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Research Paper

Modelling the impacts of volumetric and minimum unit pricing for alcohol on social harms in Australia

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ABSTRACT

Aims: Alcohol pricing policies may reduce alcohol-related harms, yet little work has been done to model their effectiveness beyond health outcomes especially in Australia. We aim to estimate the impacts of four taxation and minimum unit pricing (MUP) interventions on selected social harms across sex and age subgroups in Australia.
Methods: We used econometrics and epidemiologic simulations using demand elasticity and risk measures. We modelled four policies including (A) uniform excise rates (UER) (based on alcohol units) (B) MUP $1.30 on all alcoholic beverages (C) UER + 10 % (D) MUP$ 1.50. People who consumed alcohol were classified as (a) moderate (≤ 14 Australian standard drinks (SDs) per week) (b) Hazardous (15–42 SDs per week for men and 14–35 ASDs for women) and (c) Harmful (> 42 SDs per week for men and > 35 ASDs for women). Outcomes were sickness absence, sickness presenteeism, unemployment, antisocial behaviours, and police-reported crimes. We used relative risk functions from meta-analysis, cohort study, cross-sectional survey, or attributable fractions from routine criminal records. We applied the potential impact fraction to estimate the reduction in social harms by age group and sex after implementation of pricing policies.
Results: All four modelled pricing policies resulted in a decrease in the overall mean baseline of current alcohol consumption, primarily due to fewer people drinking harmful amounts. These policies also reduced the total number of crimes and workplace harms compared to the current taxation system. These reductions were consistent across all age and sex subgroups. Specifically, sickness absence decreased by 0.2–0.4 %, alcohol-related sickness presenteeism by 7–9 %, unemployment by 0.5–0.7 %, alcohol-related antisocial behaviours by 7.3–11.1 %, and crimes by 4–6 %. Of all the policies, the implementation of a $1.50 MUP resulted in the largest reductions across most outcome measures.
Conclusion: Our results highlight that alcohol pricing policies can address the burden of social harms in Australia. However, pricing policies should just form part of a comprehensive alcohol policy approach along with other proven policy measures such as bans on aggressive marketing of alcoholic products and enforcing the restrictions on the availability of alcohol through outlet density regulation or reduced hours of sale to have a more impact on social harms.

Background

Alcohol consumption is a significant avoidable risk factor for premature death and illness (Wood et al., 2018). In 2016, alcohol consumption accounted for 1.6 % (95 % uncertainty interval [UI] 1.4–2.0) of total disability-adjusted life years (DALYs) globally among females, and 6.0 % (95 % UI 5.4–6.7) among males (Wood et al., 2018). It was the seventh leading risk factor for premature death and disability worldwide (Wood et al., 2018). By 2018, alcohol was responsible for 4.5 % of the total disease burden in Australia, ranking it as the fifth leading risk

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factor for disease burden (Australian Institute of Health & Welfare, 2021).The harmful effects of alcohol use extend beyond individual health risks and also include social harms such as violence, aggression, crime and work absences which may also impact the drinkers' friends, family and the whole society (Babor, 2010; Laslett et al., 2019; Room, 1998; Waleewong, 2018). In 2019, a multi-criteria decision analysis by experts in Australia ranked alcohol as the most harmful drug as compared to other licit and illicit drugs such fentanyl, methamphetamine, heroin, and cigarette smoke among others in terms of the propensity to cause harm to users and others (Bonomo et al., 2019).

Pricing policies have been shown to reduce alcohol consumption and harms (Wagenaar et al., 2009, Wagenaar, Tobler, & Komro, 2010). As of 2022, the global landscape of alcohol taxation featured three main structures, used independently or in combination. First, the ad valorem tax, applied in 96 countries, is based on the total cost or value of alcoholic products, with tax rates proportional to product prices (World Health Organization, 2022). Second, the volumetric tax, used in 50 countries, hinges on the alcohol content within the beverages, levying higher taxes for those with greater alcohol concentrations (World Health Organization, 2022). Lastly, the unitary tax, present in 41 countries, relies on the total volume of alcoholic products, with a fixed tax rate per unit of volume, irrespective of content or cost (Sornpaisarn et al., 2017b; World Health Organization, 2022). These diverse tax systems aim to regulate the alcohol industry and generate revenue while considering different aspects of alcoholic products. Traditionally, governments have used alcohol taxation to increase prices (Hunt et al., 2011). A tax change impacts prices uniformly across the board (Sornpaisarn et al., 2017b). In contrast, Minimum Unit Pricing (MUP) sets a minimum price for selling alcohol, specifically targeting low-priced products and having minimal impact on higher-priced items (Robinson et al., 2020; Taylor et al., 2021; Vandenberg et al., 2019).

An alternative to tax-based approaches, an MUP sets a floor price below which alcohol cannot be sold (Robinson et al., 2020; Taylor et al., 2021; Vandenberg et al., 2019). MUP works by increasing the cost of low-priced alcohol to a fixed level. MUP is seen as an attractive policy option as it affects the prices of a relatively small section of the market that is disproportionately consumed by people who drink at heavy level (Jiang et al., 2017). In a review, Boniface and colleagues found that alcohol pricing policy measures like MUP likely lead to reduced alcohol consumption, alcohol-related harms, and deaths (Boniface et al., 2017). More recent time-series studies in Scotland and Wales (MUP £.50,) (Anderson et al., 2021; O'Donnell et al., 2019), and Australian Northern Territory (MUP $1.30 AUD) (Taylor et al., 2021) demonstrated that MUP effectively reduced the amount of purchased alcohol following its implementation with minimal implementation costs. The most recent evaluation of MUP £.50 implementation in Scotland has showed mixed results. It showed that MUP has likely contributed to a reduction in alcohol-attributable deaths and wholly alcohol-attributable hospital admissions (Public Health Scotland, 2023). These positive outcomes occurred without clear negative or positive impacts on the alcoholic drinks industry. (Public Health Scotland, 2023) However, there is no consistent evidence of either positive or negative effects on social outcomes, such as alcohol-related crime or illicit drug use, at the population level (Public Health Scotland, 2023). Additionally, some qualitative evidence points to negative health and social consequences at an individual level, particularly for those who are financially vulnerable and have alcohol dependence (Public Health Scotland, 2023).

