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Binge Drinking and Antisocial and Unlawful Behaviours in Australia*

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This paper presents individual-level evidence from Australia to examine the factors associated with binge drinking and several alcohol-related antisocial and unlawful behaviours. We study in particular the role of binge drinking in increasing the likelihood of engaging in these negative behaviours. We use individual-level data from a national representative survey and a system econometric model that allows unobservable factors for all negative behaviours to be correlated. Potential misclassification of individuals' drinking pattern is accounted for. We find evidence of under-reporting for bingeing and significant effects of binge drinking on drink-driving, physical and verbal abuse, public disturbance, and stealing and damaging property.

I Introduction

Binge drinking and its related adverse effects have long been one of the major policy concerns in many countries. Although there has been evidence showing that moderate alcohol consumption benefits health among middle-aged and older people (for example, Gaziano *et al.*, 1993; Rimm, 1996; Fagrell *et al.*, 1999; Malinski *et al.*, 2004), the toll taken by excessive alcohol consumption or binge drinking on many societies significantly exceeds the benefit from moderate consumption. For instance, alcohol harm was responsible for 3.2 per cent of the total burden of disease and injury in Australia in 2003, while the benefit prevented 0.9 per cent of the total burden (Begg *et al.*, 2007).

As in many other developed countries, alcohol consumption is inherent in Australian culture. However, recent statistics show that consumption of alcohol at harmful levels in Australia is considerable. According to the 2010 Australian National Drug Strategy Household Survey (Australian Institute of Health and Welfare (AIHW) 2011), around 39.8 per cent of Australian people who are 14 years or older drank at least once in the previous 12 months (on a single drinking occasion) to an extent that put them at risk of an alcohol-related injury. Much of the recent concern arises from the evidence of a bingeing epidemic and the increasing popularity of premixed ready-to-drink spirits, especially among youth and young adults. In 2010, almost two-thirds (64.6 per cent) of males aged 18–19 years, and more than half (54.9 per cent) of males aged 20–29 years placed themselves at risk of an alcohol-related injury at least once a month (Australian Institute of Health and Welfare, 2011). In this context, the evidence from Australia and its ongoing experience in addressing the alcohol abuse epidemic constitutes an interesting case study.

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In addition to education and regulation, one of the main policy tools used by governments around the world for reducing alcohol abuse is alcohol taxation. Excessive alcohol consumption is associated with a range of negative externalities in areas of road accidents, criminal activities, abuse of family members and others, health care, law enforcement costs, and some labour market participation and productivity implications (Freebairn, 2010). These external costs are often not included as private costs in a consumer's personal consumption decision-making and are borne by the society. Whilst attempts to separately estimate the private and public costs of alcohol abuse are controversial (Manning *et al.*, 1989; Richardson & Crowley, 1997; Freebairn, 2010), there is no doubt that the extent of market failure is substantial. The key rationale for alcohol tax is to correct market failure by reducing excessive consumption that induces high external social costs. Thus, quantifying the associated harm to the society from excessive alcohol consumption is a necessary step in formulating alcohol-related policies.

Drinking can increase the probability of people participating in behaviours that are antisocial, harmful or even criminal. For example, excessive alcohol consumption can lead to risky sexual activities and violent behaviours. On the other hand, alcohol consumption in conjunction with normal activities, such as driving or swimming while under the influence of alcohol, can increase the probability that such activities result in harm. Some studies have looked at the link between alcohol drinking patterns and alcohol-related antisocial behaviours using both population- and individual-based data and methods. Specifically, incidences of alcohol-related antisocial behaviours have been compared across different populations (for example, Wechsler *et al.*, 1994; Douglas *et al.*, 1997; Weiser *et al.*, 2006; Lane *et al.*, 2008; Umana *et al.*, 2014; Zetola *et al.*, 2014). Individual-based studies, on the other hand, have examined the correlation between individual alcohol drinking patterns and incidence of alcohol-related antisocial or risky behaviours. They have found that heavy drinkers are more likely to participate in risky activities or undertake antisocial and unlawful behaviours (for example, Cherpitel, 1995; Greenfield & Weisner, 1995; Beck *et al.*, 2009; Petrie *et al.*, 2010; Bègue *et al.*, 2012).

To the best of our knowledge, drinking patterns have mostly been treated as exogenous in this literature (see, for example, Greenfield & Weisner, 1995; Markowitz *et al.*, 2005; Salomé *et al.*, 2005; Brown & Vanable, 2007). However, individuals' drinking patterns and their inclination towards antisocial behaviours under the influence of alcohol are very likely to be driven by a common set of unobservable factors. Thus, it may be inappropriate to treat drinking patterns as exogenous. For instance, as Gottfredson and Hirschi (1990) argued, people who lack self-control are more likely to engage not only in antisocial or unlawful activities, but also negative behaviours such as drinking, gambling and smoking. In addition, some other personality traits linked to individuals' differences in behaviours, such as impulsiveness, risk-taking and sensation-seeking, are also believed to be related to alcohol use and abuse (Cherpitel, 1993). Such confounding factors can potentially obscure the extent of correlations and induce endogeneity or simultaneity bias (Hayashi, 2000). Exceptions in this literature are Chatterji *et al.* (2004) and Sen (2002), where a recursive endogenous bivariate probit model is used to respectively examine suicide attempts among youth and sexual intercourse among adolescents.

This paper aims to contribute to this growing body of literature by studying the association of binge drinking with alcohol-related antisocial and unlawful behaviours, using a nationally representative individual-level dataset in Australia. We make several specific contributions to this empirical literature. We allow for the endogeneity of binge drinking behaviour in its association with negative behaviours and use alcohol price variation as instrumental variable to identify the endogenous treatment effect. We also consider several negative alcohol-related behaviours separately rather than focusing on a single crime alone as in most of the existing studies. We use a system approach with a multivariate probit model to allow for unobservable factors for all negative drinking behaviours to be correlated. In addition, as the self-reported drinking pattern variable is potentially subject to misclassification, we explicitly allow for possibilities of misclassification using a modified maximum likelihood approach following Hausman *et al.* (1998). Finally, our results provide useful evidence to contribute to the limited empirical literature in both Australia and overseas on the association between binge drinking and antisocial and unlawful behaviours.

The rest of this paper is set out as follows. Section II details the data. Section III presents

the econometric framework. Section IV discusses the estimation results, and Section V concludes.

II Data

The data we use in this study are drawn from the 2001, 2004, 2007 and 2010 waves of the Australian National Drug Strategy Household Survey (NDSHS), involving 106,193 individuals (NDSHS, 2010). The NDSHS is a nationally representative cross-sectional survey of the non-institutionalised Australian civilian population aged 12 years and older and is administered by the AIHW. The survey provides information on drug use patterns, attitudes and behaviour. It also provides a wide range of information on respondents' demographic and socioeconomic backgrounds.

Key to our study is information on individuals' antisocial behaviours undertaken under the influence of alcohol. In the survey, information on individuals' antisocial behaviours is collected via a question asking 'In the last 12 months, did you undertake the following while under the influence of or affected by alcohol?' The respondents then tick 'Yes' or 'No' for each of the following activities: 'Went to work', 'Went swimming', 'Operated a boat', 'Drove a motor vehicle', 'Operated hazardous machinery', 'Created a public disturbance or nuisance', 'Caused damage to property', 'Stole money, goods or property', 'Verbally abused someone' and 'Physically abused someone'.

In this paper, we focus on the following antisocial and unlawful behaviours: 'Drove a motor vehicle', 'Created a public disturbance or nuisance', 'Caused damage to property', 'Stole money, goods or property', 'Verbally abused someone' and 'Physically abused someone'. Table 1 displays the proportions of individuals in the sample who participated in each of these antisocial behaviours while under the influence of alcohol, across waves of survey from 2001 to 2010.

