximum likelihood estimates of the intercept and slope parameters, and associated *p*-values. A distribution of *p*-values for each parameter is available via the 1,000 replicated difference datasets. Examination of the *p*-values reveals that many parameters are not meaningfully contributing to the intervention model. To reduce model complexity and attribute changes to the most likely policies, a process of backward selection is implemented (see Appendix). The reduced intervention models only retain significant (or potentially significant) policies, and their mean response is shown in Figure 6 (blue lines). Model diagnostics cannot reject hypotheses of independent and normally distributed residuals.

Tables 3, 4, and 5 summarise the estimated effects of the selected policies in the reduced models, with the first and second rows presenting the mean estimated instantaneous (c_k) and over time (β_k) intervention effects of each policy, along with their 95% confidence intervals. These estimates indicate the expected change in the number of assaults due to each policy compared to no policy interventions

and conditional on the effects of previous policies. The third row presents the cumulative reduction or increase in assaults over all policies up to and including policy k, compared to a scenario with no policies introduced. The final row breaks down the individual percentage change contribution of each policy, which measures the contribution of policy k as a percentage change in assaults, evaluated at the last time point before the next selected policy was introduced, conditional on the effect of all previous policies.

Rest of NSW (RNSW)

By the end of the study, the combined effect of policies 1, 2, 4, and 7 resulted in an estimated 18.73% reduction in non-domestic violence-related assaults in the RNSW compared to a scenario without policy interventions. Policy 1 (Violent Venues Scheme and Six-Hour Closure Period) led to an initial decrease of 35.72 assaults, totalling a 5.05% reduction by the time policy 2 was introduced in 2012. Policy 2 (Three Strikes Scheme) contributed an instant drop of 57.72 assaults, an additional 9.66% reduction by the time policy 4 was introduced. Policy 4 (Period Licence Fee Scheme and statewide take-away alcohol restrictions) didn't have an instantaneous impact but instigated a reduction of 0.29 assaults per week, persisting until policy 7's introduction over four years later, ultimately contributing a further 10.85% reduction. Policy 7 (Tiered Industry Training Framework) led to a 0.47 weekly increase in assaults, resulting in a 6.28% increase by the study's end. Policies 3 (Small Bar Licence), 5 (Minor Sanctions Scheme), and 6 (Updated Small Bar Licence and take-away liquor trading hours extension) showed no significant changes in assault rates beyond the effects of previous policies.

Table 3. Summary of estimated policy intervention effects for statewide policies in RNSW

	Policy 1	Policy 2	Policy 4	Policy 7
Constant (c_k)	-35.72	-57.72	---	---
95% CI	(-53.87, -17.57)	(-82.99, -32.45)	---	---
Change in slope (β_k)	---	---	-0.29	0.76
95% CI	---	---	(-0.43, -0.15)	(-0.21,1.73)
Cumulative change	-5.05%	-14.22%	-23.53%	-18.73%
Individual change	-5.05%	-9.66%	-10.85%	6.28%

Sydney Central Business District (CBD)

The reduced model in Table 4 highlights three significant CBD-focused policies (1, 2, and 4), which together reduced non-domestic violence-related assaults by an estimated 44.78% compared to a scenario without policy interventions. Policy 1 (Liquor Licence Freeze) resulted in an average reduction of 15.48% in assaults. Policy 2 (Sydney CBD Entertainment Plan of Management) resulted in a subsequent 25.99% reduction following policy 1's initial decrease. Policy 4 (Late-night drinks restrictions lifted on CBD and Kings Cross small bars) contributed a further 11.72% reduction. Policies 3 (30-min relaxation of Lock Out Laws for Live Entertainment Venues) and 5 (Liquor Licence Freeze lifted for entertainment and arts venues) showed no apparent change in assault rates.

Table 4. Summary of estimated policy intervention effects for CBD centric policies in the CBD

	Policy 1	Policy 2	Policy 4
Constant (c_k)	-6.48	-11.37	-6.28
95% CI	(-9.176, -3.784)	(-15.35, -7.39)	(-11.06, -1.51)
Change in slope (β_k)	---	---	---
95% CI	---	---	---
Cumulative change	-15.48%	-37.45%	-44.78%
Individual change	-15.48%	-25.99%	-11.72%

Kings Cross Precinct (KCP)

Table 5 presents the results for KCP-focused policies. After backward model selection, the reduced model identifies five significant parameter contributions across five policies. Collectively, these policies decreased non-domestic violence-related assaults by an estimated 84.04% compared to a scenario without policy interventions. Policy 1 (Liquor Licence Freeze) corresponded to an average 11.21% reduction in assaults within the KCP. Policy 2 (Kings Cross Plan of Management) reduced assaults by 47.53% over time (by -0.07 per week) up to the start of policy 3. Policy 3 (Sydney CBD Entertainment Plan of Management, Long-Term Banning Orders, and ID Scanners in High-Risk Venues in Kings Cross) slowed the reduction in weekly assaults to (-0.07+0.03=)-0.04 per week, resulting in a 61.86% reduction in assaults by the introduction of policy 4. Policy 4 (30-min relaxation of lockout laws for live entertainment venues) led to an instantaneous 36.02% increase in assaults. Policy 6 (Liquor licence freeze lifted for entertainment and arts venues) further slowed the weekly reduction in assaults to -0.02 per week, resulting in a decrease of 39.89% in assaults by the end of the study. Policy 5 (Late-night drinks restrictions lifted on CBD and Kings Cross small bars) showed no apparent change in assault rates.