Alcohol pricing policies in Australia are governed by a complex taxation system (Byrnes, 2012; Webb, 2009). Wine and fruit-based products are taxed at a flat rate of 29 % of their wholesale value through the wine equalization tax (WET), a form of ad valorem tax (Parliamentary Budget Office, 2015). On the contrary, beer, spirits and pre-mixed drinks are taxed based on the volume of alcohol they contain Parliamentary Budget Office, (2015), although the rates vary depending on the beverage type and strength. These inconsistencies have been to the focus of several proposed amendments. For example, in 2009, the "Henry Review" – a review of Australia's future tax measures, considered a uniform volumetric tax (abolition of WET) on alcoholic products to be an effective lever to address harms related to cheap alcohol consumption in Australia (Henry, 2010; Robinson et al., 2020). Yet, the Australian government continues to maintain the current taxation system, which is not specifically structured to reduce overall alcohol consumption nor is it aimed at mitigating the associated health and social harms (Vandenberg et al., 2019).

Increasingly, complex models that combine price elasticity estimates with risk functions are being used to estimate of the potential impact of various alcohol price policies on key outcomes. Most of the recent modelling work has focused either on consumption impacts or health effects and it is well established that pricing policies can reduce consumption and improve health (Sornpaisarn et al., 2017a). The Sheffield Alcohol Policy Modelling (SAPM) group, or researchers using the SAPM, have also modelled the impact of price policies on a broader range of alcohol-related harms in three mutually exclusive groups: health, workplace, and crime for UK, Canada and South Africa (Brennan et al., 2016, 2015; Gibbs et al., 2021; Hill-McManus et al., 2012; Holmes et al., 2014; Meier et al., 2009, 2016). These models generally show that pricing policies in the form of taxation or MUP effectively decrease health and social harms. However, adopting these findings to the current Australian context is challenging, given Australia's complicated alcohol tax system, described above (Henry, 2010). Also, currently, most of the risk estimates applied to alcohol pricing policy modelling on social harms such as crime, unemployment, sickness absence, and decreased work productivity come from cross-sectional studies with the dose–response relationship assumed to be linear (Meier et al., 2009; Purshouse, 2009; White J., 2014). However, some social harms, such as sickness absence and unemployment, have *J*-shaped relationships rather than linear (Jørgensen et al., 2017; Marzan et al., 2022). For example, we found a *J*-shaped relationship between alcohol consumption and sickness absences in on our recent systematic review and meta-analysis of 22 cohort and cross-sectional studies (Marzan et al., 2022).

Current economic costing studies indicate that the social harms associated with alcohol consumption may be as costly as the health harms. However, most studies still focus primarily on health harms from alcohol. These studies demonstrate that the costs are considerable (Manning, Smith, & Mazerolle, 2013). For instance, health system costs constituted only 42.1 % of the $14.35 billion tangible cost of alcohol, while the criminal justice system (11.7 %) and lost productivity (25.5 %) also incurred substantial costs. Therefore, understanding the impacts of pricing policy options on these non-health harms is critical when making policy decisions (Manning, Smith, & Mazerolle, 2013).

In this study, we build on our previous work that examined the impact of various alcohol pricing policies on price elasticities (Jiang et al., 2020a, Jiang et al., 2020b). Our aim is to model how these policies affect alcohol consumption across different groups and provide clear, quantitative estimates of their effects on social harms in the Australian context. Additionally, we extend our analysis to evaluate the potential impacts of these policies on social harms, focusing specifically on different age and sex groups in Australia.

Methods

Overview of methods

The broad conceptual framework we used, shown in Fig. 1, was based on the Sheffield Alcohol Policy Model (SAPM), which has been employed in the U.K., Canada and South Africa (Angus et al., 2016; Brennan et al., 2015; Gibbs et al., 2021; Holmes et al., 2014; Meier et al., 2009; White J., 2014). We first chose four most realistic alcohol-pricing policies based in our previous modelling. Our prior publication (Jiang et al., 2020a, Jiang et al., 2020b) provided the estimated decline (demand elasticities) in prevalence of people who drink at each alcohol consumption categories (moderate, hazardous, harmful) by age and sex

