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Risk-based licensing of alcohol venues and emergency department injury presentations in two Australian states

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Abstract

Background: Risk-based licensing (RBL) is among the more recent policy interventions to reduce alcohol-related harm in and around licensed venues. RBL sets licence fees to reflect the venue's propensity to cause harm as a means of encouraging operators to improve their practices. We assessed whether the introduction of RBL in the Australian states of Queensland and Victoria was associated with a reduction in the incidence of emergency department (ED) injury presentations.

Methods: We employed an interrupted time series design using Prais-Winsten and Cochrane-Orcutt regression modelling to estimate step and slope parameters in injury incidence rates in each state. We defined the population as residents of the state, aged 15-54 years, the age group we considered most likely to be exposed to the night-time economy. To reduce noise, we confined cases to presentations during times previously identified as correlated with a high probability of alcohol involvement, namely 'high alcohol hours' (HAH). We adjusted our models for the alcopops tax, implemented shortly before RBL, and for assaults during low alcohol hours (LAH) as a proxy for other risk factors for assault.

Results: RBL was not associated with an overall reduction in the incidence of ED injury presentations during HAH in Queensland (β=0.003; 95% CI: -0.010, 0.003, p=0.318) or Victoria (β=-0.010; 95% CI: -0.021, 0.001, p=0.087). Post-hoc subgroup analyses showed a reduction in ED injury presentations among men aged 20-39 years in Victoria (β=-0.026; 95% CI:-0.012, -0.040, p-0.0003) but this was not replicated in Queensland.

Conclusion: There was little evidence that RBL affected the incidence of ED presentations for injury. This may be due to weak financial penalties being applied to venues assessed as high-risk.

Key words: emergency department; alcohol-related harm; liquor licensing

Alcohol-related intentional and unintentional injury often occurs in or around licensed premises. For example, in a survey undertaken in the entertainment districts of five Australian cities, 17% of participants reported having sustained unintentional injury because of their drinking in the past three months (Coomber et al., 2017). Underpinning such findings is evidence of a sharply increasing injury risk associated with higher blood alcohol levels; a systematic review and meta-analysis of case-control and case-crossover studies estimated that the odds of intentional and unintentional injury increased by 38% and 32%, respectively, for every 10g ethanol (1 *standard drink* in Australia) consumed (Taylor et al., 2010).

Various interventions have been introduced to reduce alcohol-related harm in and around licensed venues internationally (Graham & Homel, 2008), and specifically in Australia (Miller, Curtis, Chikritzhs, & Toumbourou, 2015). A recently-implemented intervention, Risk-Based Licensing (RBL), is an alcohol-licensing framework for on-premise venues, based loosely on responsive regulation theory, whereby fees for liquor licenses are levied according to risks associated with the venue (e.g., previous violations, size, etc.). Australian RBL schemes require venues determined to be riskier to pay a higher annual liquor license fee, whereas whereas the only other place to implement RBL outside Australia and New Zealand, namely Ontario, Canada, used RBL to target enforcement resources rather than for fee setting. Roche and Steenson (2013) have proposed that RBL motivates licensees to adopt practices that reduce their level of risk in order to reduce fees. They suggest that the approach moves from reactive regulation to one that is proactive and preventative. They note, however, that RBL also demonstrates a regulator's willingness to accept a certain level of risk, potentially weakening licensees' resolve to comply with the regulatory regime, particularly where the penalty for non-compliance is insignificant.

RBL was introduced in the Australian Capital Territory (ACT) in December 2010. Mathews and Legrand (2013) found that from May 2010 to December 2012, there was a 25% decline in alcohol-related offences deemed relevant to RBL (e.g. common assault, property damage) but also a 21%

decline in all police-recorded offences, i.e., no evidence that RBL was effective. Stakeholder interviews revealed that alongside RBL there was additional policing of licensed venues overall (Mathews & Legrand, 2013), which, they proposed, may have exerted generalised downward pressure on offending. Mathews and Legrand suggested that the greater presence of police may have initially increased the number of offences detected (as seen in the first year of RBL in the ACT), and then decreased the number of offences through deterrence (Mathews & Legrand, 2013).

The current study focusses on the Queensland and Victorian RBL schemes, introduced in January and August 2009, respectively. In Victoria, risk is assessed on trading hours, compliance history (i.e., breaches of liquor license conditions such as serving an intoxicated person), and venue capacity (see https://www.vcglr.vic.gov.au/sites/default/files/liquor_licence_fees_july_2018_final.pdf). In Queensland risk is assessed on trading hours and compliance history (see https://publications.qld.gov.au/dataset/olgr-publications/resource/a622ec53-72e8-4812-a7b7-f159899df608). Trading hours is the only one of the three criteria based on published research evidence. For example, Stockwell and Chikritzhs (2009) concluded that increased trading hours were associated with higher risk of a variety of alcohol-related harm, and Australian evaluations concluded that restricting trading hours resulted in a reduction in assaults (Kypri, Jones, McElduff, & Barker, 2011; Kypri, McElduff, & Miller, 2014, 2016; Miller et al., 2014; Miller et al., 2012). The most recent systematic review on this topic found strong evidence to support reducing trading hours for on-premise venues to reduce rates of violence (Wilkinson, Livingston, & Room, 2016).

Effects of venue capacity on alcohol-related harm has received less attention in the peer-reviewed literature. Homel and Clark (1994) found that there was only a weak relationship the between size of a venue and physical violence. Most research in this area has focused on issues with crowding and aggression (Chikritzhs, 2009), finding that if people experience crowding negatively (such as waiting at the bar or for the toilet), aggression is more likely (MacIntyre & Homel, 1997). A review by

Graham and Homel (2008) found that larger numbers of patrons within venues was associated with an increased risk of aggression, however, the number of people within a venue was not associated with a greater risk of physical or severe aggression, and the association was not observed across all studies. They suggest possible explanations for this finding, including that an increased number of people provides more potential targets for aggression by motivated offenders, combined with less guardianship due to the difficulty of monitoring a large venue. They also noted that a higher incidence of aggression may merely reflect greater patron numbers (i.e., increased person hours of exposure). Lastly, they argue that venue size may influence aggression through its impact on crowding, noise, and level of intoxication, all of which might increase patron irritation ability (i.e., greater risk per person hour of exposure).

Compliance history is the most complex of all the RBL criteria, given the heavy weighting it applies to supply of liquor offences. While intoxication levels are related to many problems in licensed premises (Graham, Osgood, Wells, & Stockwell, 2006), enforcement of the relevant legislation is often complicated by legislative definitions that are broad and difficult to prosecute.

RBL in these states has not yet been evaluated and has been in place for long enough to estimate post-RBL trends in outcomes of interest such as emergency department (ED) presentations. ED presentation data may be more sensitive to the incidence of assault and violence than police recorded data (Sutherland, Sivarajasingam, & Shepherd, 2002). Although other states (ACT and New South Wales (NSW)) have introduced forms of RBL, ED presentation data were unobtainable for the ACT. We excluded NSW because RBL regulations there have changed over time, with additional components (compliance history and location risk loading) introduced in March 2017. Because alcohol consumption of the attended or other involved parties is not routinely reported in ED data, we investigated the impact of RBL on ED presentations during times when there is a high incidence of injury associated with alcohol consumption (i.e., 'high alcohol hours' (HAH)) (Chikritzhs, Stockwell, Heale, Dietze, & Webb, 2000).

In accordance with responsive regulation theory we hypothesised that the introduction of RBL in Queensland and Victoria would be associated with a reduction in the incidence of ED presentations for injury during HAH.

Method

This study is a retrospective analysis of archival records recorded in EDs in Victoria and Queensland.

Design: Interventions

i) Risk-Based Licensing

RBL was introduced to Queensland in January 2009, and to Victoria in August 2009.

Data

ED injury presentations were defined as conditions allocated an ICD-10 S or T code (World Health Organization, 2004). ED injury presentation data were obtained for Victoria from 2000-2015; however, Queensland ED data were only available from 2007-2015.