Table 5. Summary of estimated policy intervention effects for KCP centric policies in the KCP

	Policy 1	Policy 2	Policy 3	Policy 4	Policy 6
Constant (c_k)	-1.01	---	---	2.28	---
95% CI	(-1.9,-0.12)	---	---	(-0.61,5.17)	---
Change in slope (β_k)	---	-0.07	0.03	---	0.02
95% CI	---	(-0.10, -0.04)	(-0.02, 0.08)	---	(-0.03, 0.07)
Cumulative change	-11.21 %	-53.41%	-82.23%	-75.83%	-84.04%
Individual change	-11.21%	-47.53%	-61.86%	36.02%	-33.97%

DISCUSSION

This research aimed to quantify the effects of individual liquor licensing policies introduced in NSW over the last decade on rates of violent crime. Evaluating the impact of these policies was challenging, given the short time intervals between their promulgation and their often-interconnected nature. This issue is commonly faced when assessing the impact of alcohol policies. To address this problem, we combined several policies implemented in quick succession, but this approach makes it difficult to determine which element of the intervention package was driving the observed changes in crime. This underscores the need for policy makers to look for opportunities where singular policy changes can be introduced and tested to identify the specific levers that produce the greatest benefit in terms of maintaining public safety.

Overall, our method was able to establish that the suite of public safety measures introduced in the last decade by the NSW Government have contributed to a significant decline in non-domestic assaults both in Sydney and across NSW. By the end of 2019, the number of non-domestic violence-related assaults in NSW had reduced by an estimated 19% (56,695 cases) from levels that would have been achieved had no alcohol control policies been introduced. Our results also suggest a significant decline in violent crime in the Sydney CBD, with a 45% (7,677 cases) reduction due to the controls implemented since 2008. Much larger effects were observed in the KCP, though primarily due to lower overall assault numbers, with an estimated 84% (3,117 cases) decline in the number of non-domestic violence-related assaults above what would be expected if no policy changes had occurred.

When considering the impact of individual policies, our research suggests that three policies contributed most to the statewide decline: the Violent Venues Scheme and mandatory six-hour closure periods for licensed venues; the Three Strikes Scheme; and the Periodic Licence Fee Scheme and statewide take-away alcohol restrictions. The beneficial impact of the Violent Venues scheme and the mandatory six-hour closure has been documented elsewhere using different methods (Menéndez, Tusil & Weatherburn, 2015). Our findings also indicate additional benefits from the statewide introduction of the Periodic Licence Fee Scheme and restrictions on take-away alcohol sales. It is impossible to know which of these policies were driving the observed effect since they were introduced very close in time (approx. 3 weeks), but the evidence for risk-based licensing (RBL) is not strong (see Curtis et al., 2019a; Mathews & Legrand, 2014; Nepal et al., 2019).

Consistent with other research we also find a significant impact of the lockout laws on non-domestic assaults in the Sydney CBD and Kings Cross areas (Athanasopoulos et al., 2022; Donnelly & Poynton, 2019; Kypri & Livingston, 2020; Menéndez, Kypri & Weatherburn, 2017). The falls in violent crime estimated here are somewhat larger than those reported in previous papers. There are two possible reasons for this: (1) we have only measured the impact of the lockout laws up until the next new policy was implemented in the precinct areas (i.e., until January 2017)[10] and (2) the use of a counterfactual dataset allowed us to isolate the impact of the lockout laws from the effect of other statewide policies.

However, our results also indicate that the lockout laws were just one of several initiatives introduced in the Sydney CBD and Kings Cross precincts over the last decade (or so) that worked to enhance public safety in these areas. Implementation of a Liquor Licence Freeze in the Sydney CBD and Kings Cross areas in 2009, which prevented the granting of new licences for hotels, nightclubs, registered clubs, and packaged liquor outlets, was associated with sizeable reductions in non-domestic assault in both sites. This result is consistent with evidence linking higher density of liquor outlets with increased rates of violence (Gruenewald et al., 2006; Livingston, Chikritzhs, & Room, 2007) - although this may not extend to all venue types (see for example the reductions in assaults observed in the CBD after restrictions on small bars were loosened). The introduction of a Liquor Accord in the Kings Cross precinct in December 2012

10 Donnelly and Poynton (2019) report that the decline in incidents of police recorded assault diminished over time, particularly in the Sydney CBD. They analysed data up until end of March 2019 and estimated a 4% reduction in non-domestic assault in the CBD and 53% reduction in the KCP over the 62-month period.

was found to have further beneficial effects on violent crime; a finding that is consistent with the more robust evaluations of community-based multicomponent programmes (see Miller et al., 2011; Quigg et al., 2018; Warpenius, Holmila & Mustonen, 2010).

The methodology employed in this study presents a pioneering approach, yet it is imperative to acknowledge certain limitations. Firstly, it is essential to recognize that the seemingly substantial percentage changes documented in this research stem from low weekly assault figures. Consequently, caution is warranted when interpreting the significance of these findings, as the inherent uncertainty may be propagated into the forecast counterfactual. A second limitation of our study is that trends in non-domestic assault were observed only up until the end of 2019, which prevents us from evaluating more recent liquor licensing policies. This was to avoid the impact of the COVID-19 pandemic response where the NSW Government issued various public orders, including ordering the closure of all licensed venues and many other retail outlets. Future research should continue to monitor trends in non-domestic assault in these areas to assess any change in crime trends emerging from these policy reversals.

A final important limitation is that our intervention model assumes that the effects of policies continue indefinitely (and linearly) from their introduction. This means that it is difficult to represent, for example, the effect of a policy that results in an initial weekly reduction in assaults before levelling off to a new constant value. Rather, this levelling off will tend to be attributed to an increase in the weekly assault rate due to a subsequent policy. This latter model could be appropriate to account for the apparent slowing of the weekly decline in assaults following policy 2 but attributed to policy 3 in the KCP. This could be avoided by introducing a new parameter per policy into the intervention model that limits the over-time linear scope of each policy or expressing the impact of each policy as an exponentially decaying function with an estimated rate. However, initial exploration of modelling with this approach resulted in scope/rate parameters that were difficult to estimate, particularly when the levelling off could occur after the introduction of later policies, and so the parameters are conflated with later policy effects. That is, unless one is willing to make strong functional assumptions on how assault numbers will respond to policy interventions, it is challenging to completely disentangle the effects of individual policies when these effects overlap.

