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The dynamic effects of changes in prices and affordability on alcohol consumption: an impulse response analysis

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Abstract

**Aims:** To investigate how changes in alcohol price and affordability are related to aggregate level alcohol consumption in Australia to help to inform effective price and tax policy to influence consumption.

**Material and methods:** Annual time series data between 1974 and 2012 on price and per-capita consumption for beer, wine and spirits and average weekly income were collected from the Australian Bureau of Statistics. Using a Vector Autoregressive model and impulse response analysis, the dynamic responses of alcohol consumption to changes in alcohol prices and affordability were estimated.

**Results:** Alcohol consumption in Australia was negatively associated with alcohol price and positively associated with the affordability of alcohol. The results of the impulse response analysis suggest that a 10% increase in the alcohol price was associated with a 2% decrease in the population-level alcohol consumption in the following year, with further, diminishing, effects up to year 8, leading to an overall 6% reduction in total consumption. In contrast, when alcohol affordability increased, per capita alcohol consumption increased over the following 6 years.

**Conclusions:** Our findings suggest that increasing alcohol prices or taxes can help to reduce alcohol consumption at the population level in Australia. However, the impact of affordability in our findings highlights that pricing policies need to consider increases in income to ensure effectiveness. Alcohol price policy should only cautiously focus on individual beverage types, because increasing the price of one beverage generally leads to an increase in consumption of substitutes.

**Key words:** Alcohol price, affordability, price policy, VAR model, impulse response
INTRODUCTION

Preventing and reducing the health and social burden caused by the harmful use of alcohol has become a public health priority and one of the objectives of the World Health Organization (WHO) (2014). Policies that increase alcohol tax or retail prices are regarded as one of the most effective means to reduce population level alcohol consumption and related harm (Anderson et al., 2009). Studies examining the impact of price on consumption generally talk about the price elasticity of a commodity – that is, the relative reduction in consumption for a unit increase in price. If a 10% increase in price leads to a 10% reduction in consumption, then the price elasticity is -1. Using this measure, a number of systematic reviews have shown that the mean price elasticity of demand is -0.4 for beer, -0.7 for wine, -0.7 for spirits and for overall, the response of alcohol consumption to changes of alcohol price is estimated at approximately -0.5 (Gallet, 2007; Wagenaar et al., 2009; Fogarty, 2010). This elasticity implies that a 10% rise in alcohol price will be expected to decrease the overall demand for alcohol by about 5%. However, the price elasticity of alcohol demand varies substantially depending on drinking culture, economic conditions and across different beverages, which may have different social meanings and roles (Zhang and Casswell, 1999).

The meta-analyses described above summarise a significant literature on the price elasticity of alcohol demand, but much of this research has focused on just the own-price elasticity of beverages (own-price elasticity measures the responsiveness of demand for a good to a change in its own price and cross-price elasticity measures the responsiveness of the demand for a good to a change in the price of another good). As the prices and taxes for difference types of alcohol are different in many countries (e.g. U.K., U.S., Australia, New Zealand and etc.) and consumers may respond to price rises by shifting brand or beverage (Gruenewald et al., 2006), estimating both own-price and cross-price elasticities is very important. The
estimation of cross-price elasticities can help to identify whether there are substitute or complement relationships between two types of alcohol beverages (Meng et al., 2014), providing clearer evidence on the likely changes in consumption following particular tax or price changes. A substitute is something that can be used instead of a particular good or service, and a complement is an item that can be used in conjunction with one another. In this instance if, for example, beer and wine were substitutes then an increase in beer prices and corresponding decrease in beer consumption may be offset by an increase in wine consumption. If they were complements, then a beer tax increase would reduce both beer and wine consumption.

Income or affordability has also been shown to be a significant factor that can affect alcohol consumption. When income increases, alcohol consumption may increase as alcohol products become more affordable for consumers (Gallet, 2007; Nelson, 2013). A study in European countries found that alcohol beverages have become more affordable in most European countries since the mid-1990s, with positive relationships found between affordability and alcohol consumption and related harms (Rabinovich et al., 2009). Based on a time series analysis, Wall and Casswell (2013) found that affordability had a stronger association with demand for alcohol than the real price in New Zealand and suggested that alcohol affordability is an important parameter to be considered in alcohol price or taxation policy. If the income index increases faster than the real alcohol price index, then alcohol beverages will become more affordable for consumers.