For practical purposes, we categorise the activities into three groups. Given similarities among some of these behaviours, a natural manner of grouping would be: driving (drove a motor vehicle), disturbance (created a public disturbance/nuisance or caused damage to property), stealing (stole money, goods or property), and abuse (verbally or physically abused someone). However, as can be seen in Table 1, compared to other groups, the percentage of the sample in the stealing group is rather small. We therefore merge this group with the disturbance group. Consequently, this combined group includes both disturbance and stealing.

TABLE 1
Sample Participation in Antisocial Behaviours for Drinkers (per cent)

	2001	2004	2007	2010
Drove a motor vehicle	13.11	12.75	12.11	11.35
Created a public disturbance or nuisance	2.39	2.27	2.12	1.91
Caused damage to property	1.39	1.28	1.21	1.10
Stole money, goods or property	0.50	0.35	0.33	0.32
Verbally abused someone	5.49	5.30	4.68	4.09
Physically abused someone	1.01	0.92	0.88	0.74

Table 2 depicts the proportions of subgroups of individuals in the sample who participated in each of the three groups of antisocial behaviours while under the influence of alcohol, conditioned on age, gender and waves of survey from 2001 to 2010. Throughout these four waves of survey, participation rates of drink-driving dominate for both males and females across all the age groups except 12–17, who usually do not have a full licence and to whom substantial restrictions on driving apply in Australia. Clearly, disturbance and abuse show a declining trend, but the proportions are still quite significant, especially for youth and young adults. The decline in drink-driving for the 18–22 group may also reflect the effectiveness of the introduction of a longer probation period and zero alcohol tolerance policy for probationary drivers. We also see that in all age groups ranging from 18–22 to 60+, male drinkers tend to be more likely to participate in all the three types of antisocial behaviours than female drinkers, while under the influence of alcohol. In contrast, female drinkers in the 12–17 age group who were surveyed in 2004 and 2010 are more likely to have verbally or physically abused someone than male drinkers from the same age group surveyed in the same year.

Binge drinking is generally recognised as drinking heavily on an occasion. The harmful consequences pertaining to alcohol consumption are generally linked with heavy or binge drinking. Not only does binge drinking, especially among adolescents and young adults, result in a high incidence of vehicle crashes, crime and violence, but it also has detrimental and often irreversible

TABLE 2
Sample Participation in Aggregate Antisocial Behaviour Groups for Drinkers Conditioned on Age, Gender and Year (per cent)

Age group			2001	2004	2007	2010
12–17	Male	Driving	8.00	4.95	4.70	3.52
		Disturbance	24.48	15.52	15.05	16.02
		Abuse	23.56	17.37	14.81	10.09
	Female	Driving	4.20	3.60	2.28	4.15
		Disturbance	16.33	11.92	14.73	16.21
		Abuse	17.96	17.62	14.53	12.11
18–22	Male	Driving	29.73	28.73	22.74	21.59
		Disturbance	29.30	25.20	25.78	20.58
		Abuse	31.68	29.32	26.00	20.94
	Female	Driving	17.51	15.35	16.23	13.65
		Disturbance	11.39	10.72	10.09	9.60
		Abuse	15.49	17.68	15.63	14.00
23–29	Male	Driving	34.49	34.92	33.38	24.69
		Disturbance	10.35	13.48	16.05	13.10
		Abuse	15.68	17.99	18.48	15.14
	Female	Driving	17.22	18.02	16.52	15.15
		Disturbance	3.36	4.32	4.27	5.12
		Abuse	8.34	9.27	9.22	7.70
30–39	Male	Driving	27.73	30.33	25.09	24.40
		Disturbance	2.94	4.34	4.65	3.56
		Abuse	8.47	10.03	9.20	7.43
	Female	Driving	14.77	14.30	13.48	11.59
		Disturbance	1.00	1.61	1.11	1.53
		Abuse	4.70	4.72	4.40	4.30
40–49	Male	Driving	25.48	26.11	22.17	21.00
		Disturbance	1.15	1.62	1.47	1.77
		Abuse	6.28	6.28	5.51	4.94
	Female	Driving	15.07	14.82	12.74	10.55
		Disturbance	0.38	0.87	0.97	0.62
		Abuse	3.24	3.97	3.20	2.89
50–59	Male	Driving	19.05	20.28	19.06	18.65
		Disturbance	0.58	1.05	0.95	0.82
		Abuse	4.58	3.27	4.06	3.32
	Female	Driving	8.05	8.31	10.62	8.56
		Disturbance	0.24	0.30	0.24	0.43
		Abuse	1.65	1.46	2.16	1.98
60+	Male	Driving	8.53	9.74	11.50	11.02
		Disturbance	0.15	0.25	0.09	0.22
		Abuse	1.36	1.34	1.49	1.38
	Female	Driving	2.00	3.18	3.87	3.18
		Disturbance	0.00	0.10	0.05	0.08
		Abuse	0.48	0.45	0.50	0.44

Notes: Driving: drove a motor vehicle; Disturbance: created a public disturbance/nuisance, caused damage to property, or stole money, goods or property; Abuse: verbally or physically abused someone.

consequences in terms of health, human capital and social status. However, while drinkers can be clearly defined as those who have consumed alcohol in the past year and the rest are defined as abstainers, which results into a subsample of 82,053 drinkers in this study, how to define bingeing has been controversial in the literature. The definition disagrees on, among other things, the units of measurement of alcohol beverages and the number of drinks. In the absence of a unified measurement of binge drinking, in this study risk levels related to short-term harm from

drinking, as defined in the 2001 National Health and Medical Research Council Alcohol Guidelines (National Health and Medical Research Council, 2001), are used to group drinkers by different drinking patterns. Therefore, bingers are defined as those who have engaged in medium- to high-risk drinking in the past year: specifically, men drinking at least seven standard drinks and women drinking at least five standard drinks on a single occasion. This definition of binge or heavy drinking has also been adopted in several other studies on binge drinking (for example, Chaloupka & Wechsler, 1996; Williams *et al.*, 2002; Srivastava & Zhao, 2010).[1,2]

We define individuals as bingers based on the survey question where they were asked to report their drinking patterns in the last 12 months. Specifically, respondents were requested to record 'how often in the last 12 months you have had each of the following number of standard drinks in a day'. Respondents had to choose from a grid with the vertical array displaying the number of standard drinks, from '20 or more drinks', '11–19 standard drinks' to 'less than 1 standard drink' or 'none', and the horizontal array displaying the frequency from 'every day', '5 to six days a week' to 'about once a month', 'less often' or 'never'. A snapshot of this question is given in Figure A1 in the supplementary online appendix.

On the basis of the 2001 NHMRC Alcohol Guidelines, if a man has ever, even if the frequency is 'less often' (see Figure A1), found himself associated with any of the three drinking scenarios '7–10 standard drinks a day', '11–19 standard drinks a day' and '20 or more standard drinks a day', he is defined as a binger engaging in medium- to high-risk drinking; if a woman has ever, even if the frequency is 'less often' (see Figure A1), found herself associated with any of the four drinking scenarios '5–6 standard drinks a day', '7–10 standard drinks a day', '11–19 standard drinks a day' and '20 or more standard drinks a day', she is defined as a binger engaging in medium- to high-risk drinking.

TABLE 3
Participation Rates by Drinking Patterns (per cent)

	2001	2004	2007	2010
Abstainer	19.36	19.42	21.23	22.79
Drinker	80.64	80.58	78.77	77.21
Binger	34.77	35.95	31.63	30.61

Note: Figures pertain to percentages out of the whole sample of a specific year.
Source: NDSHS (2010).

In Table 3, we see that most of the respondents (about 80 per cent) from each wave of the survey are drinkers and around 30–35 per cent are bingers. For obvious reasons, in this study drinkers and bingers are of principal interest to us. The observed unconditional correlation coefficients between the antisocial behaviours undertaken under the influence of alcohol and drinking pattern are presented in Table A1 in the supplementary online appendix. Table A1 clearly shows that drinking pattern (bingeing or not) is correlated with alcohol-related antisocial behaviours.