While our study identified several successful liquor licensing interventions introduced in NSW in the last decade, most of these policies feature one of two key elements: (1) restrictions on late-night (or 24-hour) trading of licensed premises and (2) targeted enforcement focusing on the most high-risk venues. This research therefore adds to the mounting evidence that restricting trading hours of licensed venues can substantially reduce the risks associated with acute alcohol intoxication and can be a cost-effective crime reduction strategy when combined with enforcement that targets the small number of premises that account for the majority of harm (Burton et al., 2017). Whether further restrictions of this nature in NSW and the Sydney CBD can achieve similar-sized benefits in the future is not known.

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APPENDIX

Vector Auto Regression (VAR) Model

A VAR model is a natural extension of the univariate autoregressive AR (p) model to dynamic multivariate time series. The VAR model has proven to be useful for describing the dynamic behavior of time series and for forecasting. Forecasts from VAR models are useful because they can be made conditional on the potential future paths of specified variables in the model (here we will predict y_t given p_t).

In its basic form, a VAR (p) model operating on a vector of k endogenous variables $y_t = (y_{1t},..., y_{kt})'$ is defined as

$$\boldsymbol{y}_t = C + A_1\boldsymbol{y}_{t-1} + \cdots + A_p\boldsymbol{y}_{t-p} + \boldsymbol{e}_t,$$

where C is a k-dimensional constant vector, the A_i are $k \times k$ coefficient matrices for $i = 1, \ldots, p$, and $\boldsymbol{e}_t$ is a k-dimensional zero-mean white noise process with covariance matrix Σ. In the present setting, $k = 2$, and $\boldsymbol{y}_t = (y_t, p_t)'$, where both y_t and p_t contain related seasonal and trend terms. We assess the seasonal strength as described by Wang et al. (2006) for the whole of NSW and VIC. The R^2 values are 0.5644 and 0.64, respectively, signifying notable weekly seasonality. Hence, we model $\boldsymbol{y}_t = (y_t, p_t)'$ as

$$\boldsymbol{y_t} = C + A_1\boldsymbol{y}_{t-1} + \cdots + A_p\boldsymbol{y}_{t-p} + \boldsymbol{T}_t + \boldsymbol{S}_t + \boldsymbol{e}_t,$$

where T_t and S_t are 2-dimensional trend and seasonal vectors (Pfaff, 2008). Explicitly, we have

$$\begin{pmatrix} y_t \\ p_t \end{pmatrix} = \begin{pmatrix} C_1 \\ C_2 \end{pmatrix} + \begin{pmatrix} a_{11}^{(1)} & a_{12}^{(1)} \\ a_{21}^{(1)} & a_{22}^{(1)} \end{pmatrix}\begin{pmatrix} y_{t-1} \\ p_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} a_{11}^{(p)} & a_{12}^{(p)} \\ a_{21}^{(p)} & a_{22}^{(p)} \end{pmatrix}\begin{pmatrix} y_{t-p} \\ p_{t-p} \end{pmatrix} + \begin{pmatrix} T_{1t} \\ T_{2t} \end{pmatrix} + \begin{pmatrix} S_{1t} \\ S_{2t} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix}, \quad \text{(Equation 1)}$$

where $E(e_{it}e_{jt}) = \sigma_{ijt}^2$ denotes the elements of Σ, for $\mathrm{i} = 1,2$. Note that each of y_t and p_t are regressed on lagged versions of both series. The coefficients of a VAR (p) model can be estimated efficiently by least-squares or maximum likelihood estimation and the degree of the process p can be determined via standard goodness of fit tests and the AIC. This model is easily fitted using the vars package in R. In the following we assume that the error vector $(e_{1t}, e_{2t})'$ is normally distributed with zero mean and time-constant variance, that $T_{i,t+1} = \alpha\mathrm{t}$ is a simple linear trend, and $S_{i,t}$ is an annual seasonal component with a cycle of 52 observations (1 per week).

After fitting the chosen VAR model over the 2000-2008 data $\{(y_t, p_t)'\}$, as this model then describes the relationship between the proxy data p_t and the counterfactual dataset $\{y_t^*\}$, we can then forecast the unobserved counterfactual dataset from 2009 onwards given the fitted model and the observed values of p_t from 2009-2019. Explicitly, from Equation 1, $(y_t, p_t)'$ follows the bivariate normal distribution

$$\begin{pmatrix} y_t \\ p_t \end{pmatrix} \sim N\left(\begin{pmatrix} \mu_{1t}^* \\ \mu_{2t}^* \end{pmatrix}, \quad \begin{pmatrix} \sigma_{11}^2 & \sigma_{12}^2 \\ \sigma_{21}^2 & \sigma_{22}^2 \end{pmatrix}\right),$$

where

$$\mu_{1t}^* = C_1 + a_{11}^{(1)}y_{t-1} + a_{12}^{(1)}p_{t-1} + \cdots + a_{11}^{(p)}y_{t-p} + a_{12}^{(p)}p_{t-p} + T_{1t} + S_{1t},$$
$$\mu_{2t}^* = C_2 + a_{21}^{(1)}y_{t-1} + a_{22}^{(1)}p_{t-1} + \cdots + a_{21}^{(p)}y_{t-p} + a_{22}^{(p)}p_{t-p} + T_{2t} + S_{2t},$$