Definitions of high alcohol hours (HAH) and low alcohol hours (LAH)

HAH and LAH were defined by Chikritzhs et al. (2000) (see Supplementary Table 1), on the basis of breath alcohol readings obtained from drivers involved in serious road crashes (including fatalities and hospitalisation) between 1990 and 1997 in all Australian states and territories, were converted to blood alcohol concentrations (BACs). They identified HAH as times of each day of the week when the proportion of fatalities with driver BACs exceeded the legal driving limit (0.05g/dL by $\geq$1 standard deviation above the mean proportion across all hours. LAH were times of day when the proportion of fatalities with driver BACs exceeded the legal driving limit (0.05g/dL) was $\geq$1 standard deviation below the mean proportion across all hours.

Outcome: monthly ED injury presentation rates during HAH

The study outcome was the number of ED injury presentations during HAH per month in each state (Victoria and Queensland). Monthly counts were converted to monthly rates per 10,000 state population using the Estimated Residential Population for each state obtained from the Australia Bureau of Statistics, 2017, to account for changes in population. We utilised data from people aged 15-54 years, on the premise that this population was most likely to be exposed to conditions affected by RBL, given they are substantially more likely than children and older people to drink in licensed premises (Callinan, Livingston, Room, & Dietze, 2016). Furthermore, injuries among those aged over 55 years of age are dominated by falls, the majority of which are not attributable to alcohol (Ridolfo & Stevenson, 2001).

Control variables

We used the same population denominators applied to HAH to calculate ED presentation rates for LAH (specified in Supplementary Table 1). We included in the models a binary indicator variable representing the introduction of the nation-wide 'alcopops' (premixed spirit-based drinks) tax which increased the retail price of these products by 70% from April 27th 2008 (Chikritzhs et al., 2009). An evaluation showed reductions in ED injury presentations in Victoria and Western Australia, particularly among those aged under 20 years (Lensvelt et al., 2016), following the tax. We adjusted models for monthly ED injury presentation rates during LAH, following the approach recommended by Stockwell and Chikritzhs (World Health Organization, 2000). Adjustment of estimates for injuries occurring during hours when alcohol was less likely to have been a contributing factor (and therefore less likely to be influenced by the implementation of RBL) mitigates against erroneously attributing underlying and unrelated change over time in ED injury rates to the intervention.

Analyses

Interrupted time series (ITS) analysis is particularly suited to interventions with clearly defined starting points that target population-level health outcomes (Lopez Bernal, Cummins, & Gasparrini, 2017). We adopted the standard ITS analytic strategy (Linden & Arbor, 2015) in Stata 15.0

(StataCorp, 2015), with Prais regression models (Lopez Bernal, Cummins, & Gasparrini, 2017) modelling injury presentation rates during HAH.

We conducted Breusch-Godfrey tests to assess residual autocorrelation (Lopez Bernal et al., 2017) and adjusted models using Prais regression which uses the generalized least-squares method to estimate the parameters in a linear regression model where errors are assumed to follow an autoregressive (AR1) process (Linden & Arbor, 2015). Prais regression offers several methods to transform the original observations based on the pooled autocorrelation estimate (*rho*) to remove the correlation between first-order errors, i.e., the correlation between the errors of each observation period and those of the preceding observation period (Linden & Arbor, 2015). We employed robust standard errors and rhotype(tscorr),which bases *rho* on the autocorrelation of the residuals (Linden & Arbor, 2015).

We report model parameter estimates, 95% confidence intervals, and p-values, along with the Akaike (AIC) and Bayesian (BIC) information criteria used to compare models. We designated the RBL intervention variable and the control variable for the alcopops tax as dichotomous ‘event’ variables (0=pre-intervention; 1=intervention) and ED injury presentation rates during LAH as a covariate. Models include a time variable (month) and interaction terms for RBL*time and alcopops tax*time.

We present the intervention effects in terms of both a ‘step’ function (0 before the RBL intervention, 1 after) and a ‘slope’ function (0 before the RBL and increasing/decreasing steadily afterwards). These may be considered an immediate effect of RBL (a step), and gradual change with RBL in place (a slope). We applied the same approach to the alcopops tax (see Supplementary Material 1 for equation detail).

Results

ED injury presentations for 15-54 year olds in Victoria

For those aged 15-54 years there were 507,870 ED injury presentations in Victoria during HAH, and 639,635 during LAH over the period January 2000 to December 2015. Figure 1 shows the unadjusted monthly rate of ED injury presentations during HAH per 10,000 population in Victoria.

<INSERT FIGURE 1 HERE>

The unadjusted model in Table 1 shows the association between RBL and the incidence of HAH assault, adjusting for the alcopops tax, but not LAH. The ED injury presentation rate increased by 0.020 per 10,000 population per month (95%CI: 0.011, 0.029, $p<0.001$) until the introduction of the alcopop tax in 2008. There was no significant step change in ED injury presentations, nor a change in the slope after the introduction of the alcopops tax, nor after the introduction of RBL. The Time*Intervention interaction estimate suggests a small decrease in the rate of ED injury presentations (β= -0.012, 95% CI: -0.024, -0.001; $p=0.032$), however, this attenuated after adjusting for ED injury presentations during LAH. Supplementary Figure 1 provides a visual presentation of these results.

<INSERT TABLE 1 HERE>

ED injury presentations among 20-39 year-olds in Victoria: Analyses by gender

In light of the lack of association between RBL and ED injury presentations among 15-54 year olds in Victoria, we conducted post-hoc sub-group analyses in the group that previous research suggests would be most likely affected by the intervention, persons aged 20-39 years of age who more often participate in nightlife (Miller et al., 2013). There were 299,198 ED injury presentations of people aged 20-39 in Victoria during HAH and 383,811 in LAH from January 2000 to December 2015. Figure 2a shows the unadjusted monthly rate per 10,000 population of ED injury presentations during HAH in Victoria for those aged 20-39 years. Figures 2b and 2c show the unadjusted monthly rate of ED injury presentations for men and women, respectively, during HAH in Victoria.

<INSERT FIGURES 2A, 2B, 2C HERE>

In Table 2, the LAH adjusted model shows the trends in ED attendances associated with the introduction of RBL, adjusting for the alcopops tax, for those aged 20-39 years. There was no evidence of a step change in ED injury presentations, nor of a change in slope. The LAH adjusted model for men shows the impact of RBL when adjusting for the introduction of the alcopops tax. The linear combination estimate after the introduction of alcopops and RBL interventions shows that the ED injury presentation rate decreased by 0.026 per 10,000 persons (95% CI: -0.040, -0.012, p=0.0003). There were no significant changes evident for women.

<INSERT TABLE 2>

ED injury presentations for 15-54 year olds in Queensland

There were 167,411 injury-related ED presentations in Queensland for 15-54 year olds during HAH and 487,144 during LAH from January 2007 to December 2015. Figure 3 shows the unadjusted monthly rate per 10,000 population of ED injury presentations during HAH in Queensland.

<INSERT FIGURE 3 HERE>

In Table 3, the unadjusted model shows the impact of RBL during HAH, adjusting for alcopops tax, but not LAH. ED injury presentations increased over the two years prior to 2009 by 0.139 cases per 10,000 persons per year (95%CI: 0.032, 0.247; p=0.011). However, there were no significant changes after the introduction of RBL in the unadjusted or the adjusted models.

<INSERT TABLE 3 HERE>

ED injury presentations 20-39 year olds in Queensland: Analyses by gender

There were 95,236 injury-related ED injury presentations in Queensland for those aged 20-39 years during HAH and 262,203 during LAH from January 2007 to December 2015. Figure 4a shows the monthly rate per 10,000 population of injury-related ED presentations during HAH in Queensland for those aged 20-39 years, and Figure 4b shows the monthly rate of ED injury presentations during HAH in Queensland for those aged 20-39 years, adjusted for LAH. Figure 4b shows the monthly rate of ED injury presentations for men aged 20-39 years during HAH in Queensland, and Figure 4c for women aged 20-39 years.