In our econometric model, we control for a range of individual socioeconomic, demographic and lifestyle factors, as well as (aggregated) alcohol price. Details of all dependent and explanatory variables used in this study are presented in Table A2 and Table A3 in the supplementary online appendix.

III Econometric Framework and Estimation Issues

To jointly study the association between binge drinking and alcohol-related antisocial behaviours, we specify a system of probit equations with a triangular endogenous structure,[3] which

[1] In March 2009, the NHMRC released a new set of guidelines on alcohol consumption and health risks. However, this new set of guidelines is controversial in that although, in recognition of the fact that the lifetime risk of harm from consuming alcohol increases progressively with the amount consumed (National Health and Medical Research Council, 2009), the previous threshold-based definitions for risky or high-risk drinking were removed. In particular, the 2009 guidelines recommend that drinking no more than two standard drinks, for both men and women, on any day reduces the lifetime risk of harm from alcohol-related disease or injury. To conform to the definition of binge drinking conventionally used in previous studies we follow the 2001 guidelines.

[2] We have also rerun our model with the alternative definition of binge drinking, which only represents the high-risk drinking pattern. It shows that our results are generally robust against this alternative definition. The full results are available from the authors upon request.

[3] For a similar bivariate case, see Greene (2007, p. 823) and Maddala (1983, p. 123).

allows binge drinking to be determined endogenously. Let $Y^*_{i,\mathrm{B}}$, $Y^*_{i,\mathrm{Driving}}$, $Y^*_{i,\mathrm{Disturbance}}$and $Y^*_{i,\mathrm{Abuse}}$ denote the propensity of the ith individual to participate in binge drinking and the three alcohol-related antisocial behaviours. The four latent variables are mapped to observed binary dummy variables $Y_{i,\mathrm{B}}$, $Y_{i,\mathrm{Driving}}$, $Y_{i,\mathrm{Disturbance}}$and $Y_{i,\mathrm{Abuse}}$ using:

$$Y_{i,L} = \begin{cases} 1, \text{ if } Y^*_{i,L} > 0, \\ 0, \text{ if } Y^*_{i,L} \leq 0, \end{cases} \tag{1}$$

where $L\epsilon\{\mathrm{B}, \mathrm{Driving}, \mathrm{Disturbance}, \mathrm{Abuse}\}$, and $Y_{i,L} = 1$ denotes participation and $Y_{i,L} = 0$ otherwise.

We specify the system of equations as follows:

$$\begin{cases} Y^*_{i,\mathrm{B}} = X'_{i,\mathrm{B}}\beta_{\mathrm{B}} + \varepsilon_{i,B}, \\ Y^*_{i,\mathrm{Driving}} = X'_{i,\mathrm{Driving}}\beta_{\mathrm{Driving}} + \alpha_{\mathrm{Driving}}Y_{i,\mathrm{B}} + \varepsilon_{i,\mathrm{Driving}}, \\ Y^*_{i,\mathrm{Disturbance}} = X'_{i,\mathrm{Disturbance}}\beta_{\mathrm{Disturbance}} + \alpha_{\mathrm{Disturbance}}Y_{i,\mathrm{B}} + \varepsilon_{i,\mathrm{Disturbance}}, \\ Y^*_{i,\mathrm{Abuse}} = X'_{i,\mathrm{Abuse}}\beta_{\mathrm{Abuse}} + \alpha_{\mathrm{Abuse}}Y_{i,\mathrm{B}} + \varepsilon_{i,\mathrm{Abuse}} \end{cases} \tag{2}$$

where $X'_{i,\mathrm{B}}$, $X'_{i,\mathrm{Driving}}$, $X'_{i,\mathrm{Disturbance}}$ and $X'_{i,\mathrm{Abuse}}$ are vectors of exogenous covariates. The error terms in the respective equations are assumed to independently and identically follow a multivariate normal distribution with mean zero and covariance matrix Σ; that is, $(\varepsilon_{i,\mathrm{B}}, \varepsilon_{i,\mathrm{Driving}}, \varepsilon_{i,\mathrm{Disturbance}}, \varepsilon_{i,\mathrm{Abuse}})'\sim\mathrm{MVN}\ (0, \Sigma)$, where

$$\sum = \begin{pmatrix} 1 & \rho_{\mathrm{B,Driving}} & \rho_{\mathrm{B,Disturbance}} & \rho_{\mathrm{B,Abuse}} \\ \rho_{\mathrm{B,Driving}} & 1 & \rho_{\mathrm{Driving,Disturbance}} & \rho_{\mathrm{Driving,Abuse}} \\ \rho_{\mathrm{B,Disturbance}} & \rho_{\mathrm{Driving,Disturbance}} & 1 & \rho_{\mathrm{Disturbance,Abuse}} \\ \rho_{\mathrm{B,Abuse}} & \rho_{\mathrm{Driving,Abuse}} & \rho_{\mathrm{Disturbance,Abuse}} & 1 \end{pmatrix} \tag{3}$$

We assume $\mathrm{Var}(\varepsilon_{i,L}) \equiv 1$ ($L \in \{\mathrm{B}, \mathrm{Driving}, \mathrm{Disturbance}, \mathrm{Abuse}\}$) in order for the parameters to be identified separately from the variance of ε (Greene, 2007). Equations (1)–(3) together specify an endogenous multivariate probit (MVP) system model with a recursive simultaneous structure that jointly determines the binge drinking decision and the three decisions to participate in antisocial behaviours while under the influence of alcohol. Specifically, the MVP specification with potentially non-zero off-diagonal elements in Σ allows for correlations across the disturbances of the four latent equations. Note that when the off-diagonal elements in Σ equal zero the MVP model reduces to four independent probit models which can then be estimated separately.

Identification is a major concern when estimating systems of equations. Although identification can be achieved under the assumed data generating process (DGP) of the multivariate normal distribution due to the non-linearity of the MVP model, Li *et al.* (2014) show that, under the partial identification framework where the true DGP is allowed to be from a broader class beyond the MVP, the existence of instrumental variables is crucial for narrowing the confidence bounds for average treatment effects. Monfardini and Radice (2008) also show that even if the distribution of errors is misspecified, exclusion restrictions preserve the validity of the inference in finite sample. So, besides relying on the functional form of the MVP for identification, we follow the literature and impose exclusion restrictions to allow identification under more robust assumptions. Specifically, $X_{i,\mathrm{B}}$ needs to contain instrument(s) which do not appear in $X'_{i,\mathrm{Driving}}$, $X'_{i,\mathrm{Disturbance}}$ and $X'_{i,\mathrm{Abuse}}$.

In the literature a wide range of variables have been used to instrument the use of drugs such as tobacco, alcohol, marijuana, cocaine (for a detailed survey of various instruments, see French & Popovici, 2011). Typical instruments for alcohol consumption include family characteristics, such as parent with alcohol problems and parent's smoking status (Koch & McGeary, 2005; French & Maclean, 2006; Renna, 2007); personal beliefs/characteristics, such as religiosity,

smoked at age 18, and chronic disease/health (Wolaver, 2002; Williams *et al.*, 2003; Renna, 2007); and state laws, taxes, policies and prices, such as state minimum legal drinking age, state beer taxes and alcohol prices (Bray, 2005; Williams, 2005; Renna, 2008).

We use the Australian price index of alcohol deflated using the consumer price index (which varies by state of residence and year) as an instrument for alcohol consumption in this study (Australian Bureau of Statistics, 2011). A price index, defined as a normalised average of price relatives, compares how price relatives differ between time periods. According to the downward-sloping standard demand schedule, the demand for alcohol is inversely proportional to its price. There is a rich body of evidence in the literature showing that alcohol price is significantly correlated with alcohol consumption (Bray, 2005; Anderson *et al.*, 2009; Babor *et al.*, 2010). In addition, since the variation in alcohol price index is not directly correlated with unobservable factors affecting individuals' antisocial behaviour participation, such as impulsiveness, risk-taking and sensation-seeking, once alcohol drinking pattern and other observables have been controlled for, the alcohol price index can be regarded as a valid instrument for the purpose of this study.