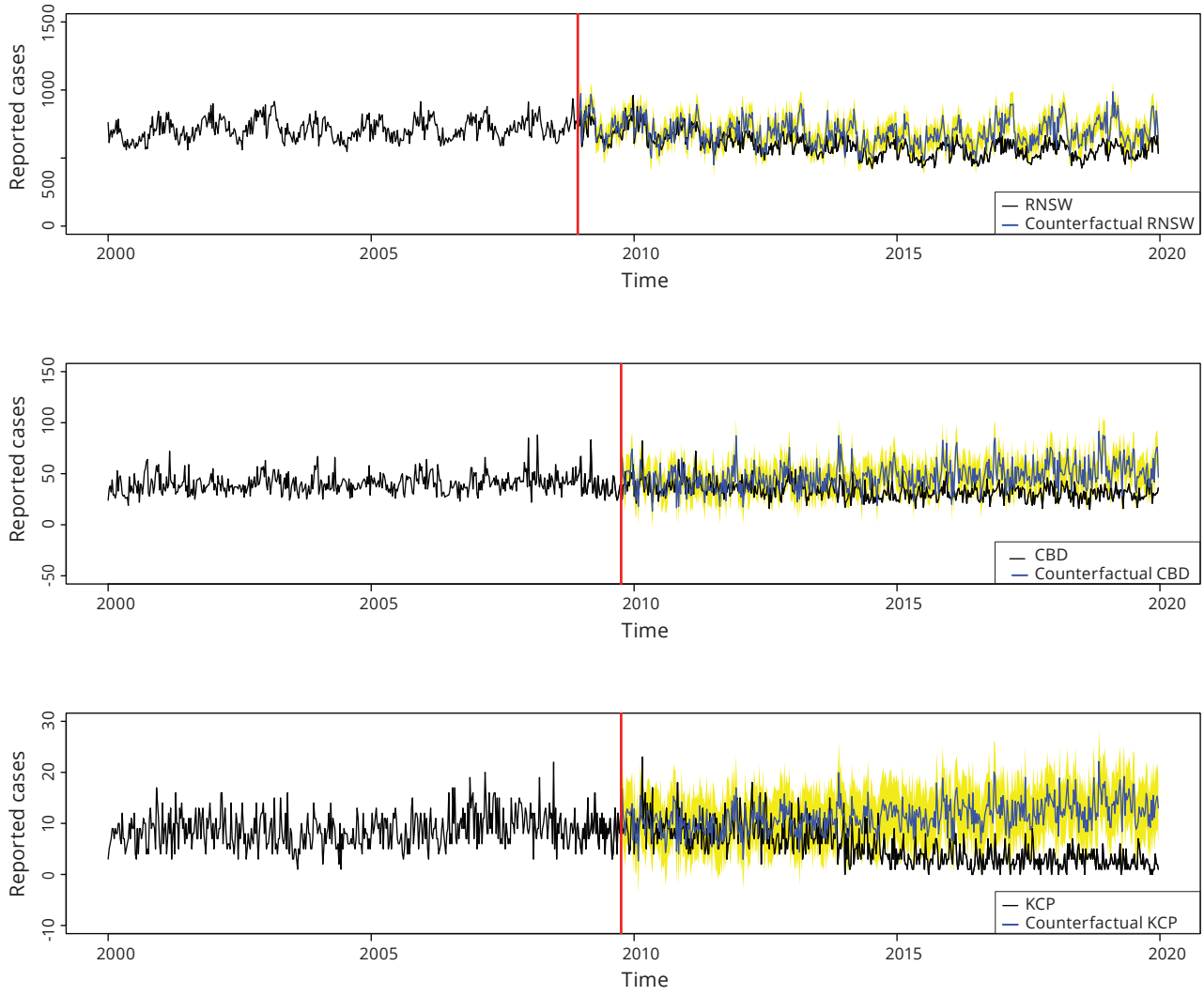
and so the conditional distribution of y_t (i.e. y_t^*) is

$$y_t^* | \{p_{1:t}\}, \{y_{1:(t-1)}^*\} \sim N\left(\mu_{1t}^* + \sigma_{11}^2/\sigma_{22}^2(p_t - \mu_{2t}^*), \quad \sigma_{11}^2 - \sigma_{12}^2\sigma_{21}^2/\sigma_{22}^2\right),$$

in [2009, 2019]. Hence, we can forecast the unobserved portion of $\{y_t^*\}$ using the above equation and construct the difference between the observed and counterfactual datasets, $D_t = y_t - y_t^*$, for each geographical area. Because the forecasts are stochastic, we simulate 1,000 $\{y_t^*\}$, and hence 1,000 $\{D_t\}$ under the fitted VAR model.

Figure A1 displays the observed $\{y_t\}$ (black lines) and forecast counterfactual datasets $\{y_t^*\}$ (blue line for mean forecast, shaded area for central 95% simulation envelope) based on the fitted model. The counterfactual mean is above the observed data for RNSW, suggesting that liquor licensing changes may have reduced assault rates. The impact is less clear for the CBD, but there is a hint of reduction in assaults for KCP starting from ~2014.

Figure A1. Time series of actual ($\{y_t\}$; black line) and counterfactual ($\{y_t^*\}$; blue line) non-domestic assault time series; Counterfactual series is illustrated by forecast mean (solid line) and 95% central simulation envelope (shaded area)



The intervention model

We specify an intervention model to analyse the structure in the difference datasets $\{D_t\}$, which can then be attributed to the relevant liquor policy laws. Intervention analysis provides a framework for assessing the effect of an intervention on a time series (Box & Tiao, 1975). In the following we consider that interventions can have an instantaneous effect on assaults, in addition to a further change over time. Accordingly, we construct an intervention model incorporating both intervention-specific intercepts and a piecewise linear spline, with knot points placed at the intervention occurrence times.