<INSERT FIGURES 4A, 4B, 4C HERE>

In Table 4, the LAH adjusted model shows the impact of RBL in Queensland on those aged 20-39 years, with adjustment for the alcopops tax. There was no evidence of a step change in ED injury presentations, nor of a change in slope. The LAH adjusted models for men and women including both RBL and the alcopops tax also show no significant change over the time period.

<INSERT TABLE 4 HERE>

Discussion

We aimed to determine whether RBL would be associated with a reduction in alcohol-related ED presentations,finding no reduction in ED presentations for injury during HAH in Queensland or Victoria among 15-55 year-olds after the introduction of RBL. Our post hoc subgroup analysis showed a reduction in ED presentations for injury during HAH among 20-39 year-old men in Victoria, however, the results was not replicated in Queensland.

RBL was implemented state-wide, and as such it is difficult to develop a counterfactual that permits exclusion of important competing explanations. A between-state comparison would not be informative, given the array of different policies, and environmental factors that vary by state.

Importantly, both states had policy changes during the periods investigated in the current study. For example, prior to RBL in Victoria, a lockout trial was conducted in Melbourne in 2008 which was found to be ineffective at reducing alcohol-related harm (KPMG, 2008). In 2008, a freeze was placed on the granting of new liquor licence applications for trading after 1am in several local government areas of Melbourne, however this too was found to have little impact on nightlife (Wilkinson, Manton, & Livingston, 2017). Further, the freeze was in place for the entirety of the period studied here, and as such would not be expected to bias our RBL effect estimates, and assists our analysis by controlling late-night venue density.

After RBL, only one policy change was implemented in 2016, namely 24 hour public transport on Friday and Saturday nights in Melbourne (Curtis et al., 2019), however this occurred after the study period. In Queensland, prior to RBL, Brisbane City implemented a Safety Action plan in 2005, which included a 3am lockout, advertising bans on happy hours and promotions, and mandatory RSA training in venues trading after 1am. Research does not support the effectiveness of lockouts (as opposed to restrictions in trading hours) in reducing alcohol related harms (Nepal et al., 2018), including in Queensland (de Andrade, Homel, & Townsley, 2016b). Further, given the Safety Action Plan was in place from 2005 one would not expect there to be impacts on ED trends three or more years post introduction of advertising bans on happy hours and promotion, or mandatory RSA training. In 2010, the Queensland government introduced 'Drink Safe Precincts', however an evaluation conducted by the Queensland Auditor General after 18 months found no evidence supporting its efficacy (Queensland Audit Office, 2013). In late 2014, the 'Safe Night Out' strategy was implemented, which included the establishment of 'Safe Night Precincts', and the introduction of police banning orders in and around licensed areas although these bans were not supported by mandatory scanning at nightclubs until July 2017, and previous research has shown that such bans are ineffective with voluntary ID scanning, or with no other systematic way to identify people on banned lists from other venues or sources as banned patrons can simply go to other venues (Miller et al., 2012). While it is theoretically possible that these interventions had an impact, it is not apparent in the data presented and given these interventions were introduced late in the study period and the existing evidence showing no impact for introduction of brief patron bans (Miller et al., 2013), it is unlikely that these have impacted on the results of this study.

A further limitation was that ED data were only available for QLD from 2008, limiting the pre-post comparison and reducing statistical power through a lack of equally distributed data points before and after the intervention (Lopez Bernal et al., 2017; Zhang, Wagner, & Ross-Degnan, 2011). It is important to note that ED attendance data may only capture the severe end of the injury spectrum compared to police recorded incidents or ambulance attendances, given police officers and ambulance officers would assess injuries for severity and transfer the person to an ED where necessary. As such it may be that there have been reductions in less severe injuries not evident in ED data. On the other hand, ED attendances also record injuries and intoxication attendances which are not recorded by police (Shepherd, 2007). Given the variations in the data available (see (de Andrade, Homel, & Townsley, 2016a) as an example), an important next step is to investigate if RBL has affected the incidence of alcohol-related offences as reported to police, similar to analyses done by Mathews and Legrand (2013), but expanded to the other three states that have implemented RBL.

The finding of an association in young men in Victoria, if it reflects a casual effect, may be a result of the specific components of the Victorian scheme. The Victorian RBL scheme includes incremental fees for venues as the licensed capacity increases, which the QLD scheme does not. This may have encouraged operators to reduce their licensed capacity to obtain a lower fee, in turn reducing the likelihood of assaults that would otherwise result in ED injury presentations during HAH. It may also have been a result of licensed premises improving serving practices in order to avoid compliance breaches, and in turn, further fees. However, this is speculative, and requires further investigation through identification of the number of venues that reduced their license capacity after the introduction of RBL, as well as the number of compliance checks and breaches at licensed premises.

Further, using state licensing data to explore whether venues are modifying their business practices to obtain a lower annual fee would be beneficial to further understand the impact of RBL.

One confounding variable in determining whether RBL is an effective intervention is the legislation details underpinning it, especially regarding the enforceability of laws. For example, the law requires that the person be demonstrated to be served when intoxicated before the server can be charged ("Liquor Control Reform Act," 1998). In reality, venues can claim the intoxicated person may have taken other drugs, or that they were intoxicated, not drunk. Evidence of this regulatory malaise is that only six venues were successfully prosecuted for serving drunks on premise in 2014, while over 11,000 people were fined for being drunk on premise (Crime Statistics Victoria, 2019). In Queensland, only nine venues were successfully prosecuted for serving an intoxicated person in 2014/5 (Office of Liquor and Gambing Regulation, 2016). In such a context, it is doubtful that venue operators will change serving behaviour based on the possibility of a license fee increase, because they are not being prosecuted for breaking the law. An effort to increase enforcement was implemented in Victoria in 2009, through the introduction of a 'Compliance Directorate' which comprised 40 civilian inspectors whose role was to assist Victoria Police to enforce liquor licensing requirements, however a review of this found that intoxication related offences were insufficiently enforced (Wilkinson & MacLean, 2013). Importantly, enforcement agencies, such as the Victorian Commission for Gambling and Liquor, have been identified as not undertaking meaningful compliance checks, instead simply meeting target numbers of inspections (Victorian Auditor-General, 2017).

Further, if RBL is to change licensee behaviour, the financial penalty associated with poor compliance history must be sufficient to deter future non-compliance (Loxley, Pascal, Lyons, Chikritzhs, & Allsop, 2007a, 2007b; Stockwell, 2006). If the fee is perceived as too small, particularly in comparison to the potential gains in revenue expected from maintaining current behaviour, it is unlikely to be effective. Some licensees have argued that higher fees would disadvantage small businesses that have less capacity to bear such costs than larger operators (Mathews & Legrand, 2013). It may therefore be more appropriate for penalties to be more closely aligned with business size and income stream (i.e., fines being a percentage of turnover), or that the penalties act on other aspects of business, such as restricting a percentage of hours traded, meaning that the consequences are meaningful.

Given that RBL mostly only applies to on-premise venues, it is also likely that the impact of the scheme is undermined by the lack of application to off-premise/packaged liquor outlets, although this has recently been implemented in the ACT. This is particularly relevant, as previous research has shown that an increased number of packaged liquor licenses in any specific area has been linked with increased domestic violence (Gale et al., 2015; Lensvelt et al., 2016), alcohol-related hospitalizations (Richardson, Hill, Mitchell, Pearce, & Shortt, 2015) and rates of violence in the community (Liang & Chikritzhs, 2011; Livingston, 2008), although evidence on attributing harm to specific outlets does not yet exist. As such, although on-premise venues may have altered their trading practices to reduce risk and rates of harm, the contribution of harms by packaged liquor and off-premise licenses may impede the progress of this group of industry actors. Other risk factors that are important to consider in any RBL scheme, and which may improve effectiveness, include incrementally higher fees for later trading hours, larger venues paying higher fees, the location of the venue, consideration of the volume of liquor available for sale, the number of licenses owned by the licensee, and compliance history (breaches of Liquor Act and/or Licence conditions) (PAAC and FARE, 2019).