Another potential issue with our analysis is 'misclassification' with respect to the dichotomous binge variable. Misclassification refers to a response classified in the wrong category. As described in the previous section, the binge drinking variable is constructed from a survey question which asks respondents to report their drinking patterns in the last 12 months. Respondents had to choose from a grid with the vertical array displaying the number of standard drinks from '20 or more drinks', '11–19 standard drinks' to 'less than 1 standard drink' or 'none', and the horizontal array displaying the frequency from 'every day', 'five to six days a week' to 'about once a month', 'less often' or 'never' (see Figure A1). Given the complex structure of this question, which involves a multitude of alternatives and a long recall period, the information used to construct the drinking pattern variable is more likely to be subject to misclassification error than if a straightforward and general question had been presented. In a discrete-response model, the misclassification of dependent variables renders coefficient estimates inconsistent when estimation techniques such as probit or logit are used. This potentially has even more severe consequences in the MVP system specification where the alcohol consumption variable is endogenous.

Note that one may also have similar concerns with regard to the other three dependent variables (i.e. antisocial behaviours). Given the long recall period (one year) and the antisocial and unlawful nature of these behaviours, responses relating to these behaviours are also likely to be misclassified. However, we do not explicitly account for misclassification for these for the following reasons. First, unlike the binge question, the behaviour-related survey question is quite straightforward and general. Second, the survey is anonymous and uses a drop-and-collect method which should significantly reduce the need for intentional misreporting. So we expect the degree of misreporting is lower than that for the binge question. Finally, further allowing for misclassification in the antisocial behaviours increases the complexity of the model substantially, given the need to numerically evaluate another four-dimensional integral. The maximisation of the very complex likelihood function failed in such an attempt.

A modified maximum likelihood approach, proposed by Hausman *et al.* (1998), is employed to correct for potential misclassification of the binge drinking variable. This approach is further extended to dynamic discrete choice scenarios by Keane and Sauer (2009). Specifically, let $\tilde{Y}_{i,\mathrm{B}}$ denote the true response for the underlying latent variable $Y^*_{i,\mathrm{B}}$, that is,

$$\tilde{Y}_{i,\mathrm{B}} = I(Y^*_{i,\mathrm{B}} > 0), \tag{4}$$

where $I(E)$ is the indicator function equal to one if E is true and zero otherwise. Following Hausman *et al.* (1998), the probability of misclassification of the bingeing variable depends on the values of $\tilde{Y}_{i,\mathrm{B}}$, and is assumed to be independent of the covariates and other dependent variables in the MVP model. Accordingly, if $Y_{i,\mathrm{B}}$ denotes the observed bingeing indicator variable, the misclassification probabilities can be defined as:

$$\begin{aligned} \alpha_0 &= P(Y_{i,\mathrm{B}} = 1 | \tilde{Y}_{i,\mathrm{B}} = 0), \\ \alpha_1 &= P(Y_{i,\mathrm{B}} = 0 | \tilde{Y}_{i,\mathrm{B}} = 1), \end{aligned} \tag{5}$$

where α_0 is the probability that a zero is misclassified as a one, and α_1 is the probability that a one is misclassified as a zero.

Given a random sample of N households, on the assumption that error terms in (2) follow a

multivariate normal distribution, the system of equations can be consistently and efficiently estimated by maximising the following modified log-likelihood function, corrected for misclassification:

$$\sum_{i=1}^{N}\sum_{l=0}^{1}\sum_{m=0}^{1}\sum_{n=0}^{1}\sum_{k=0}^{1} d_{i,lmnk}\log\{P(\tilde{Y}_{i,\mathrm{B}}=l, Y_{i,\mathrm{Driving}}=m, Y_{i,\mathrm{Disturbance}}=n, Y_{i,\mathrm{Abuse}}=k| X_{i,\mathrm{B}}, X_{i,\mathrm{Driving}}, X_{i,\mathrm{Disturbance}}, X_{i,\mathrm{Abuse}})\cdot(1-\alpha_l) + P(\tilde{Y}_{i,\mathrm{B}}=1-l, Y_{i,\mathrm{Driving}}=m, Y_{i,\mathrm{Disturbance}}=n, Y_{i,\mathrm{Abuse}}=k|X_{i,\mathrm{B}}, X_{i,\mathrm{Driving}}, X_{i,\mathrm{Disturbance}}, X_{i,\mathrm{Abuse}})\cdot\alpha_{1-l}\}, \tag{6}$$

where $d_{i,lmnk} = I(\tilde{Y}_{i,B}=l, Y_{i,Driving}=m, Y_{i,Disturbance}=n, Y_{i,Abuse}=k)$ and

$$P(\tilde{Y}_{i,\mathrm{B}}=l, Y_{i,\mathrm{Driving}}=m, Y_{i,\mathrm{Disturbance}}=n, Y_{i,\mathrm{Abuse}}=k|X_{i,\mathrm{B}}, X_{i,\mathrm{Driving}}, X_{i,\mathrm{Disturbance}}, X_{i,\mathrm{Abuse}}) = \Phi_4[(2l-1)X'_{i,\mathrm{B}}\beta_{\mathrm{B}}, (2m-1)(X'_{i,\mathrm{Driving}}\beta_{\mathrm{Driving}}+\alpha_{\mathrm{Driving}}l), (2n-1)(X'_{i,\mathrm{Disturbance}}\beta_{\mathrm{Disturbance}} + \alpha_{\mathrm{Disturbance}}l), (2k-1)(X'_{i,\mathrm{Abuse}}\beta_{\mathrm{Abuse}}+\alpha_{\mathrm{Abuse}}l); \Sigma],$$

where

$$\Sigma = \begin{pmatrix} 1 & (2l-1)(2m-1)\rho_{\mathrm{B,Driving}} & (2l-1)(2n-1)\rho_{\mathrm{B,Disturbance}} & (2l-1)(2k-1)\rho_{\mathrm{B,Abuse}} \\ (2l-1)(2m-1)\rho_{\mathrm{B,Driving}} & 1 & (2m-1)(2n-1)\rho_{\mathrm{Driving,Disturbance}} & (2m-1)(2k-1)\rho_{\mathrm{Driving,Abuse}} \\ (2l-1)(2n-1)\rho_{\mathrm{B,Disturbance}} & (2m-1)(2n-1)\rho_{\mathrm{Driving,Disturbance}} & 1 & (2n-1)(2k-1)\rho_{\mathrm{Disturbance,Abuse}} \\ (2l-1)(2k-1)\rho_{\mathrm{B,Abuse}} & (2m-1)(2k-1)\rho_{\mathrm{Driving,Abuse}} & (2n-1)(2k-1)\rho_{\mathrm{Disturbance,Abuse}} & 1 \end{pmatrix},$$

and $\Phi_4(\cdot, \sum)$ is a four-variate standard normal cumulative distribution function (cdf) with the variance–covariance matrix $\sum$. Hausman *et al.* (1998) pointed out that the only assumption required for identification of this model (besides the usual condition that $E(X'X)$ exists and is of full rank) is that $\alpha_0 + \alpha_1 < 1$. This implies that the classification problem cannot be so severe that respondents are misclassified more often than not, which is certainly a mild assumption.

Our system model is estimated using Stata 13. Since the estimation of the model involves evaluating a four-variate standard normal cdf, a recursive conditioning procedure known as the GHK smooth recursive probability simulator (Geweke, 1989; Borsch-Supan & Hajivassiliou, 1993; Keane, 1994) is employed. The computation of marginal effects and treatment effects is complex, given the endogenous structure of the model and the presence of common variables across the four equations. This results in joint and conditional probabilities that are highly non-linear functions of X, making analytical solutions of marginal effects and treatment effects difficult to obtain. We therefore estimate them in R via numerical derivatives of the multivariate normal distribution function with respect to the exogenous variables. Standard errors of the estimated marginal effects and treatment effects are computed by a bootstrapping procedure in which 500 new samples are randomly drawn with replacement.