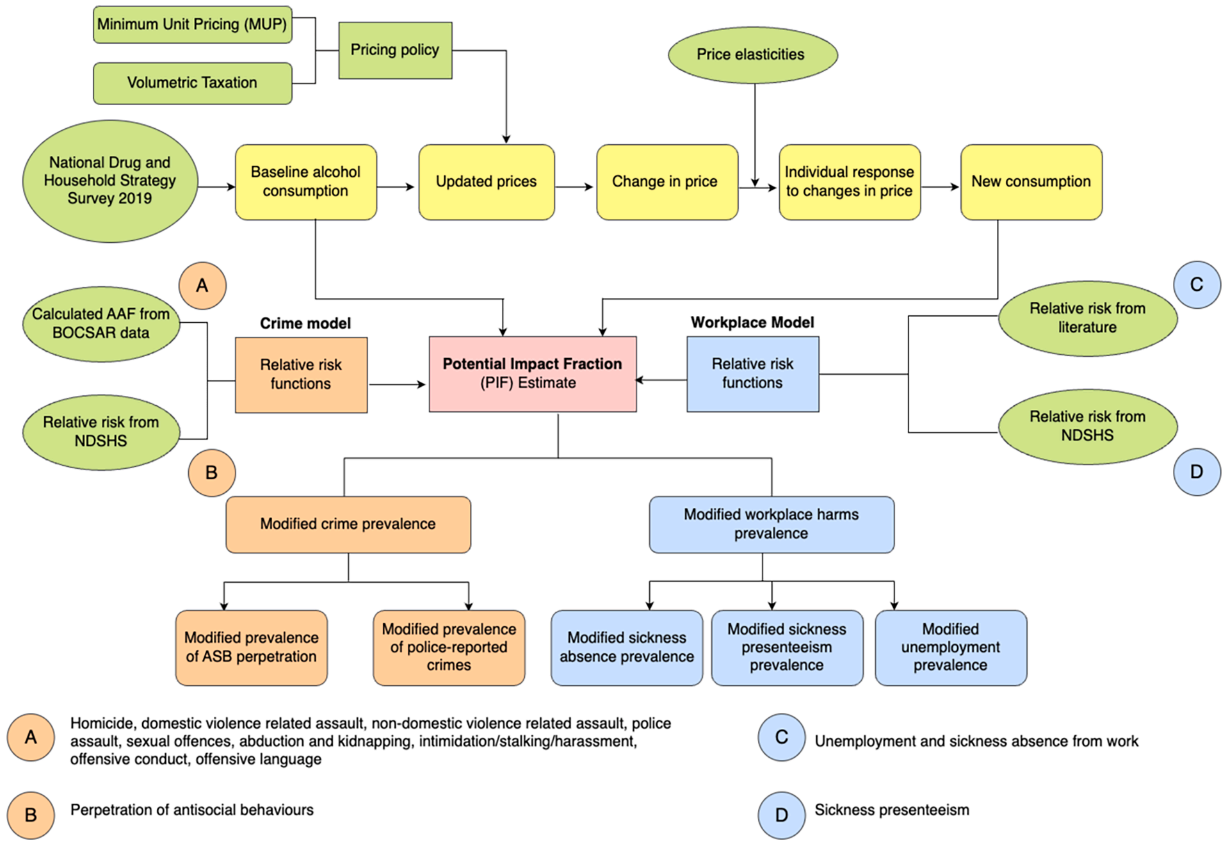

Fig. 1. Schematic diagram of the effectiveness modeling approach
Workplace model includes sickness absence, alcohol–related workplace/sickness presenteeism, unemployment
The crime model includes antisocial behaviour and crimes reported to the police.

subgroup. We then used these alcohol demand elasticities to measure the expected change in consumption (estimated at the baseline from 2019 survey) after the implementation of pricing policies (Jiang et al., 2020a, Jiang et al., 2020b). We used relative risk (RR) functions linking consumption to each of our social harms to derive the risk estimates and calculate the potential impact fraction (PIF). Our framework was based on two modelling methodologies.

1) The price-to-consumption model, which is an econometric model on the effects of proposed pricing policies on consumption; and is summarised in detail in our previous studies (Jiang et al., 2020a, Jiang et al., 2020b)
2) Epidemiologic modelling of the link between alcohol consumption and social harms [sickness absence, sickness presenteeism, unemployment, alcohol-related antisocial behaviours (ASB) and crimes], which are outlined here.

Our data analysis plan was not pre-registered since this is a mathematical modelling and not a confirmatory statistical analysis. All analyses were performed in Stata 18, Microsoft Excel and R Studio.

Data sources

Alcohol consumption

We used the Australian cross-sectional survey, National Drug Strategy Household Survey (NDSHS), to measure alcohol consumption. NDSHS used a multi-stage stratified sampling with the complete methodologies discussed elsewhere (Australian Institute of Health & Welfare, 2020). The 2019 wave had a response rate of 49 % (Australian Institute of Health & Welfare, 2020) and 22,015 respondents. Respondents' alcohol consumption was asked for the previous 12 months, with those who consumed alcohol in the past 12 months flagged as current people who drink.

Consumption was measured using a graduated frequency measuring the frequency (every day, 5–6 days a week, 3–4 days a week, 1–2 days a week, 2–3 days a month, about 1 day a month, less often or never) of consumption at different levels in standard drinks (10 g alcohol; 20 or more, 11–19, 7–10, 5–6, 3–4, 1–2, less than 1, or none) (Australian Institute of Health & Welfare, 2020). The respondents' total alcohol consumption was approximated by multiplying the mid-point of every consumption volume category (e.g. for the 11–19 drinks category, a volume of 15 was used) by the mid-point of each frequency category (e.g. for 5–6 days per week, a frequency of $5.5 \times 52 = 286$ was used) (Brick, 2006). If the respondents reported greater than 365 drinking episodes in the previous year, the maximum 365 occasions were used to estimate the annual consumption (please see (Brick, 2006) for more details)

Our analyses only included people who drink alcohol based on the NDSHS questionnaire. Average daily alcohol consumption was then categorized into 3 mutually exclusive groups based on the classification used in our pricing modelling study (Jiang et al., 2020a, Jiang et al., 2020b):

- Moderate ($\leq$ 14 standard drinks (SDs) per week for men and women)
- Hazardous (15–42 SDs per week for men and 14–35 SDs for women)
- Harmful ($>$ 42 SDs per week for men and $>$ 35 SDs for women)

We also modelled the effects across three age groups:

- Younger age group (16–34 years)
- Middle age group (35–54 years)
- Older age group (55 years and over)

Alcohol pricing policy scenarios

We selected four pricing policy options (including its price elasticity of demand estimates) that we thought were the most realistic and feasible pricing policies from our previous study (Jiang et al., 2020a, Jiang et al., 2020b). The proposed alcohol pricing policies were selected based on their potential for real-world application and political viability in Australia. They include both moderate reforms, like a 10 % tax increase, and more impactful measures, such as a $1.50 MUP. The $1.30 MUP is also already implemented in the Northern Territory, Australia (Taylor et al., 2021). This would allow us to compare the results to the baseline, the current federal tax system (volumetric taxation to all beverages except wine and wine is taxed per unit price). The example of the current taxation system is demonstrated in Supplementary Fig. 1.

A. UER - Applying a uniform excise tax rate (UER – uniform excise rate) per unit of alcohol to all beverages equal to the current spirits tax rate.
B. MUP $1.30 - Introducing a minimum unit price on all beverage categories at $1.30 per standard drink.
C. UER+10 % - Applying a uniform excise rate to all beverages equal to a 10 % increase in the current spirits tax rate.
D. MUP $1.50 - Introducing a minimum unit price on all beverage categories at $1.50 per standard drink.

Pricing policy effects to alcohol consumption

We used the previously modelled elasticities in Australia (Jiang et al., 2020a, Jiang et al., 2020b) to derive the shifts in consumption among the defined subpopulation groups for specific pricing policies. We applied the modelled elasticities of four policy options and recalculated the alcohol consumption prevalence using the 2019 NDSHS. It is important to clarify that our model assumes pricing policies do not affect the decision to either start or abstain from drinking alcohol. The upper and lower confidence interval of these elasticity coefficients were used in our Monte Carlo simulations.

