




# Prices, taxes and alcohol use: a systematic umbrella review

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## Abstract

**Aim:** To measure the impact of taxes and prices on alcohol use with particular attention to the different context of rising alcohol consumption in low- and middle-income countries.

**Methods:** Systematic review: we searched MEDLINE, Embase, EconLit and LILACS, grey literature, hand-searched five specialty journals and examined references of relevant studies. We considered all reviews that included studies that quantitatively examined the relationship between alcohol prices or taxes and alcohol use. At least two reviewers independently screened the articles and extracted the characteristics, methods and main results and assessed the quality of each included study. We identified 30 reviews.

**Results:** There was overwhelming evidence that higher alcohol prices and taxes were associated with lower total alcohol consumption and that price responsiveness varied by beverage type. Total own-price elasticities of alcohol demand were consistently negative and substantial enough to be policy meaningful; total own-price elasticities for beer, wine and spirits were found to be approximately -0.3, -0.6 and -0.65. Reviews generally concluded that higher taxes and prices were associated with lower heavy episodic drinking and heavy drinking, although the magnitude of these associations was generally unclear. Reviews provided no evidence that alcohol price responsiveness differed by socioeconomic status, mixed and contradictory evidence with respect to age and sex and limited evidence that price responsiveness in low- and middle-income countries was approximately the same as in high-income countries.

**Conclusions:** Taxes are effective in reducing alcohol use. Moreover, increasing the price of alcohol by increasing taxes can also be expected to increase tax revenue, because the demand for alcohol is most certainly inelastic.

## KEYWORDS

Alcohol, elasticity, low- and middle-income countries, prices, review, taxes

## INTRODUCTION

Research has depicted the indisputable link between alcohol consumption and substantial negative consequences at the individual, community and societal levels [1]. Globally, alcohol consumption accounted for 3 million deaths in 2016, 1 million more from 2000 [2].

Alcohol use is associated with more than 200 diseases, such as liver cirrhosis, cancer, ischemic heart disease and strokes [3]. In youth, heavy episodic drinking (HED), such as binge drinking, has been associated with long-term consequences such as cognitive, structural and functional brain changes and liver disease [4]. The United Nations formally recognized the importance of controlling alcohol abuse in 2015;

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sustainable development goal 3 specifically called on Member States to strengthen the prevention and treatment of substance abuse, including harmful use of alcohol [5]. In 2017, the World Health Organization specifically recommended that Member States increase excise taxes on alcoholic beverages in its 'best buys' for the prevention and control of noncommunicable diseases [6]. Alcohol use has dramatically increased in many countries since the coronavirus disease (COVID)-19 pandemic started, highlighting alcohol consumption as a chief area of concern for public health [7–9].

Numerous reviews have examined the effect of prices and taxes on alcohol use, since at least the 1980s. Given the increasing burden of disease attributable to alcohol use, it is opportune to synthesize existing evidence and identify research gaps. A specific focus on the relevance of existing research to the context of low- and middle-income countries (LMICs) is warranted because theory suggests that price responsiveness may differ between high- and lower-income countries. First, price responsiveness in lower-income countries may be higher because alcohol users have fewer resources relative to users in wealthier countries. Second, given the generally lower levels of education in lower-income countries, economic models of addiction predict that the demand for goods such as tobacco and alcohol is likely more price responsive [10]. Third, the availability and prices of complements and substitutes likely differ between high-income and lower-income markets (e.g. local and home-made distilled alcoholic beverages). Fourth, there is evidence that unrecorded alcohol consumption is higher in lower-income countries [11]. With alcohol consumption rising in many LMICs, public health policies need to account for their different context [3].

The harmful impact of alcohol varies by drinking behaviour (e.g. heavy and binge drinking) and beverage type (e.g. beer, wine and spirits) [1]. Additionally, price responsiveness may vary by socioeconomic status (SES) (e.g. income, education), sex or age. Consequently, good evidence on differences in the effectiveness of tax and price policies is essential for policy design. Our objective was to systematically review existing reviews of quantitative studies on the impact of taxes and prices on alcohol use. Our review examined results from all reviews relevant to the following outcomes, by beverage type if available:

1. Total own-price elasticities, including short-run versus long-run.
2. Participation/consumption own-price elasticities.
3. Associations between prices/taxes and the transition from non-drinkers to drinkers and from drinkers to non-drinkers.
4. Associations between prices/taxes and heavy episodic drinking such as binge drinking, or any type of excessive, unhealthy or harmful drinking;
5. Associations between non-tax price strategies such as minimum pricing of alcohol on alcohol use.
6. Cross-price elasticities, between alcohol products and between alcohol products and other non-alcoholic goods such as tobacco and psychoactive drugs.