There has been some previous analyses of price and income elasticities of alcohol in Australia, the price and income elasticities of demand for alcohol have been examined in a number of studies (Haque, 1990; Clements and Selvanathan, 1991; Selvanathan and
Selvanathan, 2004; Fogarty, 2010). In an aggregate study of data between 1956 and 1999, (Selvanathan and Selvanathan, 2004) found that income and prices were significantly related to the consumption patterns of alcohol in Australia with the mean price and income elasticities of -0.61 and 0.72 respectively. Based on panel survey data, Sharma et al. (2014) estimated price elasticities of -0.49 for beer, -0.53 for wine and -1.28 for spirits in Victoria. Using time series data from 1955 to 1986, Clements and Selvanathan (1991) reported that own-price elasticity was -0.15 for beer, -0.32 for wine and -0.61 for spirits while income elasticity was 0.73 for beer, 0.61 for wine and 2.51 for spirits.

The studies discussed above and reviewed in the cited meta-analyses have examined the relationships between price, affordability and demand for alcohol using individual or aggregate data, and by various methods (e.g. linear regression, autoregressive integrated moving average model, panel data regression, survey analysis etc. (Clements and Selvanathan, 1991; Gallet, 2007; Fogarty, 2010; Sharma et al., 2014). However, none of them have explored the dynamic temporal effects of changes in price and affordability on alcohol demand, e.g. if the alcohol price or affordability increases 10%, what are the immediate and lagged effects on alcohol consumption and how long do the effects last. Changes in price will have an immediate effect on consumption, but there is a potential for these effects to be spread over time. For example, studies in the housing market have shown that a 10% increase in interest rates will lead to a dynamic change in housing starts or demand over time – an overall 12% decrease in following 10 quarters (Berger-Thomson and Ellis, 2004). In this case, we explore whether there are longer-term effects of price and affordability changes and how these effects are distributed over time using advanced econometric analysis techniques, namely, vector autoregressive (VAR) model and impulse response analysis.
METHODS

Data

All time series data were collected from Australian Bureau of Statistics (ABS). Annual per capita alcohol and beverage-specific (beer, wine and spirits) consumption in litres of pure alcohol were obtained for 1974 to 2012 (age 15+) – were used as the measures of demand for alcohol overall and for each of the three beverages (Australian Bureau of Statistics, 2013a).

A measure of price was estimated using data from the Consumer Price Index. A real alcohol price index can be computed as: real alcohol or beverage-specific price indices = alcohol or beverage-specific CPIs / all goods CPI (Seabrook, 2010). This method adjusts for inflation and reflects the price of alcohol relative to all other consumable goods (Wall and Casswell, 2013). Quarterly alcohol and beer CPIs are available since 1974; CPI series for spirits and wine both start in 1980 (Australian Bureau of Statistics, 2014). Quarterly time series were all averaged to annual data for the analysis.

An alcohol affordability index was calculated, defined as the average income index divided by real alcohol price index. The average weekly earnings from 1974 was used as the baseline for the income index. The survey of average weekly earnings is used to measure the level of average gross weekly earnings associated with employees in Australia, but does not capture all the information about the distribution (Australian Bureau of Statistics, 2013c; 2013b).

Econometric estimating techniques

Vector autoregressive models and impulse response analyses were employed to estimate the dynamic response of overall alcohol demand to changes in price and affordability. Further models were developed for specific beverages, assessing the impact of changes either in its
own price and affordability or in other beverages’ prices and affordability. The VAR model, developed by Sims (1980) in 1980, is one of the most applied models in time series analysis. Stationary series with time trends removed reduce the risk of obtaining a spurious estimation (George, 1994). In most cases, a differencing of the time series is sufficient to eliminate non-stationarity. The Augmented Dickey-Fuller (ADF) unit root test, developed by Dickey and Fuller was employed to test stationarity for the time series (Dickey and Fuller, 1979). Differencing of time-series data also helps to minimise the risk of unmeasured confounding (Norström, 2001).