IV Results

(i) Correlation and Misclassification

Tables 4 and 5 report the estimated parameters and corresponding standard errors of the MVP system model presented in equations (1)–(3). We begin by examining pairwise correlation coefficient estimates between the error terms in the four equations (Table 4). The correlations between the three antisocial behaviour equations are all statis-

TABLE 4
Estimated Correlation Coefficients $\hat{\rho}$ from the Multivariate Probit Model

	Driving	Disturbance	Abuse	Binge
Driving	1	0.283***	0.280***	0.004
		(0.014)	(0.011)	(0.023)
Disturbance		1	0.497***	−0.074
			(0.011)	(0.049)
Abuse			1	−0.033
				(0.034)
Binge				1

Notes: Driving: drove a motor vehicle; Disturbance: created a public disturbance/nuisance, caused damage to property, or stole money, goods or property; Abuse: verbally or physically abused someone. Standard errors, given in parentheses, are derived by a bootstrapping procedure in which 500 new samples are randomly drawn with replacement.
*Significant at 10%, **Significant at 5%, ***Significant at 1%.

tically significant at the 1 per cent level, suggesting that after controlling for observable individual characteristics and binge drinking, there are still significant common unobservable factors driving all three behaviours. Among these correlations, the one between disturbance (created a public disturbance/nuisance, caused damage to property, or stole money, goods or property) and abuse (verbally or physically abused someone) is the highest at 0.497, which is consistent with intuition and observed correlations in Table A1. Interestingly and somewhat surprisingly, the correlations of the error terms in the binge equation and the antisocial behaviour equations are all small and statistically insignificant, suggesting a weak case for its endogeneity. This seems to suggest that common observable factors and binge drinking are the main sources of observed correlation between negative behaviours and binge in Table A1. There are no significant unobservable common factors that lead to bingeing and also lead to antisocial behaviours, once binge drinking is explicitly controlled for in the behaviour equations.

The misclassification probability coefficient α_1 is also statistically significantly different from zero at the 1 per cent significance level as seen in Table 5, justifying the need to address misclassification. This shows that there is a 9.9 per cent chance of under-reporting when a respondent does not report bingeing but is in fact a binger. The estimate for coefficient α_0 is statistically insignificant, so we do not find evidence for falsely reporting bingeing, or over-reporting.

(ii) Effect of Bingeing on Antisocial Behaviours

We report in the first row of Table 6 the average treatment effects of binge drinking on the alcohol-related antisocial behaviours. As expected, bingers are more likely to exhibit all three types of antisocial behaviours while under the influence of alcohol. In particular, bingers are more likely to drink and drive (14.4 percentage points (pp)), create a public disturbance/nuisance, cause damage to property, or steal money, goods or property (2.3 pp), and verbally or physically abuse someone (8.4 pp), while under the influence of alcohol. This is consistent with other studies which have found a strong association between drink-driving and binge drinking (see, for example, Quinlan *et al.*, 2005). The model was rerun with the alternative definition of binge drinking, which only represents the high-risk drinking pattern. The results show even higher average treatment effects of bingeing on antisocial behaviours under the influence of alcohol. Specifically, the average treatment effects of bingeing on driving, disturbance and abuse respectively increase from 14.4 pp to 17.0 pp, from 2.3 pp to 4.2 pp and from 8.4 pp to 11.8 pp. Overall, the average treatment effect of bingeing on any antisocial behaviour under the influence of alcohol increases from 25 pp to 33 pp.[4]

In the case of the linear seemingly unrelated regressions (SUR) model with normally distributed disturbances, it was shown by Zellner (1962) that, when the equations have identical regressors or when a subset of regressors are omitted from a block of equations via exclusion restrictions, the multivariate maximum likelihood estimator is equivalent to a single-equation ordinary least square or maximum likelihood estima-

[4] The full results are available from the authors upon request.

TABLE 5
Results of Multivariate Model: Coefficients

	Binge		Driving		Disturbance		Abuse	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Binge			0.650	(0.035)***	0.998	(0.062)***	0.971	(0.051)***
Aged 12–17	0.900	(0.079)***	−0.604	(0.076)***	1.937	(0.115)***	1.030	(0.072)***
Aged 18–22	1.781	(0.137)***	0.126	(0.041)***	1.731	(0.106)***	1.021	(0.059)***
Aged 23–29	1.574	(0.101)***	0.288	(0.033)***	1.391	(0.102)***	0.761	(0.053)***
Aged 30–39	1.176	(0.075)***	0.267	(0.030)***	0.981	(0.101)***	0.525	(0.050)***
Aged 40–49	0.843	(0.059)***	0.277	(0.029)***	0.656	(0.102)***	0.403	(0.049)***
Aged 50–59	0.434	(0.041)***	0.185	(0.027)***	0.452	(0.105)***	0.240	(0.048)***
Log of real income	−1.425	(0.213)***	−0.040	(0.189)	−0.572	(0.308)*	−0.463	(0.237)*
(Log of real income)^2	0.080	(0.011)***	0.007	(0.009)	0.026	(0.015)*	0.021	(0.012)*
With dependent children	−0.149	(0.018)***	−0.047	(0.016)***	−0.148	(0.030)***	−0.013	(0.022)
Non-dependent children	−0.119	(0.024)***	−0.098	(0.023)***	−0.027	(0.042)	0.057	(0.032)*
Year 2001	−0.121	(0.057)**	0.158	(0.019)***	−0.061	(0.037)*	0.102	(0.027)***
Year 2004	0.006	(0.042)	0.147	(0.018)***	0.002	(0.035)	0.102	(0.026)***
Year 2007	−0.037	(0.030)	0.113	(0.019)***	0.041	(0.038)	0.102	(0.028)***
Male	0.277	(0.022)***	0.396	(0.014)***	0.449	(0.027)***	0.276	(0.019)***
Married	−0.289	(0.027)***	−0.205	(0.016)***	−0.268	(0.030)***	−0.177	(0.023)***
Work	0.185	(0.022)***	0.106	(0.021)***	−0.083	(0.047)*	−0.045	(0.031)
Unemployed	0.199	(0.047)***	0.128	(0.044)***	0.078	(0.074)	0.194	(0.054)***
Studying	0.020	(0.061)	0.018	(0.059)	0.009	(0.074)	−0.194	(0.065)***
Tertiary degree	−0.237	(0.028)***	0.181	(0.021)***	−0.060	(0.043)	−0.159	(0.031)***
Diploma	−0.029	(0.018)	0.089	(0.019)***	−0.037	(0.037)	0.005	(0.026)
Year 12	0.003	(0.024)	0.089	(0.024)***	−0.012	(0.042)	−0.033	(0.032)
Aboriginal or Torres Strait Islander origin	0.242	(0.065)***	0.067	(0.057)	0.122	(0.084)	0.317	(0.062)***
Living in capital	−0.187	(0.018)***	−0.006	(0.014)	0.012	(0.027)	0.024	(0.020)
Price of alcoholic drinks	−0.326	(0.180)*						
Constant	7.073	(1.440)***	−2.249	(0.969)**	−0.460	(1.569)	−0.196	(1.205)
α_0	0.018	(0.019)						
α_1	0.099	(0.020)***						

Notes: Driving: drove a motor vehicle; Disturbance: created a public disturbance/nuisance, caused damage to property, or stole money, goods or property; Abuse: verbally or physically abused someone. Standard errors are given in parentheses. Standard errors are derived by bootstrapping procedure wherein 500 new samples are randomly drawn with replacement.
*Significant at 10%; **Significant at 5%; ***Significant at 1%.