Conclusions

RBL was not associated with reductions in ED injury presentations during HAH in Queensland or Victoria, with the exception of males aged 20-39 in Victoria. This may be due to weak financial penalties being applied to venues assessed as high-risk. Further investigation of the role RBL plays in reducing alcohol-related harm is needed.

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Tables

Table 1

The introduction of RBL, and ED injury presentations during HAH adjusted for LAH, among 15-54 year-olds in Victoria

Injury presentation rates during HAH [1]

Monthly data	**Unadjusted Models**			**Adjusted models- LAH**		
Covariates	***β* co-eff**	**95% CI**	**p-value**	***β* co-eff**	**95% CI**	**p-value**
Time (slope)	0.020	(0.011 ,0.029)	<0.001	0.012	(0.001, 0.025)	0.063
RBL (step)	0.064	(-1.406, 1.534)	0.932	-0.037	(-1.445, 1.338)	0.959
Time X RBL (slope)	-0.039	(-0.166, 0.088)	0.544	-0.037	(-0.160, 0.085)	0.549
Alcopops (step)	-0.713	(-1.694, 0.268)	0.153	-0.542	(-1.525, 0.440)	0.277
Time X Alcopops (slope)	0.007	(-0.120, 0.133)	0.917	0.016	(-0.107, 0.138)	0.802
LAH				0.118	(-0.005, 0.240)	0.060
Constant	7.703	(7.172, 8.234)	<0.001	6.789	(5.744,7.834)	<0.001
Observations	192			192		
Rho	0.286			0.243		
AIC	504.647			504.439		
BIC	524.192			527.242		

Post intervention Linear Trend: Alcopops + Time + Time X Alcopops	0.027	(-0.099, 0.153)	0.675	0.028	(-0.094,0.149)	0.655
Post intervention Linear Trend: RBL + Time + Time X Alcopops + Time X RBL	-0.012	(-0.024, 0.001)	0.032	-0.010	(-0.021, 0.001)	0.087

95% confidence intervals in brackets [1]Prais-Winsten AR(1) regression –iterated estimates

Table 2

The introduction of RBL, and ED injury presentations during HAH adjusted for LAH, among 20-39 year olds in Victoria Injury presentation rates during HAH[1]

Injury presentation rates during HAH[1]									
Monthly data	**Adjusted Model – All 20-39 years**			**Adjusted Model - Males**			**Adjusted Models - Females**		
Covariates	***β* co-eff**	**95% CI**	**p-value**	***β* co-eff**	**95% CI**	**p-value**	***β* co-eff**	**95% CI**	**p-value**
Time (slope)	0.005	(-0.008, 0.017)	0.455	0.009	(-0.007, 0.025)	0.266	0.001	(-0.008, 0.011)	0.777
RBL (step)	-0.033	(-1.420, 1.354)	0.962	-0.304	(-2.157, 1.549)	0.747	0.277	(-0.705, 1.259)	0.579
Time X RBL(slope)	-0.023	(-0.143 ,0.098)	0.712	-0.042	(-0.202, 0.117)	0.600	0.003	(-0.081,0.088)	0.942
Alcopops (step)	-0.256	(-1.236, 0.723)	0.606	-0.481	(-1.713, 0.751)	0.442	-0.062	(-0.817, 0.693)	0.871
Time X Alcopops(slope)	0.007	(-0.114, 0.127)	0.912	0.008	(-0.153, 0.168)	0.925	-0.003	(-0.087, 0.081)	0.951
LAH	0.169	(0.041, 0.296)	0.010	0.099	(-0.024, 0.222)	0.113	0.275	(0.132, 0.417)	<0.001
Constant	7.803	(6.533, 9.074)	<0.001	11.579	(9.871, 13.287)	<0.001	4.364	(3.474, 5.253)	<0.001
Observations	192			192			192		
Rho	0.155			0.135			0.167		

AIC	544.017			646.553			444.885		
BIC	566.819			669.355			467.688		
Post intervention Linear Trend: Alcopops+ Time + TimeXAlcopops	0.012	(-0.108, 0.131)	0.850	0.017	(-0.142, 0.175)	0.837	-0.001	(-0.085, 0.082)	0.975
Post intervention Linear Trend: RBL + Time + Time X Alcopops + Time X RBL	-0.011	(-0.022, 0.001)	0.040	-0.026	(-0.040, -0.012)	0.000 3	0.002	(-0.007, 0.010)	0.676

95% confidence intervals in brackets [1]Prais-Winsten AR(1) regression –iterated estimates

Table 3

The introduction of RBL, and ED injury presentations during unadjusted HAH and HAH adjusted for LAH, among 15-54 year olds Queensland

Injury presentation rates during HAH[1]

	Unadjusted			**Adjusted**		
Covariates	**β co-eff**	**95% CI**	**p-value**	**β co-eff**	**95% CI**	**p-value**
Time (slope)	0.139	(0.032,0.247)	0.011	-0.033	(-0.117, 0.052)	0.445
RBL (step)	-0.442	(-1.607, 0.724)	0.454	0.038	(-0.644, 0.720)	0.912
Time X RBL(slope)	-0.120	(-0.297, 0.058)	0.184	-0.031	(-0.127, 0.064)	0.517
Alcopops (step)	-0.859	(-1.790,0.073)	0.070	-0.068	(-0.745, 0.609)	0.842
Time X Alcopops (slope)	-0.012	(-0.237, 0.213)	0.916	0.061	(-0.075, 0.196)	0.375
LAH				0.329	(0.262, 0.397)	<0.001
Constant	4.597	(3.553, 5.640)	<0.001	0.659	(-0.410, 1.727)	0.224
Observations	102			102		
Rho	0.362			0.342		
AIC	175.58			128.013		
BIC	191.33			146.388		

Post intervention Linear Trend: Alcopops + Time + Time X Alcopops	0.127	(-0.050, 0.305)	0.158	0.028	(-0.068, 0.124)	0.565
Post intervention Linear Trend: RBL +Time + Time X Alcopops + Time X RBL	0.008	(-0.001, 0.016)	0.063	-0.003	(-0.010, 0.003)	0.318

Table 4

The introduction of RBL, and ED injury presentations during HAH adjusted for LAH, among 20-39 year olds in Queensland

Injury presentation rates during HAH[1]

					Adjusted Models				
	Model 20-39 years			**Model - males**			**Model - females**		
Covariates	***β* co-eff**	**95% CI**	**p-value**	***β* co-eff**	**95% CI**	**p-value**	***β* co-eff**	**95% CI**	**p-value**
Time	-0.062	(-0.144, 0.019)	0.133	-0.024	(-0.145, 0.096)	0.689	-0.020	(-0.080, 0.040)	0.504
RBL	0.072	(-0.475, 0.619)	0.795	0.249	(-0.791, 1.288)	0.636	-0.387	(-1.00, 0.23)	0.214
Time X RBL	-0.031	(-0.118, 0.055)	0.475	-0.068	(-0.240, 0.104)	0.433	-0.034	(-0.13, 0.06)	0.462
Alcopops	0.100	(-0.696, 0.896)	0.804	-0.181	(-1.507, 1.145)	0.787	0.011	(-0.580, 0.602)	0.970
Time X Alcopops	0.091	(-0.019, 0.201)	0.105	0.085	(-0.117, 0.288)	0.404	0.059	(-0.045, 0.163)	0.264
LAH	0.405	(0.263, 0.485)	<0.001	0.320	(0.229, 0.410)	<0.001	0.345	(0.252, 0.438)	<0.001
Constant	-0.249	(-1.403, 0.906)	0.670	1.177	(-0.643, 2.996)	0.202	0.468	(-0.371, 1.307)	0.271
Observations	102			102			102		
Rho	0.123			0.167			0.084		