Social harms data and derivation of relative risk (RR) functions

Social harms in our analyses include, sickness absence, alcohol-related sickness presenteeism, unemployment, alcohol-related antisocial behaviour, homicide, domestic violence related assault, non-domestic violence related assault, assault police, sexual offences, abduction and kidnapping, offensive conduct, and offensive language. We have included details on the data sources used in our calculation of risk-functions and social harms data in Supplementary Table 1, including the detailed methods used to estimate the risk functions. We derived the risk functions using 3 distinct approaches such as (a) relative risk from the published studies (b) relative risk calculated from alcohol-attributable fraction (c) relative risk calculated from a cross-sectional survey. All alcohol-related social harms data and relative risks were disaggregated by sex and age group. Relative risks for sickness absence, unemployment, and crimes were assumed to be partially attributable to alcohol consumption, while alcohol-related presenteeism (presenting to work even under the influence of alcohol) and ASB were considered wholly attributable to alcohol consumption. The derived RRs were then used in the calculation of Potential Impact Fraction (PIF) described in the later section.

A. RR from published studies

We derived Relative Risks (RRs) from systematic reviews and meta-analyses for sickness absence by the authors (Marzan et al., 2022) and from a prospective cohort study in Denmark for unemployment (Jørgensen et al., 2017). We selected RRs that align with the alcohol consumption categories used in our model. For instance, we examined the alcohol consumption measures and their categorizations in these studies, then matched them to the classifications in our current model. The unemployment study categorized alcohol consumption into four levels by drinks per week (Jørgensen et al., 2017), whereas the sickness absence study used four categories based on drinks per day (Marzan et al., 2022). The RRs for both sickness absence and unemployment were disaggregated by sex.

B. RR calculated from alcohol-attributable fraction

In the absence of available nationwide data to calculate the RR for crime, we used state-wide data from the New South Wales (NSW) Bureau of Crime Statistics and Research (BOCSAR) that provided a measure of alcohol involvement in crime (NSW Bureau of Crime Statistics & Research, 2021). These datasets were disaggregated by age and sex. Two assumptions were made in calculating the RR from an alcohol-attributable fraction (AAF) [AAF is the proportion of an outcome that would disappear if a portion of a population abstained from drinking alcohol)] (Taylor et al., 2011)]. We assumed a minimum threshold (<2 SD/day - moderate drinking) where alcohol consumption is unrelated to a crime committed, and we predicted the effects of consumption change on social outcomes based on the dose–response relationships that we gathered from meta-analyses and analyses of survey data. The primary point of difference with previous modelling work is that we modelled the risk of these outcomes based on the overall volume of consumption, not explicitly on heavy episodic drinking (HED) (Brennan et al., 2015; Meier et al., 2009; Purshouse, 2009). This is because our previously modelled elasticities in Australia (Jiang et al., 2020a, Jiang et al., 2020b) used average daily alcohol consumption categories instead of HED. Moreover, previous studies have shown that harmful drinking is as useful a predictor of social harms as the frequency of HED (Jørgensen et al., 2017; Marzan.et al., 2022; Marzan et al., 2023).

C. RR calculated from a cross-sectional survey

The risk functions for antisocial behaviours and sickness presenteeism were calculated using data from the combined waves of NDSHS 2013 and 2016 (Australian Institute of Health & Welfare, 2013, 2017). Since NDSHS specifically asked about alcohol-related ASB and presenteeism, we considered ASB and presenteeism as wholly attributable to alcohol. Due to the absence of a reference group (abstainers do not fit as reference group because these harms are fully attributable to alcohol) for these harms we used an alternative approach as has been described in the SAPM for wholly attributable harms (Meier et al., 2009), we assumed the risk to start at hazardous level of drinking and that the risk for people who drink at moderate amount is “null”. The RRs from cross-sectional survey were disaggregated by sex and age group.

Potential impact fraction and estimation of changes in the prevalence of alcohol-related social harms

Potential impact fraction. The PIF is the proportional change in the mean prevalence or incidence of an outcome or disease after a change in exposure to a risk factor (Meier et al., 2009). Our exposure in this study is alcohol consumption categorised by overall consumption levels, and the outcomes were sickness absence, alcohol-related sickness presenteeism, unemployment, alcohol-related ASB, and police-reported crimes. We estimated the PIF based on the three consumption levels defined earlier (moderate, hazardous, and harmful). We calculated the PIF by sex and age group. We used the RRs calculated using 3 methods in calculating the PIF. The PIF was computed as the change in the prevalence of alcohol consumption per consumption level (i.e., people who drink at harmful level shifting to hazardous or moderate amount), with the RR assumed to be the same for each consumption level before and after prevalence change.

We used the below formula to calculate the PIF (Biderafsh et al., 2015; Drescher & Becher,1997)

$$PIF = \frac{\int_{m=0}^{m} RR\ (X)\ P(X) - \int_{x=0}^{m} RR(X)P'(X)}{\int_{m=0}^{m} RR\ (X)\ P(X)}$$

Where RR (X) is the relative risk at each exposure level, P(X) is the population distribution of alcohol consumption, P′(X) is the counterfactual distribution of exposure (in this study, the baseline prevalence for each consumption level), and m is the maximum exposure level. The PIF for each outcome was presented as percentage.

Absolute counts of estimated reduction. We calculated the estimated reduction by deriving the baseline alcohol-related counts of our modelled social harms. The baseline counts of total absences, unemployment and sickness presenteeism were calculated using '*svy*' suites function in Stata version 17 (StataCorp, 2017). We used the NDSHS 2019 (Australian Institute of Health & Welfare, 2020) data for sickness absence and unemployment figures using the number of employed respondents who drink alcohol. We used NDSHS 2016 data to estimate the number of employees who committed sickness presenteeism, we also used NDSHS 2016 to extract the number of people who drink and perpetrated ASB - due to the change in structure of NDSHS 2019 questionnaire which resulted to implausibly low prevalence of the ASB and sickness presenteeism variables (Australian Institute of Health & Welfare, 2020). We used the recorded crimes offender statistics from the Australian Bureau of Statistics (ABS) for the year 2019 (Australian Bureau of Statistics, 2021) for the baseline crime numbers, which were disaggregated by age and sex. In each scenario, we estimated the result of each outcome by multiplying the PIF by the baseline number of each analysed outcome.