TABLE 6
Results of Multivariate Model: Marginal Effects—Direct and Indirect Effects

	P(Binge = 1)	*P*(Driving = 1)			*P*(Disturbance = 1)			*P*(Abuse = 1)		
	ME	DE	IE	TE	DE	IE	TE	DE	IE	TE
Binge				0.144			0.023			0.084
				(0.008)***			(0.002)***			(0.006)***
Aged 12–17	0.357	−0.131	0.051	−0.079	0.051	0.008	0.059	0.094	0.030	0.124
	(0.032)***	(0.017)***	(0.006)***	(0.017)***	(0.002)***	(0.001)***	(0.002)***	(0.007)***	(0.003)***	(0.008)***
Aged 18–22	0.707	0.027	0.102	0.129	0.046	0.016	0.062	0.093	0.059	0.152
	(0.055)***	(0.009)***	(0.010)***	(0.012)***	(0.002)***	(0.002)***	(0.002)***	(0.006)***	(0.007)***	(0.008)***
Aged 23–29	0.625	0.062	0.090	0.152	0.037	0.014	0.051	0.070	0.052	0.121
	(0.040)***	(0.007)***	(0.008)***	(0.009)***	(0.002)***	(0.001)***	(0.002)***	(0.005)***	(0.005)***	(0.006)***
Aged 30–39	0.467	0.058	0.067	0.125	0.026	0.011	0.037	0.048	0.039	0.087
	(0.030)***	(0.007)***	(0.006)***	(0.008)***	(0.002)***	(0.001)***	(0.002)***	(0.005)***	(0.004)***	(0.005)***
Aged 40–49	0.335	0.060	0.048	0.108	0.017	0.008	0.025	0.037	0.028	0.065
	(0.024)***	(0.006)***	(0.005)***	(0.007)***	(0.002)***	(0.001)***	(0.002)***	(0.005)***	(0.003)***	(0.005)***
Aged 50–59	0.172	0.040	0.025	0.065	0.012	0.004	0.016	0.022	0.014	0.036
	(0.016)***	(0.006)***	(0.003)***	(0.006)***	(0.003)***	(0.000)***	(0.002)***	(0.004)***	(0.002)***	(0.005)***
Log of real income	−0.566	−0.009	−0.081	−0.090	−0.015	−0.013	−0.028	−0.042	−0.047	−0.089
	(0.085)***	(0.041)	(0.013)***	(0.043)**	(0.008)*	(0.002)***	(0.008)***	(0.022)*	(0.008)***	(0.023)***
(Log of real income)^2	0.032	0.002	0.005	0.006	0.001	0.001	0.001	0.002	0.003	0.005
	(0.004)***	(0.002)	(0.001)***	(0.002)***	(0.000)*	(0.000)***	(0.000)***	(0.001)*	(0.000)***	(0.001)***
With dependent children	−0.059	−0.010	−0.009	−0.019	−0.004	−0.001	−0.005	−0.001	−0.005	−0.006
	(0.007)***	(0.004)***	(0.001)***	(0.004)***	(0.001)***	(0.000)***	(0.001)***	(0.002)	(0.001)***	(0.002)***
Non-dependent children	−0.047	−0.021	−0.007	−0.028	−0.001	−0.001	−0.002	0.005	−0.004	0.001
	(0.010)***	(0.005)***	(0.001)***	(0.005)***	(0.001)	(0.000)***	(0.001)	(0.003)*	(0.001)***	(0.003)
Year 2001	−0.048	0.034	−0.007	0.027	−0.002	−0.001	−0.003	0.009	−0.004	0.005
	(0.023)**	(0.004)***	(0.003)**	(0.005)***	(0.001)*	(0.001)**	(0.001)**	(0.002)***	(0.002)**	(0.003)*
Year 2004	0.002	0.032	0.000	0.032	0.000	0.000	0.000	0.009	0.000	0.010
	(0.017)	(0.004)***	(0.002)	(0.005)***	(0.001)	(0.000)	(0.001)	(0.002)***	(0.001)	(0.003)***
Year 2007	−0.015	0.024	−0.002	0.022	0.001	0.000	0.001	0.009	−0.001	0.008
	(0.012)	(0.004)***	(0.002)	(0.005)***	(0.001)	(0.000)	(0.001)	(0.003)***	(0.001)	(0.003)***
Male	0.110	0.086	0.016	0.102	0.012	0.002	0.014	0.025	0.009	0.034
	(0.009)***	(0.003)***	(0.002)***	(0.004)***	(0.001)***	(0.000)***	(0.001)***	(0.002)***	(0.001)***	(0.002)***
Married	−0.115	−0.044	−0.017	−0.061	−0.007	−0.003	−0.010	−0.016	−0.010	−0.026
	(0.011)***	(0.004)***	(0.002)***	(0.004)***	(0.001)***	(0.000)***	(0.001)***	(0.002)***	(0.001)***	(0.002)***
Work	0.073	0.023	0.011	0.034	−0.002	0.002	−0.001	−0.004	0.006	0.002
	(0.009)***	(0.005)***	(0.001)***	(0.005)***	(0.001)*	(0.000)***	(0.001)	(0.003)	(0.001)***	(0.003)
Unemployed	0.079	0.028	0.011	0.039	0.002	0.002	0.004	0.018	0.007	0.024
	(0.019)***	(0.010)***	(0.003)***	(0.010)***	(0.002)	(0.000)***	(0.002)*	(0.005)***	(0.002)***	(0.005)***

TABLE 6
(continued)

	P(Binge = 1)	*P*(Driving = 1)			*P*(Disturbance = 1)			*P*(Abuse = 1)		
	ME	DE	IE	TE	DE	IE	TE	DE	IE	TE
Studying	0.008	0.004	0.001	0.005	0.000	0.000	0.000	−0.018	0.001	−0.017
	(0.024)	(0.013)	(0.004)	(0.013)	(0.002)	(0.001)	(0.002)	(0.006)***	(0.002)	(0.006)***
Tertiary degree	−0.094	0.039	−0.014	0.026	−0.002	−0.002	−0.004	−0.015	−0.008	−0.022
	(0.011)***	(0.005)***	(0.002)***	(0.005)***	(0.001)	(0.000)***	(0.001)***	(0.003)***	(0.001)***	(0.003)***
Diploma	−0.012	0.019	−0.002	0.018	−0.001	0.000	−0.001	0.000	−0.001	0.000
	(0.007)	(0.004)***	(0.001)	(0.004)***	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)
Year 12	0.001	0.019	0.000	0.019	0.000	0.000	0.000	−0.003	0.000	−0.003
	(0.010)	(0.005)***	(0.001)	(0.005)***	(0.001)	(0.000)	(0.001)	(0.003)	(0.001)	(0.003)
Aboriginal or Torres Strait Islander origin	0.096	0.015	0.014	0.028	0.003	0.002	0.005	0.029	0.008	0.037
	(0.026)***	(0.012)	(0.004)***	(0.013)**	(0.002)	(0.001)***	(0.002)**	(0.006)***	(0.002)***	(0.006)***
Living in capital	−0.074	−0.001	−0.011	−0.012	0.000	−0.002	−0.001	0.002	−0.006	−0.004
	(0.007)***	(0.003)	(0.001)***	(0.003)***	(0.001)	(0.000)***	(0.001)*	(0.002)	(0.001)***	(0.002)**
Price of alcoholic drinks	−0.129		−0.019	−0.019		−0.003	−0.003		−0.011	−0.011
	(0.072)*		(0.010)*	(0.010)*		(0.002)*	(0.002)*		(0.006)*	(0.006)*

Notes: ME: marginal effect; DE: direct effect; IE: indirect effect; TE: total effect. Driving: drove a motor vehicle; Disturbance: created a public disturbance/nuisance, caused damage to property, or stole money, goods or property; Abuse: verbally or physically abused someone. Standard errors, given in parentheses, are derived by a bootstrapping procedure in which 500 new samples are randomly drawn with replacement.
*Significant at 10%, **Significant at 5%, ***Significant at 1%.