AIC	159.108			228.162			147.737		
BIC	177.483			246.536			166.112		
Post intervention Linear Trend: Alcopops + Time + Time X Alcopops	0.029	(-0.059, 0.115)	0.517	0.061	(-0.111, 0.233)	0.707	0.039	(-0.054, 0.131)	0.409
Post intervention Linear Trend: RBL +Time + Time X Alcopops + Time X RBL	-0.003	(-0.009, 0.003)	0.306	-0.007	(-0.015, 0.001)	0.092	0.004	(0.001, 0.010)	0.130

95% confidence intervals in brackets [1]Prais-Winsten AR(1) regression –iterated estimates

Figures

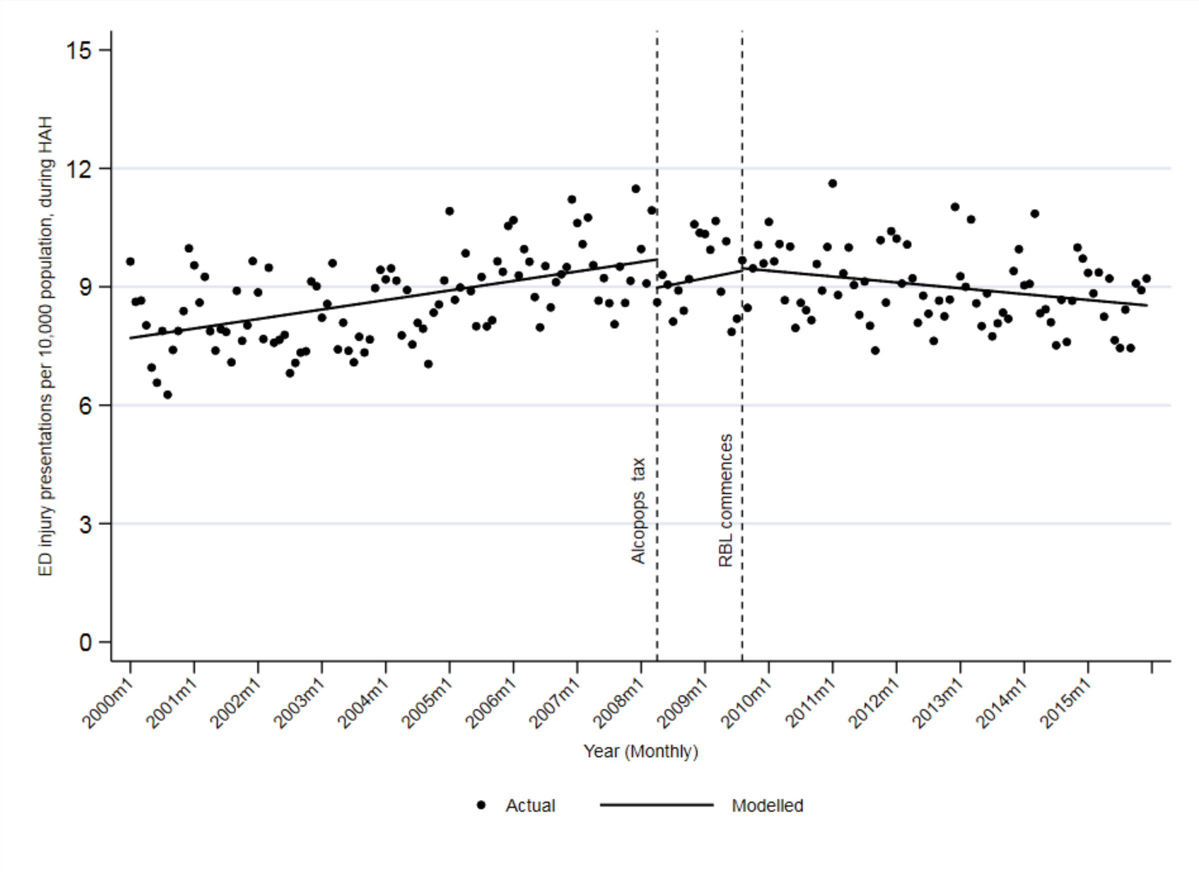


Figure 1 Monthly rate of ED injury presentations per 10,000 population in Victoria for ages 15-54 years, January 2000 to December 2015.

Figures 2a-c: Monthly rate of ED injury presentations per 10,000 in Victoria for 20-39 year olds,

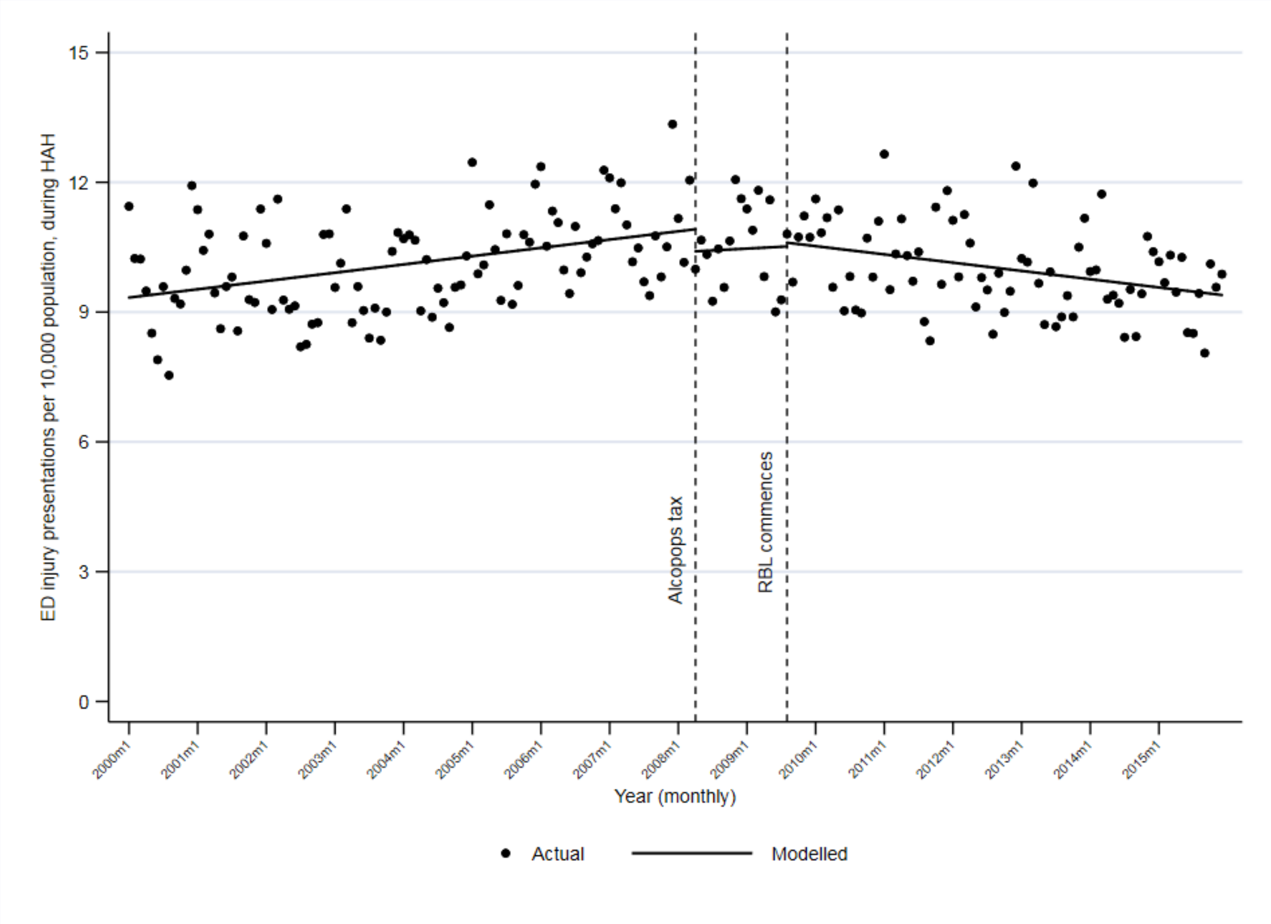


Figure 2a – model not adjusted for LAH rates (Victoria; 20-39 years)