We also examined if the association between prices and taxes and any of the above outcomes were modified by SES, sex or age.

## METHODS

We considered all reviews of studies that quantitatively examined the relationship between alcohol price and tax strategies and alcohol use. We included all review types (e.g. systematic, narrative, scoping and rapid) with narrative synthesis, meta-analysis or meta-regression methodology, regardless of the publication type. We included all reviews regardless of their geographical focus or language and excluded reviews published before 1980. We included all outcome measures of alcohol use including initiation, participation, consumption, HED and cessation, as well as aggregate measures such as national alcohol consumption or sales. We excluded reviews that only examined the effect of prices/taxes on health or social outcomes such as interpersonal violence.

### Search methods for identification of studies

We searched four bibliographic databases: MEDLINE, Embase, EconLit and LILACS. Grey literature was searched via Google and Google Scholar. Five specialty journals were hand-searched (Addiction, Applied Economic Perspectives and Policy, Health Economics, Health Economics Review and Journal of Health Economics) and references of identified reviews were examined. We also searched Chinese-language databases. We specifically searched for research written in Chinese and Spanish (using LILACS) to capture research relevant to LMICs. The database search was last updated on 17 January 2022 (MEDLINE, Embase, and EconLit) and 12 January 2022 (LILACS). Details of the search strategy are presented in the Appendix.

### Quality assessment and data extraction

A protocol was prepared in advance, but was not publicly registered (available in Appendix). In developing our approach to quality assessment, we used as a starting point the Assessment of Multiple Systematic Reviews (AMSTAR) tool, a critical appraisal tool for systematic reviews of healthcare interventions [11]. We felt AMSTAR offered useful guidance in identifying key attributes that require clear reporting or assessment. However, because of AMSTAR's focus on healthcare interventions, we felt additional components were needed to examine important methodological details of studies that reviewed own- and cross-price elasticities. The following study characteristics were extracted and assessed, where applicable: type of review; whether an a priori protocol was provided; whether there were duplicate study selection and data extraction and a comprehensive search; whether a list of included/excluded studies and the characteristics of included studies were provided; whether the quality of the included studies was assessed, documented and appropriately interpreted; whether the methods used to combine study findings were appropriate; whether the likelihood of publication bias was assessed; whether funding and competing interests were clearly reported; whether elasticities were interpreted and compared appropriately; and, given our

objective, the generalizability of the findings to LMICs. We narratively synthesized the findings of the included reviews (no further meta-analysis was conducted). All price elasticity estimates reported in our summary of findings represent our interpretation of the evidence, not weighted pooled estimates.

Studies examining the effect of prices or taxes on demand typically report effect sizes in the form of elasticities. Elasticities are a unitless measure of the responsiveness of one variable to the change of another variable. An own-price elasticity of demand measures the responsiveness of a good's demand to a change in its own price, holding all else equal; formally, an own-price elasticity of demand measures the percent change of a good's demand in response to a change in its own price. For example, an own-price elasticity of  $-0.5$  for beer indicates that a 1% increase/decrease in the price of beer would decrease/increase the demand for beer by 0.5%. Similarly, a cross-price elasticity of demand measures the responsiveness of a good's demand to another good's changing price (e.g. the demand for spirits increasing as the price of wine increases) [12]. In economic models of addiction, short- and long-run price elasticities are often computed. The short-run elasticity holds past consumption constant, whereas the long-run elasticity lets past consumption vary (i.e. current consumption depends on current and past factors so that increases in current and past price, by reducing past consumption, reduce current consumption). As a result, the long-run elasticity will exceed the short-run elasticity (i.e. long-run effect of a permanent price change will exceed short-run effect) [13].

Tax and price elasticities are not equivalent; even if taxes are fully passed-through, tax elasticities understate the true price elasticities to the extent that tax is a proportion of retail price. Price and tax elasticities are also outcome dependent. For example, total price elasticities represent the effect of price changes on total consumption; participation elasticities denote the effect of price changes on alcohol use versus no use; and consumption elasticities represent the effect of price changes on volume consumed among alcohol users.

Each step of our review was conducted independently by at least two reviewers. First, studies identified in our search were screened for relevance and assessed for inclusion. Second, data were extracted using a standardized form and synthesized in tables. Third, each included review's limitations/risks of bias were ascertained.