Monte-Carlo simulation. We computed 90 % uncertainty intervals by performing 1000 iterations of Monte Carlo simulations for each scenario and outcome, incorporating the uncertainty around the consumption model effects only. We used the previously modelled elasticities in Australia (Jiang et al., 2020a, Jiang et al., 2020b) to derive the shifts in consumption among the defined subpopulation groups for specific pricing policies. Both the higher and lower confidence intervals were used in our probabilistic uncertainty analysis (Monte-Carlo Simulation). The consumption distribution we followed in our Monte Carlo simulation is Gaussian (please refer to Supplementary Fig. 8). We computed 90 % uncertainty intervals using Monte Carlo simulations, incorporating the uncertainty around the consumption model effects only, assuming all else constant. We selected a 90 % uncertainty interval for our Monte Carlo simulations to enhance the precision of our estimates concerning the estimated changes in the relative and absolute reduction of social harms due to pricing policies. This narrower interval helps us more accurately capture the immediate effects of these policies, ensuring our analysis applicable to policy decisions (Preacher et al.,2012).

Results

Table 1 shows the mean annual consumption of SD under the current alcohol pricing policy in Australia versus the projected scenario using the four alcohol pricing policy options. On average, men consume 682 SD annually, which is nearly twice the amount consumed by women, who average 350 SD. All the modelled pricing policies decreased the mean annual per capita consumption across all age and sex groups. For both men and women, the impact is more significant among younger age groups, where more aggressive pricing policies like the Option D ($1.50 MUP) yield the most substantial decreases in consumption. Older adults also show notable declines, though these are slightly less pronounced compared to younger individuals. Overall, the data suggest that stronger pricing interventions tend to have a greater effect on reducing alcohol consumption across the board.

We present the current prevalence of alcohol consumption and the modelled shift in consumption prevalence (%) by sex and age group in Fig. 2. This figure shows that the greatest reduction in the prevalence of harmful drinking occurred in the MUP Option D ($1.50 MUP) across all compared sex and age groups. Notably, those previously drinking at harmful levels may reduce their intake, potentially moving into lower-risk categories such as "Hazardous" or –"Moderate" drinking. All policies modelled exerted wide significant impact among people who drink at harmful level across sex and age subgroups. However, only Option C (UER+10 %) shifted the consumption of men 16–34 years old and women 35–54 years old among people who drink at hazardous level.

The estimated absolute and relative reductions for each scenario are shown in Table 2. For simplicity, we present results for men and women combined here; sex-specific results are provided in the supplementary materials. The modelled impact of each pricing policy varies substantially across age subgroups. Unsurprisingly, the impacts of all policies were largest on wholly attributable social harms such as alcohol-related sickness presenteeism and alcohol-related ASB. The lowest reductions were noted in sickness absence and unemployment due to their *J*-shaped risk trajectories compared to other social harms with linear dose–response RR functions. Option C (UER+10 %) resulted in the largest reduction of all kinds of crimes perpetration among the policy options. It also led to the largest reduction of alcohol-consumption related unemployment. However, Option D ($1.50 MUP) was associated with the most reduction in the prevalences of sickness absence, sickness presenteeism, and alcohol-related sickness ASB perpetration.

Table 3 shows the overall impact of each pricing policy on all the modelled social harm outcomes. For brevity, we consolidated all police-reported crimes into a single category labelled "police-reported crimes." This category encompasses various offenses derived from police records, including homicide, domestic violence-related assault, non-domestic violence-related assault, assault directed at police, sexual offenses, abduction and kidnapping, intimidation, stalking and harassment, offensive conduct, and offensive language. We included here the minimum and maximum expected impact, the most likely impact, the 90 %

Table 1
Current annual mean alcohol consumption[Ð] in standard drinks in 2019 versus mean consumption levels under the modelled scenarios[†].

Sex	Age groups	Mean current alcohol consumption	(A) UER		(B) $1.30 MUP		(C) UER + 10 % tax increase		(D) $1.50 MUP	
			Mean consumption	(%) change	Mean consumption	(%) change	Mean consumption	(%) change	Mean consumption	(%) change
Women	16–34	333	304	–8.6 %	302	–9.2 %	294	–11.5 %	295	–11.3 %
	35–54	375	349	–6.9 %	349	–7.1 %	340	–9.3 %	340	–9.4 %
	55+	343	322	–6.1 %	322	–6.3 %	315	–8.3 %	313	–8.9 %
Men	16–34	663	598	–9.9 %	596	–10.1 %	564	–15.0 %	550	–17.0 %
	35–54	746	672	–9.9 %	667	–10.6 %	644	–13.8 %	639	–14.4 %
	55+	639	584	–8.6 %	580	–9.2 %	563	–11.9 %	559	–12.4 %

UER – Uniform excise rate.
MUP – Minimum unit price.
Ð – we used the 2019 National Drug Strategy Household Survey to calculate alcohol consumption.
† - Policy options were derived from "Modeling the effects of alcohol pricing policies on alcohol consumption in subpopulations in Australia" Jiang et al (2020).