We first specify

$$x_{kt} = \begin{cases} 0 & \text{if} \quad t < \tau_k \\ 1 & \text{if} \quad t \geq \tau_k \end{cases},$$

which is an indicator variable that takes the value 0 for $t < \tau_k$, where τ_k is the time that intervention k occurs $(k = 1, \ldots, K)$, and takes the value 1 otherwise. We can then specify the full intervention model as

$$D_t = x_t' c + \beta_1 t + \sum_{i=2}^{K} \beta_k (t - \tau_k)_+ + \epsilon_t, \qquad \text{(Equation 2)}$$

for $t \geq \tau_1$, where $x_t = (x_{1t}, \ldots, x_{Kt})'$ is a vector of dummy variables, $\mathbf{c} = (c_1, \ldots, c_K)'$ is a vector of constants (intercepts) quantifying the instantaneous change in D_t due to each intervention, $\beta_1, \ldots, \beta_K$ are slopes quantifying the time-based effect of each intervention, $(a)_+ = \max(0, a)$, and ϵ_t is an error term. Note that the (linear) slope of the intervention model after the j-th intervention (and before the $(j+1)$-th intervention) is $\sum_{k=1}^{j} \beta_k$. This means the interpretation of β_k is as the change in slope of the intervention model due to intervention k given all previous interventions. Because it is unlikely that the difference datasets are likely to satisfy independent errors, we specify $\epsilon_t \sim ARMA(p, q)$, where p and q be determined by e.g., minimising AIC scores, for each difference dataset in turn.

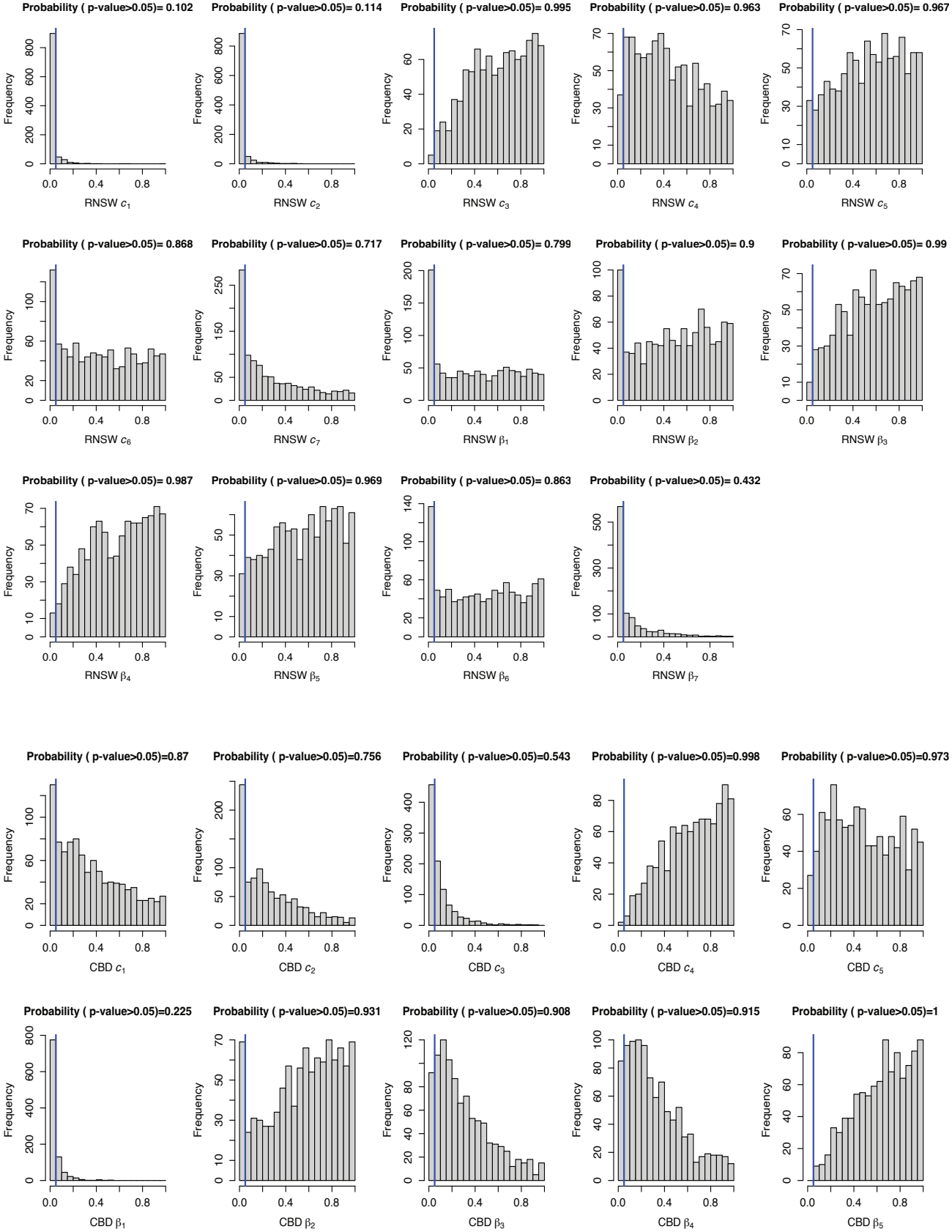
P-value histograms

Figure A2 presents histograms of the *p*-values for all intervention model parameters fitted to each of the 1,000 simulated difference datasets, in each of RNSW (top panel), the CBD (middle) and the KCP (bottom). Where the *p*-values are all small (e.g., RNSW, top panel, first plot: c_1), this is strong evidence that the policy has had a measurably significant effect (in the context represented by this parameter). Where there is a peak of small *p*-values and a tail of larger *p*-values (e.g., RNSW, top panel, 8th plot: β_1), this is evidence that the policy has a potentially significant effect. Where the *p*-values are firmly away from small values (e.g., RNSW, top panel, 3rd plot: c_3), this is evidence that the policy has had little measurable effect.