## RESULTS

We identified 30 reviews that met our inclusion criteria: six umbrella reviews [14–19], seven meta-analyses [20–26], three meta-regressions, [21, 27, 28] and 14 narrative reviews [29–42], including two reviews that specifically focused on LMICs, [24, 38] and two reviews that examined evidence relevant to China (Figure A1)[26, 39]. We identified eight reviews examining the associations between price/tax and alcohol use and related harm, seven of which met our inclusion criteria that were funded in part by the International Center for Alcohol Policies (ICAP), an organization funded by alcohol producers and authored by Jon Nelson, a researcher with links to the alcohol

industry [22, 23, 25, 36, 37, 40, 43, 44]. There is ample evidence of an association between financial conflicts of interest, including commercial research sponsorship, with publication of research favourable to the sponsor [45–47]. Despite the competing interest and substantial overlap between some of the reviews, we did not exclude them. Instead, we discuss them separately. Overall, the six umbrella reviews included 12 independent reviews, [14, 20, 21, 27, 28, 33, 48–51] and the 24 reviews included at least 364 independent studies (not all reviews clearly reported a list of included studies) (see Appendix).

Tables 1 and 2 present key characteristics, results and limitations of included umbrella reviews and reviews, respectively. Table 3 presents the same information for ICAP funded reviews. The Appendix contains more detailed characteristics of each included study and a list of excluded studies. In presenting our findings, to the extent possible, we focused on the magnitude of the associations between price/tax and alcohol use. Table 4 presents a summary of key results from reviews that reported effect sizes.

## Own-price effects

### Total consumption

Overall, five overview of reviews [14–16, 18, 19] and 14 reviews [20, 21, 24, 26–35, 38] present overwhelming evidence that higher alcohol taxes and prices were associated with lower total alcohol consumption and that price responsiveness varied by beverage type [14, 20, 21, 24, 27–31, 34]. Total own-price elasticities for beer, wine and spirits were found to be at least (in absolute value) approximately  $-0.3$ ,  $-0.6$  and  $-0.65$ ; elasticity estimates for beer and wine were fairly consistent, but elasticity estimates for spirits generally ranged from  $-0.5$  to  $-0.8$  [20, 21, 24, 27, 28, 34]. One study suggested a short- and long-run total own-price elasticity for alcohol of approximately  $-0.5$  and  $-0.8$ , respectively; a 1% increase in the price of alcohol was expected to decrease total alcohol consumption by approximately 0.5% in the short-run and 0.8% in the long-run [28].

### Participation and consumption

Few studies discussed the associations between prices/taxes and the decisions to (i) consume alcohol or not (participation own-price elasticity) and (ii) conditional on drinking, the quantity consumed (consumption own-price elasticity). These models are generally referred to as two-part or double-hurdle models. Included reviews did not provide enough details to comment on the relative magnitude of participation and consumption own-price elasticities. One meta-regression examined the associations between study characteristics, including two-part models, and found that alcohol elasticities were insensitive to this particular modelling approach, although the relative magnitude of the two elasticities (participation vs consumption) was not discussed [28].