tor, and there is no efficiency gain from a system estimation. Although what we have here is a non-linear system model that also involves an endogenous regressor on the right-hand side, it would be interesting to examine whether considering all three negative behaviours jointly in a system model makes much difference compared to considering each behaviour separately.[5] To investigate this, we estimate a separate bivariate probit model for each of the three antisocial behaviours with binge drinking as an endogenous treatment variable. The estimated coefficients and marginal effects are presented in Tables A4–A9 in the supplementary online appendix. We can see that the estimated treatment effects of binge drinking on the respective antisocial behaviours from the three bivariate probit models are not very substantial (the relevant differences in average treatment effects of binge drinking are respectively 0.00 per cent, 8.70 per cent and 11.90 per cent from those from the four-equation MVP in Table 6). The small difference for this application could be mainly due to computational differences as would be the case for a linear SUR model or due to the non-linearity of the model. It is also interesting to speculate whether the lack of evidence of endogeneity in this example contributes to similar results from the two approaches.[6]

(iii) Demographic and Socioeconomic Effects

Now, we turn towards the demographic and socioeconomic effects. Table 5 reports the estimated coefficients and corresponding standard errors for all exogenous variables. Whilst the coefficients are not very meaningful in probit models, they do indicate the direction of relationships with the latent dependent variables. For example, a negative coefficient on marital status across all four equations indicates that being married is negatively associated with the latent propensity to participate in antisocial behaviours and binge drinking. In general, the coefficients are statistically significant. More meaningful are the marginal effects in terms of probability changes rather than changes in the latent propensity. Due to the endogenous structure of the model and the presence of common variables, the marginal effect of an exogenous explanatory variable is computationally complex as it has a direct and an indirect component. Consider, for example, a common covariate x that appears in all four equations. The total marginal effect of x on, say, the probability of drink-driving comprises a direct effect of x on the probability of drink-driving and an indirect effect through the effect of binge drinking (see, for example, Greene, 2007). This indirect effect may either counter or reinforce the direct effect.

Table 6 reports the marginal effects of all exogenous variables in the model. The first column shows marginal effects on the probability of binge drinking, while the remaining columns present marginal effects related to the three antisocial behaviours. Given the presence of an endogenous variable in each of the antisocial behaviour equations, the marginal effects comprise three components: direct, indirect and total effects. Most of the significant variables in Table 6 have the expected signs. Age is a significant determinant in all four equations. To allow for a more flexible age profile for participation, we enter age bands (instead of continuous age) in the model.[7] As expected, youth and young adults are more likely to engage in binge drinking and alcohol-related antisocial behaviours. For instance, compared to individuals aged over 60, which is the reference group, young adults (aged 23–29) are 62.5 pp and 15.2 pp more likely to exhibit binge drinking and drink-driving, respectively. We find more or less similar age patterns for the disturbance and abuse behaviours,

[5] This was suggested by an anonymous referee.

[6] The 10 per cent significance for the instrumental variable coefficient and marginal effect estimates in the bingeing equation, as shown in Tables 5 and 6, as well as in Tables A4–A9, raises concerns for potential weak instrument problem and for the identification of treatment effects on outcome variables. In fact, they all have *P*-values of around 0.07. A Stock and Yogo (2005) weak instrumental variables test for linear instrumental variable models would not be appropriate as we have a non-linear model with a binary outcome variable and a binary treatment variable, and a weak instrument test for non-linear models is not yet available. However, our estimates for the average treatment effects of bingeing on all three antisocial behaviours are statistically highly significant, suggesting that there are most likely no serious issues of identification or biased estimates for the treatment effects. We thank an anonymous referee for raising this issue.

[7] Following a referee's suggestion, we split the 12–29 age group into 12–17, 18–22 and 22–29 bands in view of the age restrictions on purchasing alcohol, driving a car and the zero-tolerance policies in early years of driving.

with the 12–29 age groups being more likely to engage in such activities.

It is interesting to note some of the contrasting findings relating to the direct and indirect effects across the same variables. Let us take the marginal effect of the 12–17 age group on the probability of drink-driving as an example. Being in the 12–17 age group is associated with a 7.9 pp lower probability of drink-driving overall. This is a result of the 13.1 pp lower direct effect of this age group on drink-driving (due to being less likely to drive, being supervised driving or zero-tolerance driving restrictions in this young age group) being offset by a positive indirect effect of 5.1 pp on drink-driving via the binge drinking equation (because 12–17-year-olds have a higher probability of bingeing and engaging in antisocial behaviours).

With regard to gender, males are significantly more likely to binge and participate in all three alcohol-related antisocial behaviours, with marginal effects of 1.4 pp for disturbance, 3.4 pp for abuse, to 10.2 pp for driving. In terms of marital status, being married is associated with a lower probability of binge drinking and antisocial behaviours. We also observe some significant effects of household structure, race and remoteness on binge drinking and antisocial behaviours. Specifically, those coming from households with dependent children are less likely to binge and participate in antisocial behaviours. Being an Aboriginal or Torres Strait Islander is positively associated with binge drinking and anti-social behaviours under the influence of alcohol. Living in capital cities is associated with a significantly lower probability of binge drinking and drink-driving.

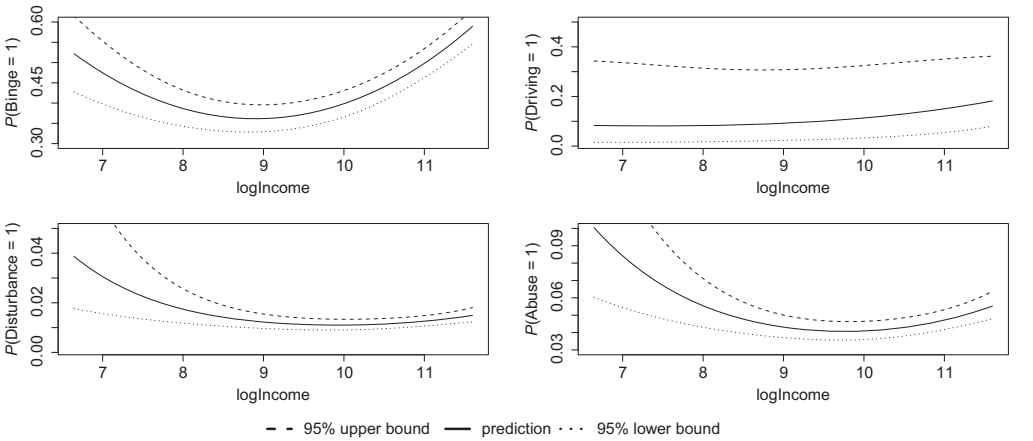
The effects of individuals' main occupation vary across binge drinking and the antisocial behaviours, although we find a consistent association of unemployment status with most activities. Relative to those who are retired, on a pension or engaged in home duties, both those who work and those who are unemployed are more likely to binge and more likely to drink and drive. While the effects on disturbance (creating a public disturbance/nuisance, caused damage to property, or stole money, goods or property) are not statistically significant or only statistically significant at 10 per cent significance level, we find that relative to the reference group, those who are unemployed are more likely, while those who study are less likely, to engage in activities such as verbally or physically abusing someone. Where significant, unemployment status has the largest effect on the activities. Specifically, relative to the reference group, those who are unemployed are 7.9 pp, 3.9 pp, 0.4 pp and 2.4 pp more likely to binge and engage in driving, disturbance and abuse, respectively, while under the influence of alcohol.

Education can be considered as a proxy for social class. Consistent with intuition, being educated is negatively related to binge drinking and antisocial behaviours such as disturbance and abuse. However, we find a significant positive association of education with drink-driving. In particular, relative to those with less than Year 12 qualifications, those who have a tertiary degree are 9.4 pp, 0.4 pp and 2.2 pp less likely to engage in binge drinking, disturbance and abuse, respectively, but 2.6 pp more likely to drink and drive.