Specifically the VAR models for alcohol demand (\( \pi_t \)) can be presented as follows,

\[
\pi_t = \sum_{j=1}^{k} \beta_j \pi_{t-j} + \sum_{j=1}^{k} \gamma_j p_{t-j} + \sum_{j=1}^{k} \delta_j a_{t-j} + \epsilon_t
\]

where \( \pi_t \) is per capita alcohol consumption at time \( t \), \( \pi_{t-j} \) is the lagged per capita alcohol consumption, \( p_{t-j} \) represent alcohol price or affordability indices, \( a_{t-j} \) is first difference of the variables, \( k \) is the number of lags, \( \beta_j \), \( \gamma_j \), and \( \delta_j \) represent the coefficients of independent variables, \( C \) is the intercept, and \( \epsilon_t \) the residuals. Estimates produced here are unconditional temporal estimates. In this study, four key analyses were conducted: 1) response of alcohol consumption to price change, 2) response of alcohol consumption to affordability change, 3) responses of the consumption of the three specific beverage types to changes in beverage-specific prices, and 4) responses of the consumption of the three beverage types to changes in beverage-specific affordability.

The lag length is selected for a time series in VAR modelling on the basis of the sequential modified likelihood ratio test statistic (LR), final prediction error (FPE), Akaike information
criterion (AIC), Schwarz information criterion (SC) and Hannan–Quinn information criterion (HQ). The appropriate lag lengths for the alcohol and beverage-specific estimating models were identified as one year. After establishing VAR models for demand for alcohol and the three types of beverages, serial correlation Lagrange multiplier tests (LM), White’s heteroskedasticity test (White) and Jarque–Bera normality tests (Jarque–Bera) were conducted to verify the standard assumptions on residual correlation, heteroskedasticity and normality respectively.

After the establishment of VAR model, the impulse response function can be conducted to assess the dynamic impacts of price and affordability on alcohol demand in Australia. The formulation and implementation of VAR model impulse response function were elaborated in the study of Lütkepohl and Reimers (1992). The VAR impulse response function procedure can be used to trace responses of a set of variables to shocks in another set of variables (Hamilton, 1994). Impulse response functions are computed to give an indication of the system's dynamic behaviour. It can indicate whether the impacts are positive or negative, or whether these impacts are a temporary jump or indicate long-run persistence.

RESULTS

Between 1974 and 2012, the trends in real alcohol price and affordability indices and per capita alcohol consumption are shown in Fig. 1. The indices of alcohol price and affordability are set to equal 100 in 2010. Per capita alcohol consumption decreased gradually from 13 L to 10 L between 1974 and 1992 and was then stable up to 2000. Between 2000 and 2006, consumption increased again to about 11 L, and has dropped back to 10 L in the last 6 years. The alcohol affordability index had similar fluctuations to per capita alcohol consumption in the last 40 years. It can be observed that the alcohol affordability index decreased during the
1970s up to 1982 and had a small increase in 1983-84 and then remained as a same level after 1984. A possible reason for this increase in affordability is the introduction of an income tax-free threshold in 1983-84, leading to an increase in average income. In contrast, the alcohol price index increased steadily over the study period.

Fig. 2 shows the trend of total alcohol and beverage-specific consumption during 1974 and 2012. Per capita beer consumption decreased dramatically from 9 L to 4 L between 1974 and 2012, while per capita wine consumption increased steadily from 2 L to 4 L and per capita spirits consumption increased slightly from 1.6 L to 2 L between 1980 and 2006 and decreased to 1.8 L after 2006.

The fluctuations of the alcohol price and affordability indices are shown in Fig. 3 for beer, wine and spirits. The wine price decreased from 1980 to 2012 and the affordability index of wine increased significantly from 70 to 105. At the same time, beer and spirits price indices both increased dramatically and their affordability indices decreased steadily during the study period.

The stationarity of the selected time series was tested using the ADF tests and the results suggest that all of the time series were stationary after first differencing I(1), (p<0.05). Based
on the VAR lag length selection system, the smallest values of the LR, FPE, AIC, SC, and HQ tests indicate that the appropriate lag lengths for the alcohol and beverage-specific estimating models were one year. Furthermore, all proposed models passed all validation tests at the 5% significance level, indicating that there were no significant departures from the standard assumptions for all VAR models, and the estimated coefficients were stable across the sample period.