From Figure A2 it is apparent that there are many parameters that are not meaningfully contributing to the intervention model. To reduce intervention model complexity (and in doing so, attribute change in the difference datasets to the policies that most likely drive the change) we implement a process of backward selection. For each area (RNSW, CBD, KCP), for those parameters that are not making a meaningful contribution, we identify the parameter that is contributing the least to the fitted model from the distribution of *p*-values. Where it is not obvious which parameter that is, we choose the one with the largest number of *p*-values greater than 0.05 (this number is reported in the title of each plot). We then re-fit the intervention model without this parameter (over all 1,000 replicate difference datasets), generate the subsequent distribution of *p*-values for the model parameters, and repeat the process until only measurably significant or potentially significant parameter effects remain.

The *p*-value histograms of the resulting reduced intervention models for each area are shown in Figure A3. All selected parameters have measurably significant or potentially significant effects.

Figure A2. Full intervention model: Histograms of *p*-values for the hypothesis $c_k = 0$ versus $c_k \neq 0$, and $\beta_k = 0$ versus $\beta_k \neq 0$ for each of the $k = 1,\ldots,7/5/6$ policies in RNSW (top), the CBD (middle) and KCP (bottom), over all 1,000 difference dataset replications. Vertical line indicates $p = 0.05$. Proportion of *p*-values greater than 0.05 is shown in plot title



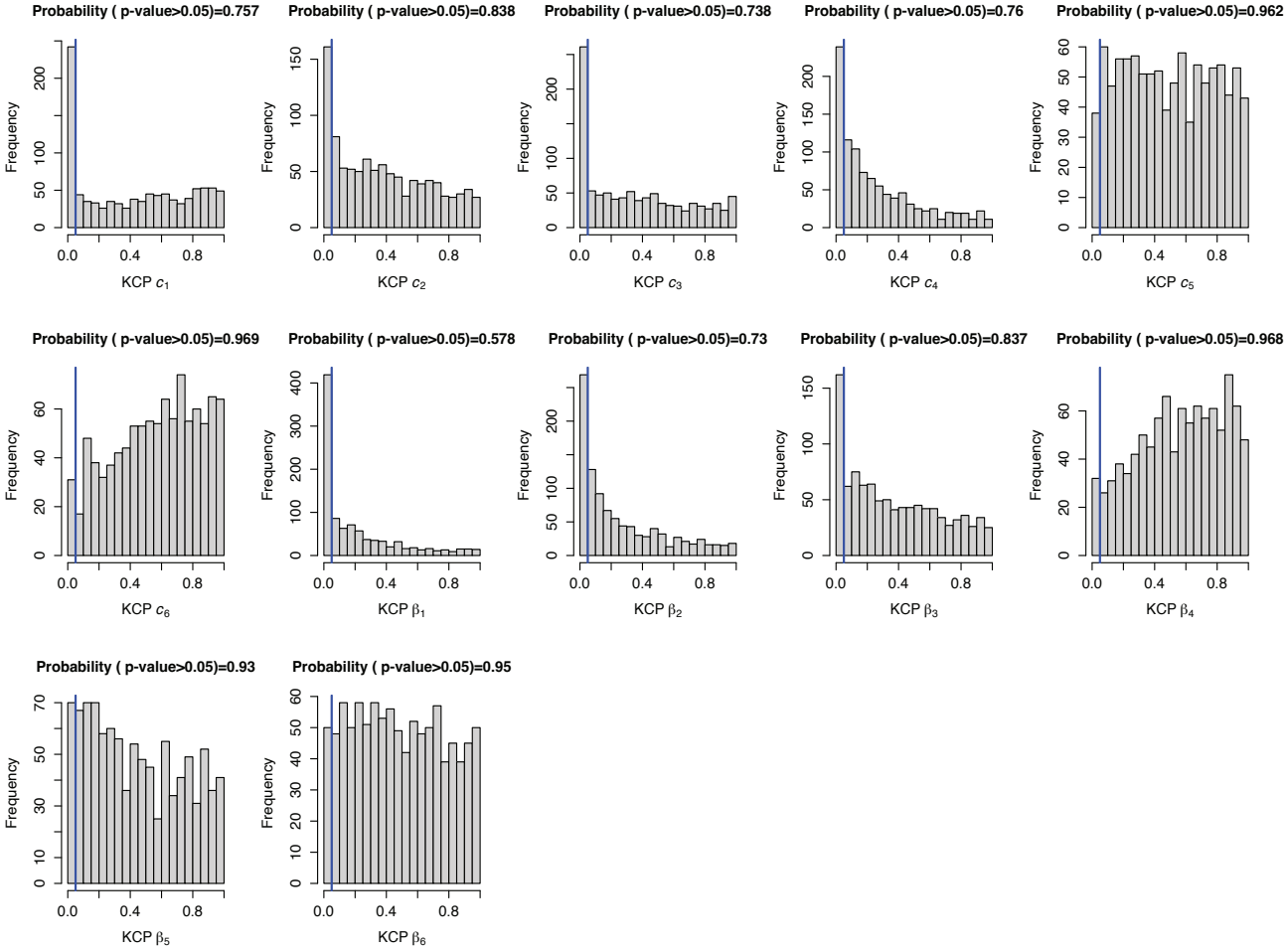
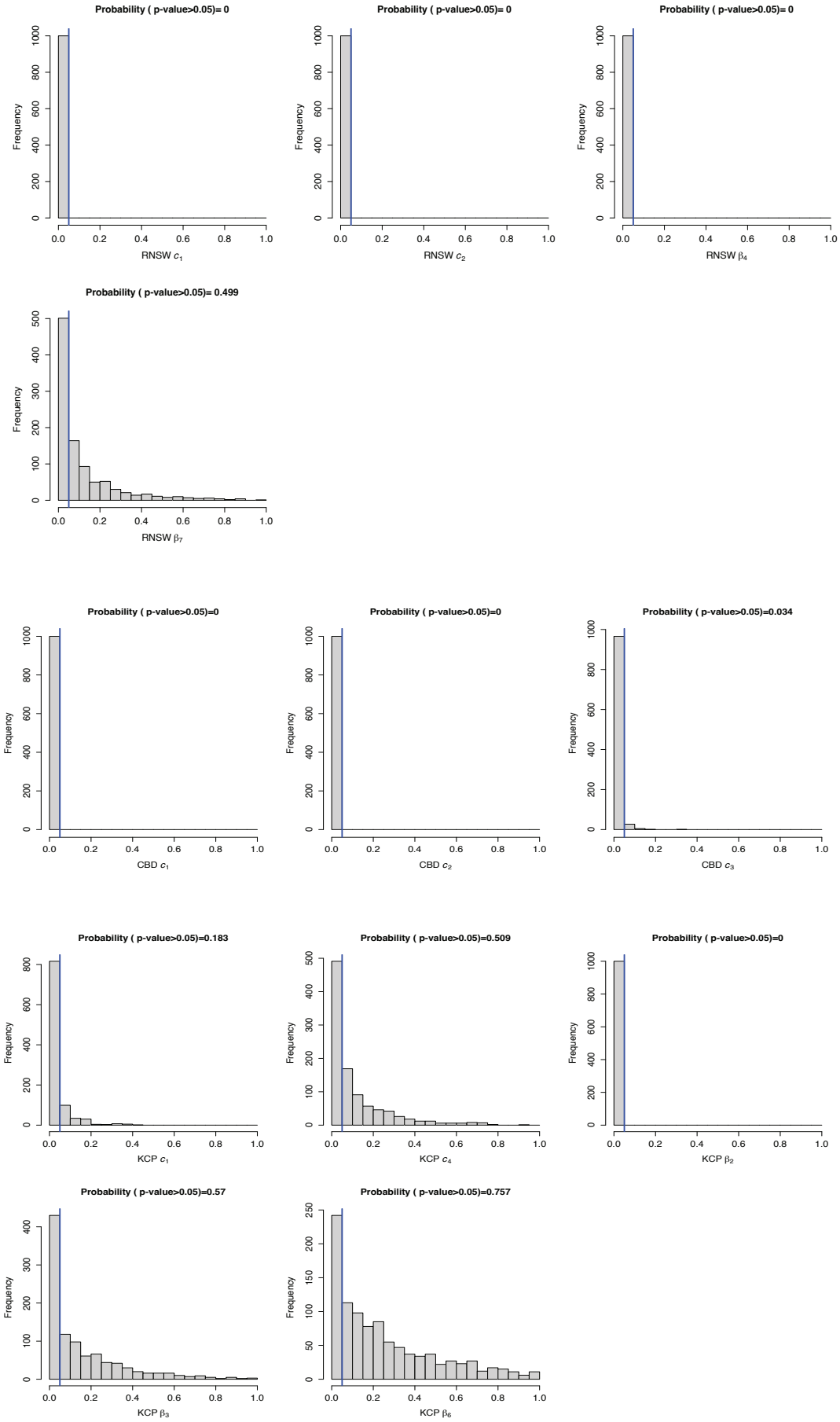