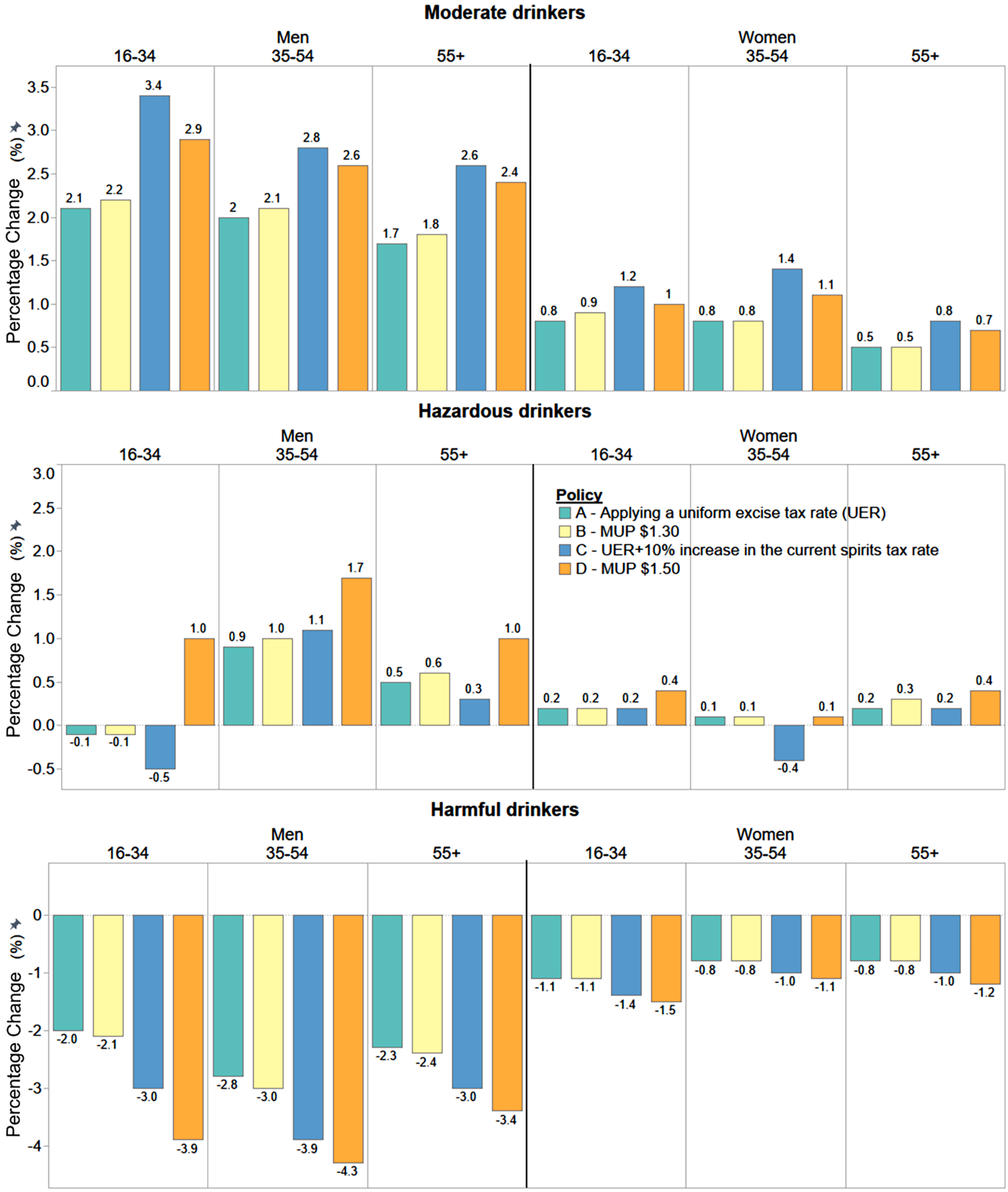

Fig. 2. Modeled changes in alcohol consumption prevalence (%) per policy option by sex and age group
The prevalence of abstainers for women was 28.80 % for 16–34, 24.60 % for 34–55, and 32.30 for 55+. Among men, the prevalence of abstainers was 27.20 % for 16–34, 18.90 % for 35–55, and 21.20 % for 55+. The prevalence of abstainers was assumed to be constant across all the appraised policy options.
Policy Options: (A Applying a uniform excise tax rate (UER – uniform excise rate) per unit of alcohol to all beverages equal to the current spirits tax rate; (B) MUP $1.30 – Introducing a minimum unit price on all beverage categories at $1.30 per/SD; (C) UER+10 % – Applying a UER to all beverages equal to a 10 % increase in the current spirits tax rate; (D) MUP $1.50 – Introducing a minimum unit price on all beverage categories at $1.50 per/SD.

CI based on Monte Carlo simulations and the probability that the policy effect may exceed the estimated impacts. The results reflected the above findings, although, in general, the (Option D – $1.50 MUP) has the lowest chance of exceeding the actual estimates compared to other options.

Discussion

Our paper is the first to model the effects of different taxation and minimum unit pricing scenarios on various social outcomes using Australian data for age and sex-specific subgroups. Our study has developed an underpinning methodological framework that links

Table 2
Estimated absolute and relative (%) modeled effects (reductions) on workplace and crime harms in Australia by age group in 2019.