Next, we look at the impact of income on binge drinking and antisocial behaviours. The inclusion of both a linear and a quadratic term of the logarithm of household real income in the analysis allows for a more flexible effect of income on the probability of engaging in the four activities. A more sensible illustration of the impact of income is a plot of the predicted participation probabilities for the real income range covered by the sample. Figure 1 depicts the plots of the predicted probabilities for the four activities and corresponding 95 per cent confidence intervals. Controlling for other observed explanatory variables, such as education and work status, we find a *U*-shaped relationship of income with bingeing and abusing under the influence of alcohol, that is, individuals at both ends of the income distribution have higher probabilities of engaging in binge drinking and abuse. In contrast, disturbance participation decreases significantly as income increases. A slightly increasing income profile of driving is observed, indicating that individuals with higher income are slightly more likely to drink and drive.

Finally, we turn to our price variable which we use as an instrument in the binge drinking equation. As expected, the marginal effect of price is negative and statistically significant. Specifically, a 1 per cent increase from the mean of the aggregate real price will reduce the probability of binge drinking by 0.13 pp. Equivalently, evaluated at the sample mean, the marginal effect represents a participation elasticity of −0.30. Note that probability elasticity represents a percentage change rather than an absolute change in drinking probability in

Figure 1
Income Effect on Binge Drinking, Driving, Disturbance and Abuse



response to a 1 per cent change in price. Here, a price probability elasticity of −0.30 indicates that a 1 per cent rise in the price index of alcohol will result in a 0.30 per cent reduction in the probability of binge drinking. This indicates that the demand for alcohol is fairly inelastic to price, which is consistent with previous studies. For instance, Gallet (2007) conducted an extensive meta-analysis of 132 studies which provide 1,172 estimated price elasticity observations for the consumption of beer, wine, spirits and alcohol. Across all the 263 elasticities reported for alcohol, the median elasticity was −0.49.

Since the price variable only appears in the binge drinking equation, it has an indirect effect on the antisocial behaviours. Our results show that a 1 per cent increase in the price index of alcohol will reduce the drink-driving probability by 0.11 per cent. The same price increase will result in 0.10 per cent and 0.18 per cent reductions in the probability of disturbance and abuse, respectively. We also re-estimated the model using the price indices of three alcohol subcategories, beer, wine and spirits, and our results are found to be quite robust.[8]

In summary, we also present in Table 7 the total marginal effects of the factors considered on the probability of participating in any one of the antisocial and unlawful behaviours.[9] Our results indicate that youth and young adults, married individuals, being unemployed and being an Aboriginal or Torres Strait Islander are positively associated with alcohol-related antisocial behaviours. On the other hand, having children at home and having higher education have a negative association with most of the antisocial behaviours. We also find a significant effect of price on binge drinking, and finally binge drinking has a significant effect on all three anti-social behaviours, with the higher impact on drink-driving.

V Conclusion

This paper uses a multivariate probit system model with a recursive structure and unit record data from the Australia National Drug Strategy Household Surveys to study the relationship between binge drinking and alcohol-related antisocial and unlawful behaviours, and the socio-economic and demographic determinants of such behaviours. Our modelling approach takes account of the potential endogeneity of bingeing and the intrinsic correlation across all four alcohol-related negative behaviours via unobserved individual heterogeneity.

[8] These results are available from the authors upon request.

[9] This was suggested by an anonymous referee.

TABLE 7
Results of Multivariate Model: Total Marginal Effects on the Probability of Any Antisocial Behaviour

	P(any antisocial behaviour = 1)	
	ME	SE
Binge	0.251	(0.012)***
Aged 12–17	0.104	(0.021)***
Aged 18–22	0.343	(0.018)***
Aged 23–29	0.325	(0.014)***
Aged 30–39	0.248	(0.011)***
Aged 40–49	0.198	(0.010)***
Aged 50–59	0.117	(0.009)***
Log of real income	−0.207	(0.054)***
(Log of real income)^2	0.012	(0.003)***
With dependent children	−0.030	(0.005)***
Non-dependent children	−0.029	(0.007)***
Year 2001	0.030	(0.008)***
Year 2004	0.042	(0.007)***
Year 2007	0.031	(0.006)***
Male	0.150	(0.005)***
Married	−0.096	(0.005)***
Work	0.035	(0.006)***
Unemployed	0.067	(0.013)***
Studying	−0.012	(0.016)
Tertiary degree	0.000	(0.007)
Diploma	0.016	(0.005)***
Year 12	0.016	(0.007)**
Aboriginal or Torres Strait Islander origin	0.071	(0.016)***
Living in capital	−0.017	(0.004)***
Price of alcoholic drinks	−0.032	(0.018)*

Notes: ME: marginal effect. Standard errors, given in parentheses, are derived by a bootstrapping procedure in which 500 new samples are randomly drawn with replacement.
*Significant at 10%; **Significant at 5%; ***Significant at 1%.

Interestingly, we do not find statistically significant evidence for binge drinking being endogenous in the determination of antisocial behaviours. Whilst bingeing significantly increases the probabilities of all three groups of negative behaviours, as shown by the significant and positive treatment effects, its error term does not seem to be significantly correlated with the three other structural error terms once bingeing explicitly enters these equations. This result seems to suggest that unobservable factors such as personal traits that make a person binge are not strongly correlated with the remaining unobservable personal traits that subject the person to antisocial behaviours once common observable exogenous factors such as age profile and the act of bingeing itself are controlled for.

We find strong evidence of common unobservable factors for all three antisocial and unlawful behaviours even after the act of binge drinking is explicitly controlled for. Although there may or may not be an argument for considering each negative behaviour separately with a simpler bivariate probit model in terms of estimating the slope coefficients, based on the results for the linear SUR models, our system model offers the extra benefit of quantifying the unobservable correlations among the different negative drinking behaviours. Such information can be useful for policy design in tackling negative drinking behaviours jointly via studying the joint and conditional probabilities, as illustrated in Ramful and Zhao (2008). Correlations of the unobservable factors between outcome variables in the linear SUR models can be easily obtained after estimating a single-equation ordinary least square, but this is not the case for the non-linear probit model here where the latent errors are not observable.

We also find strong evidence for a 9.9 per cent probability of under-reporting for binge drinking, but no evidence for over-reporting. Due to the complexity of the data collection process for alcohol consumption, the potential for misclassification in binge drinking is addressed with a modified maximum likelihood function allowing for misreporting probabilities to be estimated explicitly.

Our results show that young adults (aged: 18–29) are most likely among all age groups to be involved in binge drinking, drink-driving, creating public disturbance/nuisance, stealing money, goods or property, or verbally or physically abusing someone while under the influence of alcohol. In terms of the total effect on the probabilities of negative behaviours, males, the unmarried, the unemployed, the less educated, and Aboriginals or Torres Strait Islanders are more likely to be engaged in causing disturbance and physical and verbal abusive behaviours.

Finally, we find that bingeing has a significant effect on increasing the probabilities of participating in all three negative alcohol related behaviours. Being highly intoxicated or committing the act of bingeing is shown to increase the probability of participating in any one of the antisocial and unlawful behaviours by 25 percentage points (as shown in Table 7). This is a large effect, considering the very low participa-

tion in such behaviours among the general drinking population. As most of the related costs from such negative drinking behaviours are often not considered in the bingers' private decision-making but borne by society, given the low risk of being charged criminally or incurring private health care costs, the results in this paper contribute to the evidence for the case for an alcohol tax. Given that any proposed alcohol tax reform often implies different implications for different alcohol beverages, further research towards quantifying the link to negative behaviours by differentiated beverage types would be useful to inform alcohol tax reforms.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure A1: Survey question relating to drinking patterns.

Table A1. Observed Correlation across Bingeing and Antisocial Behaviours for the Drinkers.

Table A2. Definition of Variables.

Table A3. Summary Statistics of Variables.

Table A4. Coefficient estimates of the bivariate model for Driving.

Table A5. Coefficient estimates of the bivariate model for Disturbance.

Table A6. Coefficient estimates of the bivariate model for Abuse.

Table A7. Results of the bivariate model for Driving: marginal effects-direct and indirect effects.

Table A8. Results of the bivariate model for Disturbance: marginal effects-direct and indirect effects.

Table A9. Results of the bivariate model for Abuse: marginal effects-direct and indirect effects.

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