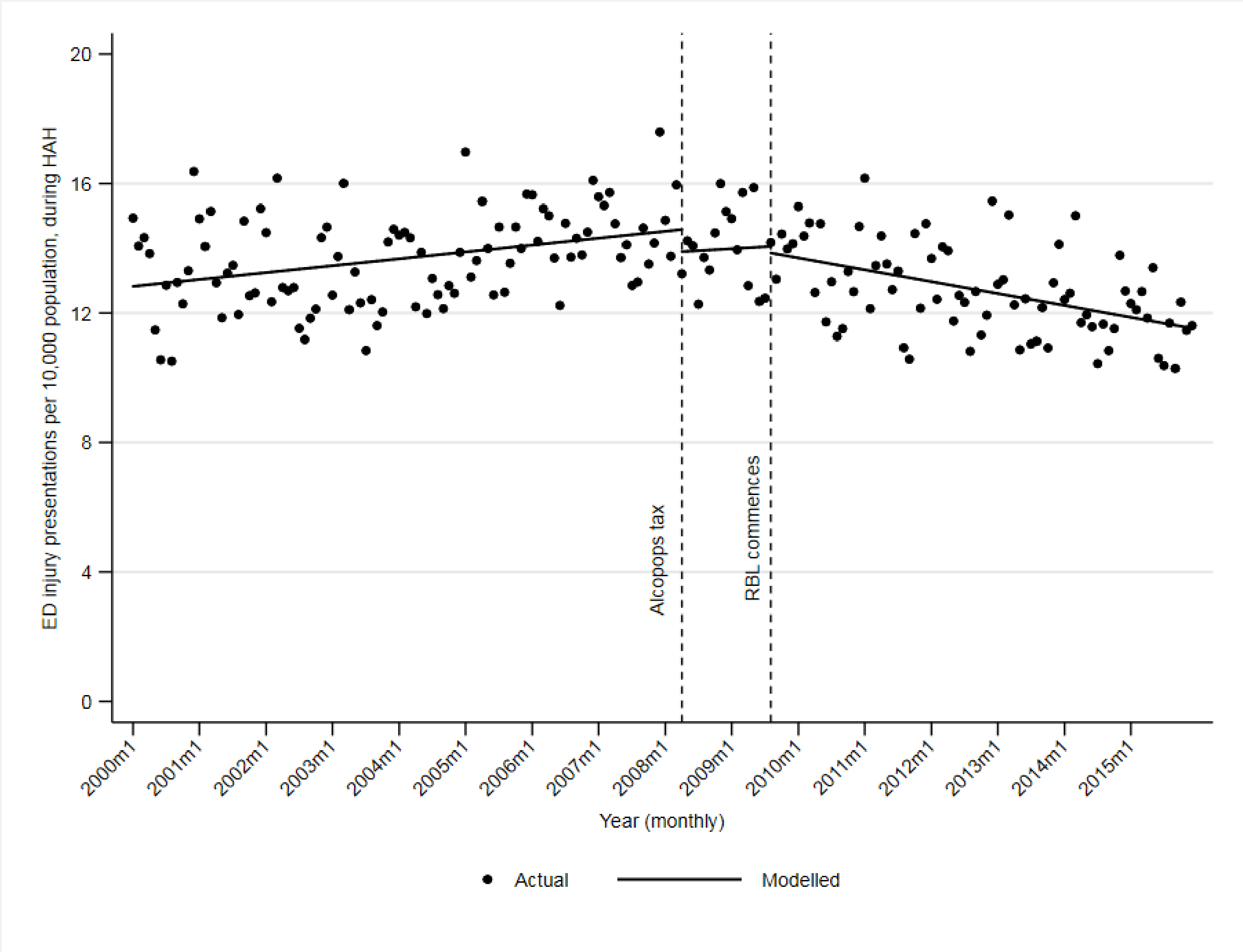


Figure 2b – model not adjusted for LAH rates (Victoria; males 20-39)

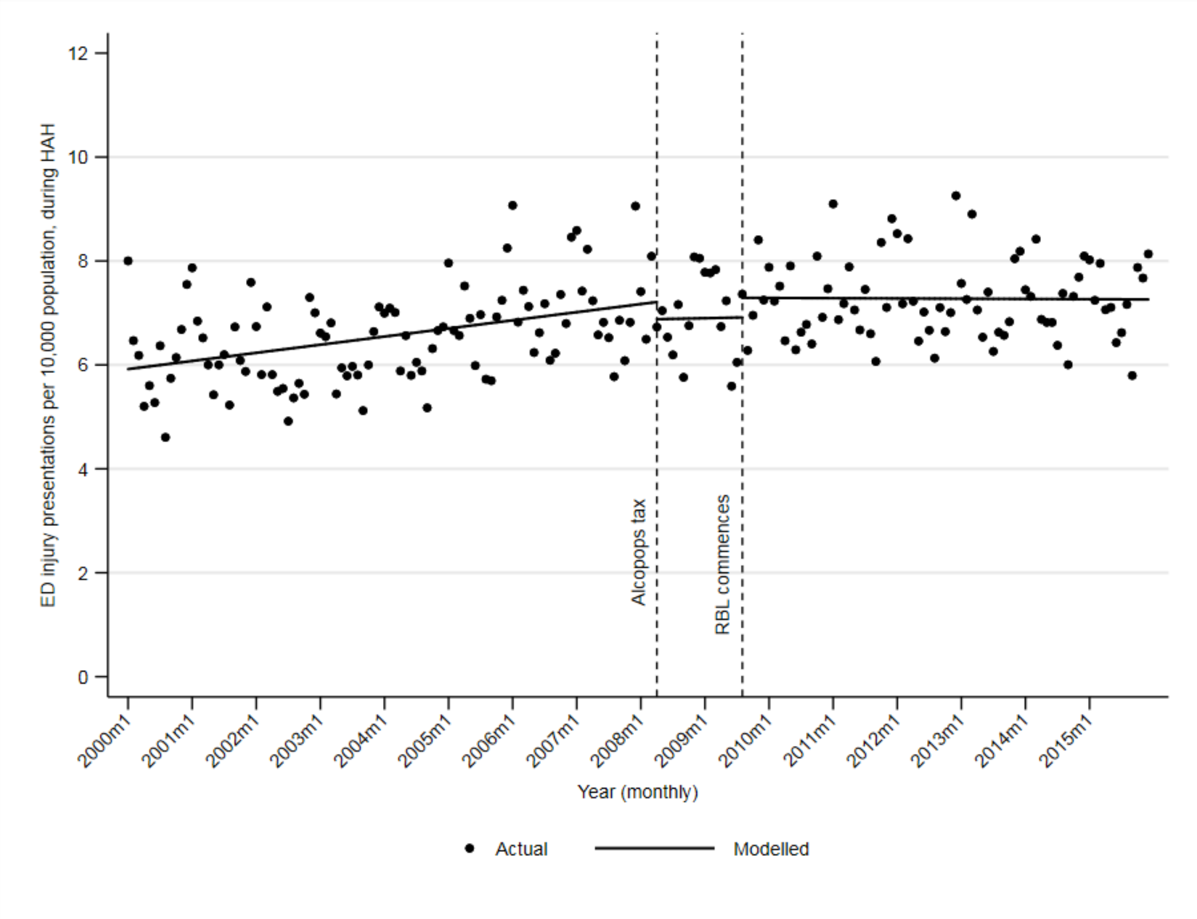


Figure 2c – model not adjusted for LAH rates (Victoria; females 20-39)