Social Harms	Sex	*Estimated baseline total counts*[Ô]	Estimated reductions							
			Option A		Option B		Option C		Option D	
			Total	(%)	Total	(%)	Total	(%)	Total	(%)
Workplace Model										
Sickness absences	Men	186,261	717	0.38 %	677	0.36 %	1091	0.59 %	1213	0.65 %
	Women	119,741	129	0.11 %	79	0.07 %	131	0.11 %	136	0.11 %
Total		*306,002*	*846*	0.28 %	*756*	0.25 %	*1222*	0.40 %	*1349*	0.44 %
Alcohol–related sickness presenteeism	Men	264,634	20,315	7.68 %	21,242	8.03 %	29,446	11.13 %	31,121	11.76 %
	Women	132,675	7460	5.62 %	7815	5.89 %	10,127	7.63 %	10,029	7.56 %
Total		*397,309*	*27,775*	6.99 %	*29,057*	7.31 %	*39,573*	9.96 %	*41,150*	10.36 %
Number of unemployed people[†]	Men	534,461	3688	0.69 %	3638	0.68 %	5749	1.08 %	5326	1.00 %
	Women	581,852	1848	0.32 %	1688	0.29 %	2299	0.40 %	2302	0.40 %
Total		*1116,313*	*5536*	0.50 %	*5326*	0.48 %	*8048*	0.72 %	*7628*	0.68 %
Crime Model										
Alcohol–related ASB	Men	347,405	29,251	8.42 %	30,347	8.74 %	42,574	12.25 %	46,520	13.39 %
	Women	183,092	9255	5.05 %	9612	5.25 %	12,420	6.78 %	12,212	6.67 %
Total		*530,497*	*38,506*	7.26 %	*39,959*	7.53 %	*54,994*	10.37 %	*58,732*	11.07 %
Homicide	Men	617	12	1.94 %	11	1.78 %	17	2.76 %	16	2.59 %
	Women	107	5	4.67 %	5	4.67 %	7	6.54 %	7	6.54 %
Total		*724*	*17*	2.35 %	*16*	2.21 %	*24*	3.31 %	*23*	3.18 %
Domestic violence related assault	Men	13,432	362	2.70 %	378	2.81 %	535	3.98 %	505	3.76 %
	Women	4976	231	4.64 %	238	4.78 %	321	6.45 %	308	6.19 %
Total		*18,408*	*593*	3.22 %	*616*	3.35 %	*856*	4.65 %	*813*	4.42 %
Non–domestic violence related assault	Men	32,700	1071	3.28 %	1084	3.31 %	1668	5.10 %	1550	4.74 %
	Women	42,268	1672	3.96 %	1729	4.09 %	2353	5.57 %	2226	5.27 %
Total		*74,968*	*2743*	3.66 %	*2813*	3.75 %	*4021*	5.36 %	*3776*	5.04 %
Assault directed to police	Men	35,830	1346	3.76 %	1369	3.82 %	2095	5.85 %	1950	5.44 %
	Women	10,997	690	6.27 %	720	6.55 %	951	8.65 %	914	8.31 %
Total		*46,827*	*2036*	4.35 %	*2089*	4.46 %	*3046*	6.50 %	*2864*	6.12 %
Sexual offences	Men	6749	124	1.84 %	128	1.90 %	191	2.83 %	177	2.62 %
	Women	1273	35	2.75 %	36	2.83 %	47	3.69 %	46	3.61 %
Total		*8022*	*159*	1.98 %	*164*	2.04 %	*238*	2.97 %	*223*	2.78 %
Abduction and kidnapping	Men	2935	30	1.02 %	31	1.06 %	48	1.64 %	44	1.50 %
	Women	939	5	0.53 %	5	0.53 %	8	0.85 %	7	0.75 %
Total		*3874*	*35*	0.90 %	*36*	0.93 %	*56*	1.45 %	*51*	1.32 %
Intimidation, stalking and harassment	Men	12,460	292	2.34 %	303	2.43 %	435	3.49 %	410	3.29 %
	Women	3594	129	3.59 %	133	3.70 %	177	4.92 %	171	4.76 %
Total		*16,054*	*421*	2.62 %	*436*	2.72 %	*612*	3.81 %	*581*	3.62 %
Offensive conduct	Men	35,830	1586	4.43 %	1616	4.51 %	2471	6.90 %	2303	6.43 %
	Women	4039	216	5.35 %	224	5.55 %	302	7.48 %	289	7.16 %
Total		*39,869*	*1802*	4.52 %	*1840*	4.62 %	*2773*	6.96 %	*2592*	6.50 %
Offensive language	Men	1097	38	3.46 %	40	3.65 %	57	5.20 %	53	4.83 %
	Women	469	28	5.97 %	29	6.18 %	39	8.32 %	37	7.89 %
Total		*1566*	*66*	4.21 %	*69*	4.41 %	*96*	6.13 %	*90*	5.75 %

Policy Options: (A Applying a uniform excise tax rate (UER – uniform excise rate) per unit of alcohol to all beverages equal to the current spirits tax rate; (B) MUP $1.30 – Introducing a minimum unit price on all beverage categories at $1.30 per/SD; (C) UER+10 % – Applying a UR to all beverages equal to a 10 % increase in the current spirits tax rate; (D) MUP $1.50 – Introducing a minimum unit price on all beverage categories at $1.50 per/SD.
Ô – only alcohol-related counts.
† – These would only pertain to unemployment of the people who drink alcohol.
ASB – Antisocial behaviour.

multiple datasets and several methodologies to model the impacts of alcohol pricing policies on various social outcomes.

Our results showed that the four policy options modelled could reduce the total number of sickness absences, alcohol-related sickness presenteeism, unemployment, alcohol-related ASB and police-reported crimes compared to the current base taxation scenario. This is unsurprising given that all our modelled scenarios include increased costs of at least some types of alcohol compared to current settings which would be associated with decrease alcohol consumption that might lead to less social harms. Our findings support the calls for a more consistent taxation and/or pricing policy across all states in Australia and that replacing the current Wine Equalization Tax (WET) with either a uniform excise rate and/or an MUP may lead to significant reductions in social harms. Our results here mirror the interrupted time series analysis in the Northern Territory, which showed that the MUP $1.30 implementation in the state led to a significant decline in experience of physical abuse (Coomber et al., 2020). We found that the more impactful the policy to increase alcohol price, the more it reduces the social harms we modelled, although there was some variation. For instance, taxation policy (Option C – UER + 10 %) performed better than MUP (Option D - $1.50 MUP) in its potential impact on unemployment and crimes, most likely due to variations in the dose–response relationship between alcohol consumption. This highlights the importance of considering the dose–response relationship of each alcohol-related harm when designing or modelling policy options to address these harms, as emphasized elsewhere (Rehm et al., 2021).

Overall, (Option D – $1.50 MUP) had the greatest impact on reducing the prevalence of people who drink at harmful level for both men and women and all age groups and led to the biggest reductions in most social harms. Although this is the case, we do not conclude that other pricing policy options are necessarily inferior, as pricing policies need to balance out the impacts on consumers in terms of loss welfare alongside the health and social benefits. Our results are comparable to previously published modelling studies done in New Zealand, Wales, Scotland, England, Northern Ireland, Ireland, Canada, and South Africa (Brennan et al., 2016, 2015; Gibbs et al., 2021; Hill-McManus et al., 2012; Holmes et al., 2014; Meier et al., 2009; White J., 2014).

We acknowledge the key limitations of our study. Firstly, our alcohol

Table 3
Monte Carlo simulations on impact of pricing policy options to workplace and crime social harms.