Probability (p-value>0.05)=0.757
Probability (p-value>0.05)=0.838
Probability (p-value>0.05)=0.738
Probability (p-value>0.05)=0.76
Probability (p-value>0.05)=0.962
Probability (p-value>0.05)=0.969
Probability (p-value>0.05)=0.578
Probability (p-value>0.05)=0.73
Probability (p-value>0.05)=0.837
Probability (p-value>0.05)=0.968
Probability (p-value>0.05)=0.93
Probability (p-value>0.05)=0.95
Frequency
KCP c_1
KCP c_2
KCP c_3
KCP c_4
KCP c_5
KCP c_6
KCP β_1
KCP β_2
KCP β_3
KCP β_4
KCP β_5
KCP β_6

Figure A3. Reduced intervention model: Histograms of *p*-values for the hypothesis $c_k = 0$ versus $c_k \neq 0$, and $\beta_k = 0$ versus $\beta_k \neq 0$ for each of the $k = 1,\ldots,7/5/6$ policies in RNSW (top), the CBD (middle) and KCP (bottom), over all 1,000 difference dataset replications. Vertical line indicates *p*=0.05. Proportion of *p*-values greater than 0.05 is shown in plot title

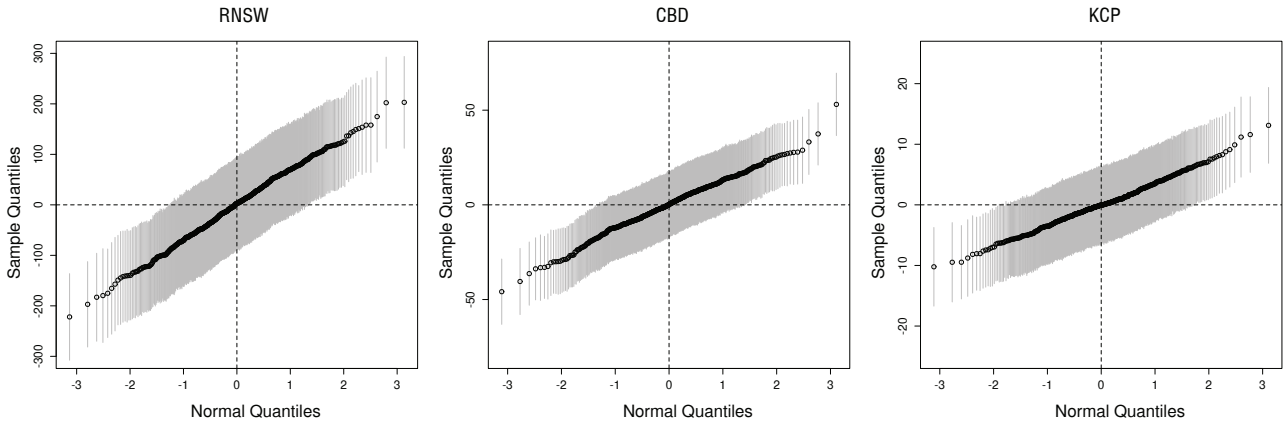


Intervention model residuals

When fitting an ARMA (p, q) process to the intervention model residuals, for RNSW we obtained mean values (over the 1,000 replicate datasets) of p = 2.688 and q = 2.860, for the CBD we obtained means of p = 2.792 and q = 2.588 and for the KCP we obtained means of p = 2.689 and q = 2.674, indicating that there is still a lot of structure in the difference datasets after accounting for policy interventions. Figure A4 presents qq-plot summaries of the residuals of the 1,000 replicate reduced intervention model fits. Shapiro-Wilks tests for normality for each replicate effectively can't reject normality for the RNSW (with a central 95% interval of *p*-values of [0.037, 0.972], and 37 out of 1,000 *p*-values below 0.05) and the CBD (with an interval of [0.018, 0.961], and 61 *p*-values below 0.05). There is more support for possible deviations from normality for the KCP (with an interval of [0.024, 0.966], and 60 *p*-values below 0.05).

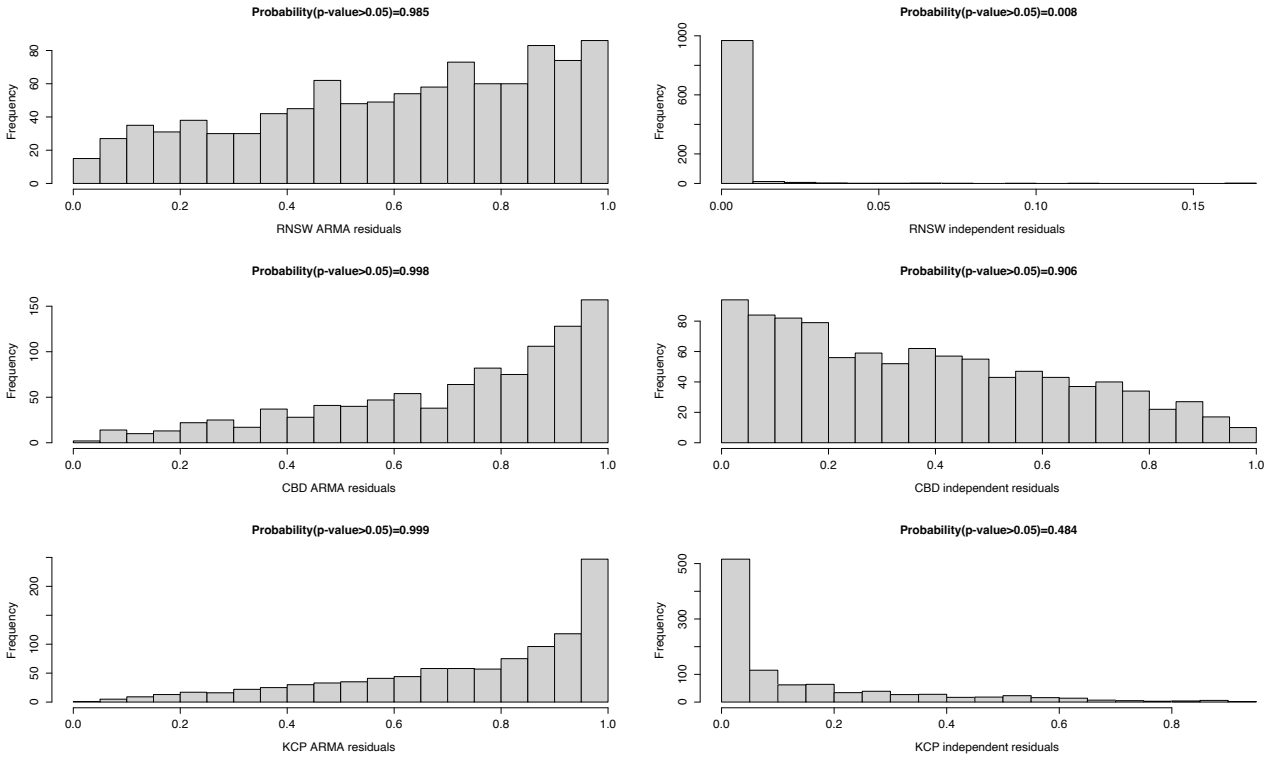
Figure A5 illustrates histograms of *p*-values from performing a Ljung-Box test for zero correlations in a time series for each region (rows) and assuming ARMA (left column) or independent (right column) intervention model residuals. From the left column it is apparent that the residuals for each innovation model with an ARMA error structure broadly do not reject (e.g., $p > 0.05$) the hypothesis of zero correlations, whereas assuming independence of residuals is clearly inappropriate.

Figure A4. Quantile-quantile plots versus the normal distribution for the reduced intervention model residuals for each geographical location. Each point represents the mean value of the quantile over the 1,000 dataset replicates, with a central 95% simulation envelope represented by the vertical grey line



(a) RNSW (b) CBD (c) KCP

Figure A5. Histograms of p-values of the Ljung-Box test for intervention model residuals. Rows correspond to RNSW (top), the CBD (middle) and the KCP (bottom), and columns denote a model with ARMA (left column) or independent (right column) noise



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