January 2000 to December 2015

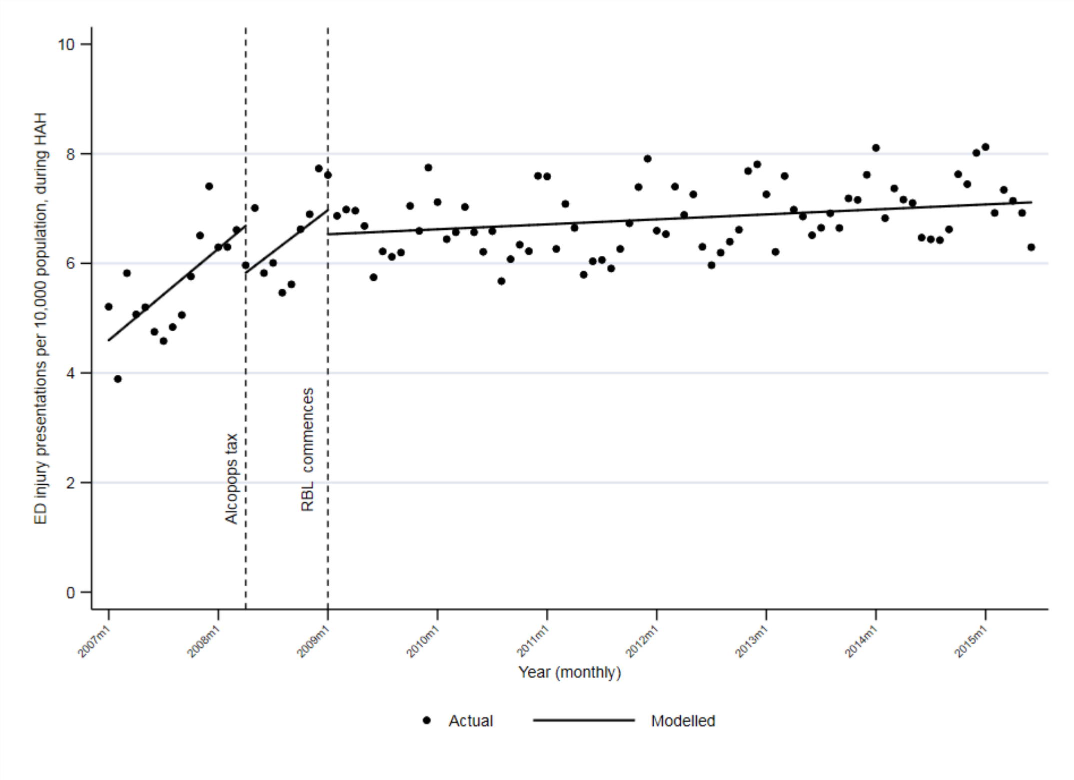


Figure 3 Unadjusted monthly rates of ED injury presentations per 10,000 in Queensland for 15-54 year olds, January 2007 to July 2015.

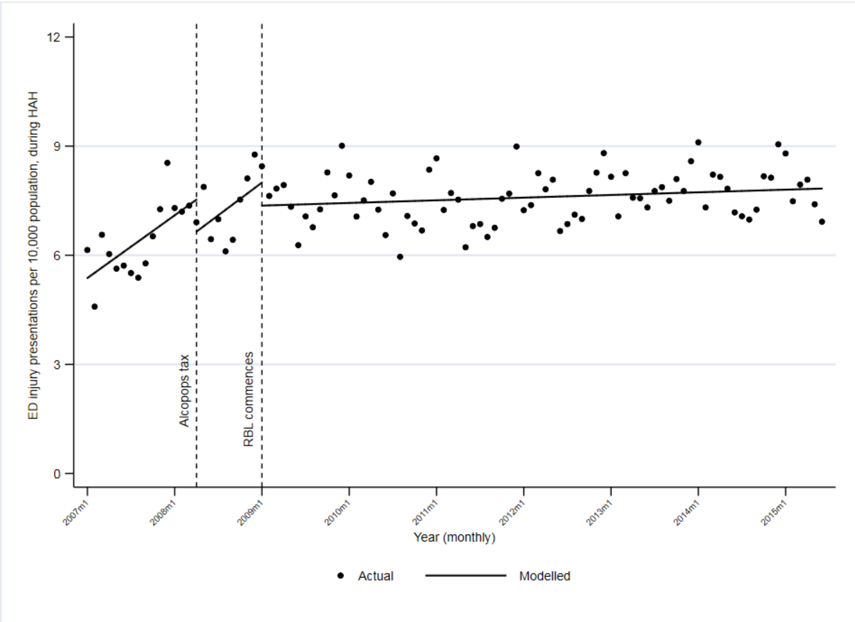


Figure 4a – model not adjusted for LAH rates (QLD; 20-39 years)

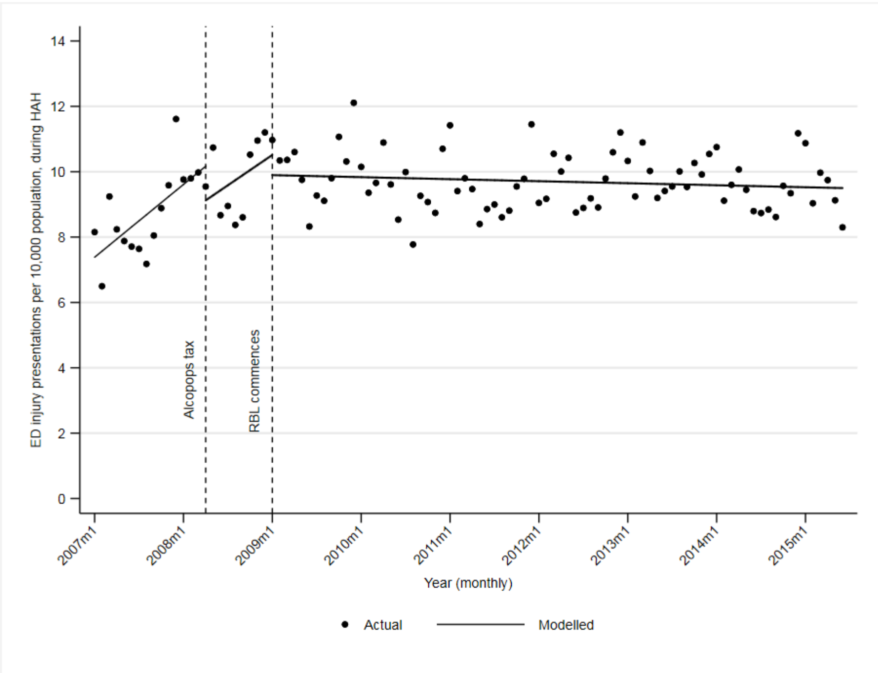


Figure 4b – model adjusted for LAH rates (QLD; males 20-39 years)

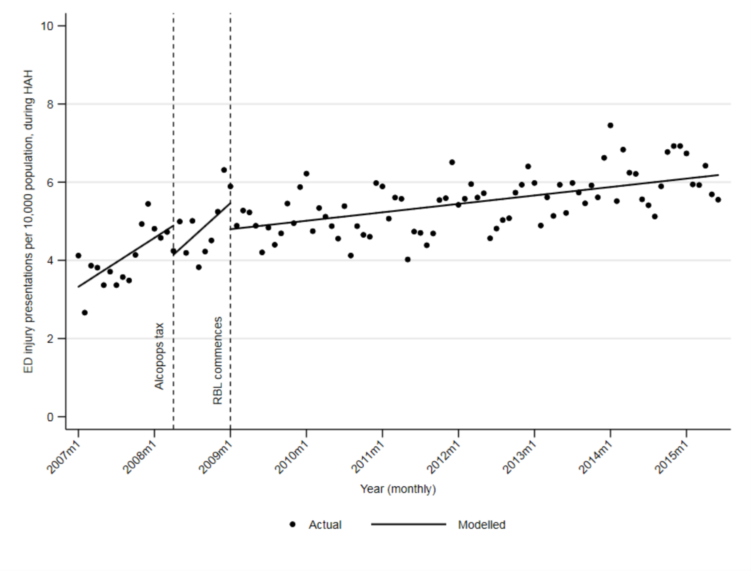


Figure 4c – model not adjusted for LAH rates (QLD; females 20-39 years)

Figures 4a-c: Monthly rate of ED injury presentations per 10,000 in Queensland for 20-39 year olds, January 2007 to July 2015.