Social Harm	Policy	Actual reduction	Max	Min	Mean	Median	10 % CI	90 % CI	(%) exceed[b]
Sickness Absences	A	846	1135	569	846	847	1006	679	50.30 %
	B	757	1172	476	795	785	986	622	58.30 %
	C	1221	1821	758	1273	1251	1607	964	54.50 %
	D	1350	1798	894	1349	1349	1614	1091	49.90 %
Sickness Presenteeism	A	27,775	28,685	26,420	27,642	27,674	28,217	27,024	41.70 %
	B	27,775	30,076	27,956	27,642	27,674	28,217	27,024	49.10 %
	C	39,572	40,672	38,235	39,501	39,535	40,182	38,814	46.40 %
	D	41,150	42,128	39,463	40,913	40,981	41,677	40,044	39.20 %
Unemployment	A	5536	6610	3883	5370	5401	6131	4566	41.00 %
	B	5324	6833	3438	5160	5172	6138	4165	42.00 %
	C	8048	10,178	5791	7978	7950	9276	6721	45.90 %
	D	7627	9291	5392	7510	7543	8567	6417	46.30 %
Antisocial Behaviour	A	38,506	39,782	36,637	38,370	38,407	39,252	37,404	43.90 %
	B	39,858	41,317	38,234	39,837	39,862	40,734	38,952	50.40 %
	C	54,995	56,638	53,000	54,825	54,859	55,809	53,777	43.70 %
	D	58,731	60,241	56,290	58,438	58,511	59,511	57,256	40.10 %
Police Reported Crimes[a]	A	7871	8019	7709	7864	7865	7956	7767	46.90 %
	B	8081	8325	7861	8094	8094	8224	7964	55.70 %
	C	11,722	11,957	11,456	11,712	11,716	11,858	11,568	47.30 %
	D	11,015	11,226	10,682	10,971	10,977	11,142	10,796	37.70 %

Policy Options: (A) Applying a uniform excise tax rate (UER – uniform excise rate) per unit of alcohol to all beverages equal to the current spirits tax rate; (B) MUP \$1.30 – Introducing a minimum unit price on all beverage categories at \$1.30 per/SD; (C) UER+10 % – Applying a UR to all beverages equal to a 10 % increase in the current spirits tax rate; (D) MUP \$1.50 – Introducing a minimum unit price on all beverage categories at \$1.50 per/SD.
ASB – Antisocial behaviour.
[a] Police-reported crimes – Homicide, Domestic violence related assault, non-domestic violence related assault, Assault directed to police, Sexual offences, Abduction and Kidnapping, (Intimidation, stalking and harassment), Offensive conduct, Offensive language.
[b] percent exceeding the actual number of reductions.

consumption estimates relied on a population survey with a considerable potential for recall and social desirability bias from the respondents (Zhao et al., 2009). The National Drug Strategy Household Survey substantially underestimates alcohol consumption compared to sales data (Livingston & Dietze, 2016). We did not adjust the self-reported alcohol consumption with sales data. Hence our results potentially underestimate the impact of price policies on harms. While we conducted an explicit uncertainty analysis, it only included the uncertainty around the estimates of the effects of price on consumption. We could not incorporate uncertainty around the relative risk functions or the baseline data we used. For instance, we assume all crimes flagged as alcohol involved in NSW are alcohol attributable, and that the risk relationships estimated from NSW crime data are consistent in other jurisdictions.

Another limitation of our model is that it applies overall price elasticities to a specific segment - the working population - without adjusting for potential differences in price sensitivity among various demographic groups. Further, the absolute number of crimes we included in the models is likely an underestimate as the data relies on police records without unreported crimes. However, we also have a category of ASB in the crime model which came from self-reported survey data, and this may partially account for the cases which have not been reported to the police. In the absence of disaggregated unemployment data with alcohol consumption estimates, we used the estimated unemployment figures from NDSHS 2019; these figures may not reflect the accurate numbers of people becoming unemployed because of their alcohol consumption. While previous models have studied the impact of pricing policies on socioeconomic subgroups, there were no Australian data that we can use to measure the social harm risk across the SES subgroup. Moreover, while we included uncertainty analyses here, we relied on multiple data sources and methodologies with their own accompanying uncertainties that we could not address with sensitivity or uncertainty analyses. One major difference we have as compared to the previous models done elsewhere (Brennan et al., 2016, 2015; Gibbs et al., 2021; Hill-McManus et al., 2012; Holmes et al., 2014; Meier et al., 2009, 2016; White J., 2014) is that we used the average daily alcohol consumption to model our harms while the previous models used HED or single occasion drinking. However, this should not be an issue since previous studies showed that average daily alcohol consumption and HED are equally useful predictors of social harms such as sickness absence, sickness presenteeism, unemployment, ASB, and violence (Jørgensen et al., 2017; Marzan et al., 2021, Marzan et al., 2022, Marzan et al., 2023). Lastly, our drinking classification was based on the NHMRC Australian Guidelines released in 2009 (Australian Government National Health Medical Research Council, 2009), which were updated in 2020 (Australian Government National Health Medical Research Council, 2020). This may imply that our modelling is somewhat inconsistent with the current Australian Alcohol Consumption Guidelines.

The key strengths of this study include the use of detailed price elasticity and relative risk estimate - providing the first detailed estimates of pricing policy impacts on social harms for age and sex subgroups in Australia. We used robust data and established methods to derive RRs or source them from peer reviewed sources. We also provided initial probabilistic uncertainty estimates for our model, which are rare in the literature as models are often deterministic (Brennan et al., 2015). Further research on the complementary impact of these policy options with other policies such as a ban on promotions, outlet regulations, or a combination of MUP and UER will provide more evidence to inform policy decisions. Future studies should also look at each pricing policy's cost-effectiveness or cost-benefits, especially since updated cost estimates of health and social harms for Australia were recently released (Whetton et al., 2021).

Based on our model, the adoptions of any alcohol pricing policy measures we estimated can reduce the burden of social harms attributable to alcohol use in Australia. However, pricing policies should just form a part of a comprehensive alcohol policy approach along with other proven policy measures such as bans on aggressive marketing of alcoholic products and enforcing the restrictions on availability of alcohol through outlet density regulation or reduced hours of sale to have a meaningful impact on social harms.

CRediT authorship contribution statement

Melvin Barrientos Marzan: Writing – review & editing, Writing – original draft, Visualization, Validation, Formal analysis, Data curation, Conceptualization. **Sarah Callinan:** Writing – review & editing, Validation, Supervision, Funding acquisition, Conceptualization. **Michael Livingston:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Heng Jiang:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest to declare

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Supplementary materials

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