Impulse response analysis was then conducted to explore the short-term and long-term temporal effects of changes in alcohol and beverage-specific prices and affordabilities on alcohol and beverage-specific consumption level (results shown in Figs 4-6). Fig. 4 shows a negative response from alcohol consumption to an increase in the alcohol price index and a positive response to alcohol affordability, with time lags. These results indicate that if the alcohol price increases 1% (or 10%) in one year, per capita alcohol consumption will decrease by about 0.2% (or 2%) in the second year, with effects becoming weaker in the following years, and dissipating after the 8th year. Overall, an increase of 10% in the alcohol price will lead to a 6% accumulated reduction in per capita alcohol consumption over an 8-year period. In contrast, if alcohol affordability increases 10%, per capita alcohol consumption will increase by about 1% in the second year with weaker positive effects found between the third and sixth years, leading to an overall 3% increase in per capita alcohol consumption.

The responses of consumption to changes in beverage-specific prices over a 12-year period are shown in Fig. 5. The results of impulse response analyses suggest that beer consumption
was negatively affected by increases in beer price, but was positively affected by the increases in wine price, while an increase in spirits price would lead to a slight decrease in beer consumption. Per capita wine consumption received very small impacts from the changes in wine price and nearly no shock from the changes in beer price. However, wine consumption was significantly and positively impacted by the increases in spirits price (a 10% increase in spirits price will lead to an accumulated 3% increase in per capita wine consumption over 10 years). Spirits consumption was more sensitive to its own price change. When spirits prices increased by 10%, spirits consumption decreased by 3% in the second year, 2% in the third year and 1% in the fourth year with effects becoming weaker and tending to disappear after the fourth year leading to an overall decline of 6%.

Fig. 6 shows the response of consumption of the three types of beverage to changes in affordability. Beer consumption was positively associated with an increase in beer affordability and negatively associated with an increase in wine affordability. The impact of an increase in spirits affordability on beer consumption was moderate over the estimation period. The results indicate that wine consumption level received very small impacts from changes in affordabilities of wine, beer and spirits. Changes in spirits affordability had a strong positive impact on spirits consumption at the population level (a 10% increase in spirits affordability led to a 3% increase in per capita spirits consumption in the second year and weaker increases in spirits consumption between the third and eighth years). However, an increase in wine affordability led to a significant decrease in spirits consumption, with effects spread across six years. It is worth noting that an increase in beer affordability was linked to
an increase in spirits consumption in the short-term, but in the long-term it was associated with reduced spirits consumption.

<Insert Figure 6 about here>

**DISCUSSION**

This study has explored the dynamic responses of consumption levels to changes in prices and affordabilities of alcohol overall and three types of beverages (e.g. beer, wine and spirits) using over 30 years of time series data. The study findings suggest that a 10% increase in the alcohol price was associated with a 2% reduction in per capita alcohol consumption in the year after the price change and weaker reductions spread between the third and eighth years, leading to an accumulated 6% reduction over an 8-year period (see Figure 4). In contrast, a 10% increase in alcohol affordability was associated with an increase in alcohol consumption both in the short-term and long-term with overall 3% increases. A meta-analyses suggested that the ratios of the percentage change in demand to the percentage change in alcohol price under 2% are small, 5% are medium and over 8% are large (Wagenaar *et al.*, 2009). Compared with other studies, our estimates of price effectiveness sit slightly above the middle of the broad literature, with a ratio of 6% change in total alcohol consumption, suggesting that the manipulation of tax rates or prices can reduce the harms due to alcohol consumption and achieve substantial health benefits in Australia.

Trends in beverage specific consumption are consistent with the trends in affordabilities of beer, wine and spirits in the study period, e.g. beer consumption has steadily decreased in the last 30 years and this may be linked to the continued increase in beer price and decline in beer affordability. The beverage-specific analyses suggest that wine consumption only received
moderate impact from the changes in prices and affordabilities of beer, wine and spirits. However, the increase in wine affordability was linked to large reductions in beer and spirits consumption, which may explain the long-term change in the preferences away from beer and spirits towards wine in Australia. Compared with wine, per capita beer and spirits consumption both received strong and negative impacts from the changes in prices of themselves and other types of beverages. Changes in affordability of beer and spirits will lead to significant impacts on the consumption of all three beverages.