Supplementary Material 1

We used the following segmented regression model (equation 1):

$$Y_t = \beta_0 + \beta_1 T + \boldsymbol{\beta_2 X_{1t}} + \beta_3 TX_{1t} + \boldsymbol{\beta_4 X_{2t}} + \beta_5 TX_{2t} + \beta_6 X_{3t}$$

Where

Y_t : the outcome HAH rates at time t (month) (**HAH**)

$\boldsymbol{X_{1t}}$: an indicator (dummy) variable indicating the period before the alcopops tax came into effect (coded 0) or the post intervention period (coded 1) (**alcopops)**

$\boldsymbol{X_{2t}}$: an indicator (dummy) variable indicating the period before RBL commenced (coded 0) or the post intervention period (coded 1) **(RBL**)

$\boldsymbol{X_{3t}}$: an independent continuous variable - LAH rates at time t (month) **(LAH**)

T: the time elapsed since the start of the study in which the unit represents months.

The following segmented regression model was used when adjusted for both RBL and the Alcopops tax, and LAH rates (equation 2):

$$(HAH)_t = constant + \beta_1 Time + \boldsymbol{\beta_2 alcopops_t} + \beta_3 Time \times Alcopops_t + \boldsymbol{\beta_4\, RBL_t} + \beta_5 Time \times RBL_t + \beta_6 LAH_t$$

Where

Y_t : the high alcohol hours injury presentation rates at time t (month)

β_0 : the baseline level at T = 0

β_1 : the change in outcome associated with a time unit increase (representing the underlying pre-intervention trend)

β_2 : the level change following the alcopops tax intervention

β_3 : the slope change following the alcopops tax intervention (using the interaction between time and intervention: TX_{1t}

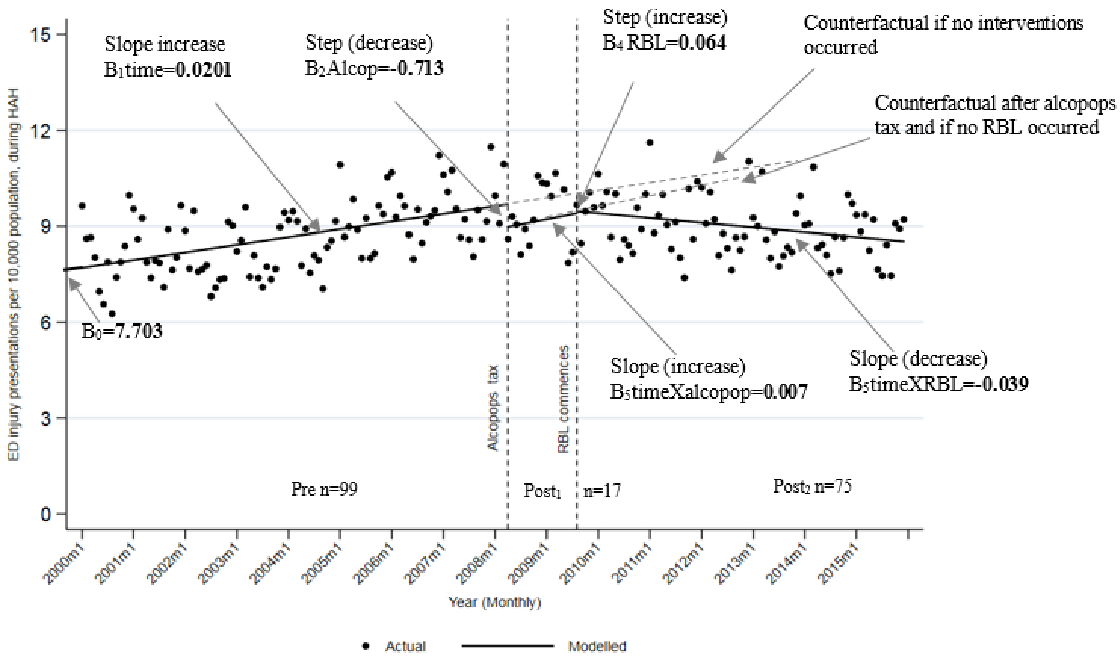
β_4 : the level change following the RBL intervention

β_5 : the slope change following the RBL intervention (using the interaction between time and intervention: TX_{2t}

β_6 : the change in low alcohol hours injury presentation rates at time t (month).

Supplementary Figure 1

Figure S1. An Explanation of the Interrupted Time Series graph with multiple interventions (alcopops and RBL; Table 1)



Supplementary Table 1

High and Low Alcohol Hours for Victoria and Queensland

	HAH		LAH	
	Victoria	Queensland	Victoria	Queensland
Sunday	10pm-12am; 12am-6am	6pm-12am; 12am-6am		
Monday	12am-6am; 10pm-12am	12am-6am	6am-6pm	6am-6pm
Tuesday	12am-2am	10pm-12am	6am-2pm	10am-2pm
Wednesday	10pm-12am	10pm-12am; 12am-2am	10am-2pm	6am-2pm
Thursday	12am-2am	6pm-12am; 12am-2am	6am-2pm	6am-3pm
Friday	10pm-12am	12am-2am; 10pm-12am	6am-10am	6am-10am
Saturday	6pm-12am; 12am- 6am	12am-6am; 6pm-12am		

Supplementary Table 2

The association between RBL in Victoria for those aged 15-54 years and injury-related emergency department presentations during High Alcohol Hours (HAH) adjusted for Low Alcohol Hours (LAH), for RBL only

Injury presentation rates during HAHs[1]						
Monthly data	**Unadjusted Model**			**Adjusted models- LAH**		
Covariates	***β* co-eff**	**95% CI**	**p-value**	***β* co-eff**	**95% CI**	**p-value**
Time (slope)	0.016	(0.009, 0.023)	<0.001	0.008	(-0.002, 0.017)	0.112
RBL (step)	-0.198	(-0.905, 0.509)	0.581	-0.097	(-0.752, 0.558)	0.770
Time X RBL (slope)	-0.028	(-0.042, -0.015)	<0.001	-0.017	(-0.033, -0.001)	0.041
LAH				0.146	(0.030, 0.261)	0.014
Constant	7.847	(7.369, 8.324)	<0.001	6.648	(5.616, 7.681)	<0.001
Observations	**192**			**192**		
Rho	0.287			0.229		
AIC	503.467			501.719		
BIC	516.497			518.006		
Post intervention Linear Trend: RBL + Time + Time X RBL	-0.0125	(-0.024, -0.001)	0.030	-0.009	(-0.020, 0.002)	0.099

95% confidence intervals in brackets [1]Prais-Winsten AR(1) regression –iterated estimates

Supplementary Table 3

The association between RBL in Queensland for those aged 15-54 years and injury-related emergency department presentations during High Alcohol Hours (HAH) adjusted for Low Alcohol Hours (LAH), for RBL only

Injury presentation rates during HAH[1]

	Unadjusted Model			**Adjusted models- LAH**		
Covariates	**β co-eff**	**95% CI**	**p-value**	**β co-eff**	**95% CI**	**p-value**
Time (slope)	0.087	(0.029, 0.144)	0.003	-0.017	(-0.060, 0.026)	0.431
RBL (step)	-0.402	(-1.266, 0.462)	0.358	0.250	(-0.328, 0.827)	0.393
Time X RBL (slope)	-0.079	(-0.137, -0.021)	0.008	0.014	(-0.029, 0.057)	0.520
LAH				0.325	(0.258, 0.392)	<0.001
Constant	4.855	(4.044, 5.667)	<0.001	0.620	(-0.441, 1.682)	0.249
Observations	102			102		
Rho	0.386			0.347		
AIC	174.178			124.565		
BIC	184.678			137.690		
Post intervention Linear Trend: RBL + Time + Time X RBL	0.008	(-0.001, 0.016)		-0.003	(-0.010, 0.004)	0.350

95% confidence intervals in brackets [1]Prais-Winsten AR(1) regression –iterated estimates