The Australian alcohol taxation system is complex, with tax rates varying between beverage types and even container type. A particular issue is that beer and spirits are taxed on the basis of alcohol content and wine on the basis of price, meaning that cheap wine (e.g. in casks) has a very low level of tax associated with it (Vandenberg et al., 2008). Government policies have tended to treat alcoholic beverages as independent, when there are complex links between them. For example, the implementation of the alcopops tax in 2008 sharply reduced alcopops consumption, but around half of this impact was offset by increases in the consumption of spirits and other beverages (Chikritzhs et al., 2009). The results of the beverage-specific impulse response analyses presented here suggest that alcohol price policy should not focus on individual type of beverages, because of the complex substitute and compliment relationships between beverages. Approaches that cover all beverages, such as volumetric based taxation based on alcohol content are more likely to reduce alcohol consumption and related harms (Sharma et al., 2014).

Additionally, our research findings highlight and confirm that raising alcohol prices or tax can help to reduce alcohol consumption at the population level in Australia. Furthermore, the results of temporal analysis reveal that when the price and affordability of alcohol changed,
consumption is affected for up to eight years (with the strongest effects immediately). This, along with the positive effects on consumption seen for increased affordability, reinforces the need for ongoing and regular review of the alcohol taxation system to ensure its effectiveness as a public health measure.

While there have been many previous studies of the relationship between price, consumption and affordability of alcohol (Gallet, 2007; Nelson, 2013), this study is the first study that explores dynamic relationships between alcohol consumption, price and affordability in the temporal dimension. This study is somewhat limited by its short time scale (39 years) and its use of aggregate level data. This last fact in particular raises the issue of the ecological fallacy and some care should be taken in applying these findings at the individual level. However, the proposed models have passed all the validation tests, indicating that the estimates are reliable and the aim of public health policies on alcohol prices is to reduce aggregate levels of consumption. Furthermore, due to the data availability only three types of beverages were estimated in proposed VAR models, and more sophisticated research on the cross-types relationships between consumption on wider range of beverages (e.g. cider, Ready-To-Drink, cask wine, and etc.), prices and affordabilities need to be conducted in the future. Additionally, there are many other factors may affect alcohol consumption and we did not include in the estimation, such as changes in economic conditions (e.g. GDP and unemployment rates), changes in expenditure on other goods and necessities (e.g. housing costs, fuel and tobacco price) and impacts of key alcohol policies (e.g. the introduction of Random Breath Testing program in 1976-1980s etc.). However, as demonstrated by Norström (2001), the use of differenced time-series data reduces the potential risk of confounding, requiring a confounding variable to be correlated with annual changes in both input (e.g. price) and output (e.g. alcohol consumption) series.
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Conflicts of Interest
Authors declare that we have no conflicts of interest.
References


Fig. 1 Trends in the alcohol price index, affordability index and per capita alcohol consumption between 1974 and 2012 (price and affordability indices=100 at 2010)
Fig. 2 Alcohol, beer, wine, spirits consumption per capita between 1974 and 2006
**Fig. 3** Real price and affordability indices of alcohol, beer, wine, spirits in Australia between 1974 and 2006 (price and affordability indices=100 at 2010)
**Fig. 4** Response of alcohol consumption (ALC) to the changes in alcohol price (ALCP) and affordability (ALCAFF) in the 12-year period [The solid line are estimated effects and dot line are standard errors; \( D(\text{ALC}) \) is the difference of alcohol per capita consumption between \( t \) and \( t-1 \) and \( D(\text{ALCP}) \) is the difference of alcohol prices between \( t \) and \( t-1 \), and same denotation for other variables].
Fig. 5 Response of beverage-specific consumption to the changes in the prices of beer, wine and spirits in the 12-year period [The solid line are estimated effects and dot line are standard errors; \( D(\text{BEER}) \) is the difference of beer per capita consumption between \( t \) and \( t-1 \) and \( D(\text{BEERP}) \) is the difference of beer prices between \( t \) and \( t-1 \), and same denotation for other beverages].
Fig. 6 Response of beverage-specific consumption to the changes in affordability of beer, wine and spirits in the 12-year period [The solid line are estimated effects and dot line are standard errors; D(BEER) is the difference of beer per capita consumption between $t$ and $t-1$ and D(BEERAFF) is the difference of beer affordability between $t$ and $t-1$, and same denotation for other beverages].