**TABLE 1** Umbrella reviews: study characteristics, main findings and limitations

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Anderson, Chisholm, Fuhr, 2009 [14]; - Narrative review - Effectiveness and cost-effectiveness of policies and programmes to reduce the harm caused by alcohol	- 'a priori' design: no - search comprehensive: unclear - grey literature: unclear - year of last search: unclear - no. of studies included: 3 reviews, 1 book, 4 individual studies (LMIC: 1) - duplicate study selection and data extraction: no	None. The quality of included studies was not assessed. The strength of the evidence was based on the type of study design of included studies: 1 = more than one systematic review; 2 = one systematic review; 3 = 2 or more randomised controlled trials; 4 = one randomised controlled trial; 5 = observational evidence; 6 = not assessed.	Specific results not presented. Alcohol taxes were found 'effective' at reducing alcohol use. Evidence statement: - a meta-analysis noted a median price elasticity for all beverage types of -0.52 in the short term and -0.82 in the long term, elasticities being lower for beer than for wine or spirits [28]; - a meta-analysis noted mean price elasticities of -0.46 for beer, -0.69 for wine, and -0.80 for spirits [27].	Non-systematic and poorly described search strategy; unclear how included studies were selected; no quality assessment; only very broad results presented, which limit usefulness of the review; limited generalizability to LMIC; some evidence statements not supported by evidence cited.
Jackson, Johnson <i>et al.</i> , 2010 [15]; - Narrative review - Assessment of the clinical and cost-effectiveness of (i) measures to detect alcohol misuse amongst adults and young people; (ii) brief interventions to manage alcohol misuse among adults and young people; and (iii) interventions to improve management of England's alcohol market	- 'a priori' design: no - search comprehensive: unclear - grey literature: no - year of last search: unclear - no. of studies included: unclear (at least 4 reviews seem to have been examined) (LMIC: 0) - duplicate study selection and data extraction: unclear	A quality checklist for reviews was developed. A subjective cut-off score of 9 criteria fulfilled (of a total of 14) was deemed of higher quality. Assessment not provided; only 3 broad quality scores provided.	Only broad results presented: - a clear relationship between price/tax increases and reductions in the demand for alcohol; - some evidence that young people, binge drinkers and harmful drinkers tended to show a preference for cheaper drinks; - limited evidence that minimum pricing may be effective in reducing alcohol consumption; - one meta-regression analysis suggested that the higher the relative market share of a beverage, the more inelastic the consumer demand.	Unclear search strategy; limited quality assessment; overly broad conclusions; limited generalizability to LMIC.
Martineau, Tyner <i>et al.</i> , 2013 [16]; - Narrative review - Population-level interventions to reduce alcohol-related harm	- 'a priori' design: yes - search comprehensive: yes - grey literature: unclear - year of last search: 2012 - no. of studies included: 3 reviews (LMIC: 0) - duplicate study selection and data extraction: yes	The quality of the reporting was assessed using the AMSTAR tool; assessment not provided; only broad quality scores (high, mid, low) provided.	Overview of 3 reviews suggested that there was clear and consistent evidence that increasing alcohol price or taxation reduced overall consumption; one review indicated that a 10% increase in alcohol prices would lead to a 3%-10% reduction in total consumption [34].	Small number of reviews included; overly broad conclusions; limited quality assessment; limited generalizability to LMIC.
Stockings, Hall <i>et al.</i> , 2016 [17];	- 'a priori' design: no	None	Only broad results presented:	(Continues)

TABLE 1 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
<ul style="list-style-type: none"> <li>- Narrative review</li> <li>- Prevention, early intervention, harm reduction, and treatment of substance use in young people</li> </ul>	<ul style="list-style-type: none"> <li>- search comprehensive: yes</li> <li>- grey literature: unclear</li> <li>- year of last search: 2012</li> <li>- no. of studies included: 2 reviews (LMIC: 0)</li> <li>- duplicate study selection and data extraction: unclear</li> </ul>		<ul style="list-style-type: none"> <li>- increasing alcohol taxation or alcohol price reduced overall alcohol consumption, with a 10% increase in alcohol prices producing a 3–10% reduction in consumption [34];</li> <li>- scarce evidence regarding the effect of increased taxation on problematic alcohol use;</li> <li>- young people no more or less responsive to price/tax.</li> </ul>	<ul style="list-style-type: none"> <li>Small number of reviews included; overly broad conclusions; no quality assessment; limited generalizability to LMIC.</li> </ul>
Burton, Henn <i>et al.</i> , 2017 [18]; <ul style="list-style-type: none"> <li>- Rapid narrative review</li> <li>- Effectiveness and cost-effectiveness of alcohol control policies</li> </ul>	<ul style="list-style-type: none"> <li>- 'a priori' design: no</li> <li>- search comprehensive: no</li> <li>- grey literature: unclear</li> <li>- year of last search: 2016</li> <li>- no. of studies included: 7 reviews, 2 individual studies (LMIC: 0).</li> <li>- duplicate study selection and data extraction: no</li> </ul>	Quality of evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) criteria. Unclear if the quality of individual studies were assessed beyond their design (e.g. systematic review, RCT, ...).	<ul style="list-style-type: none"> <li>Only broad results presented:               <ul style="list-style-type: none"> <li>- Taxation</li> <li>- increased tax was associated with a proportionate reduction in alcohol consumption;</li> <li>- all alcohol drinkers can be targeted at beverage types;</li> <li>- Minimum pricing</li> <li>- cheap relative to its strength; moderate drinkers and the on-trade are minimally affected.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Search strategy poorly described and not comprehensive; broad conclusions; unclear quality assessment of individual studies; limited generalizability to LMIC.</li> </ul>
Siegfried, Parry, 2019 [19]; <ul style="list-style-type: none"> <li>- Narrative review</li> <li>- Alcohol control interventions included in the 2010 World Health Organization Global Strategy to Reduce the Harmful Use of Alcohol</li> </ul>	<ul style="list-style-type: none"> <li>- 'a priori' design: yes</li> <li>- search comprehensive: yes</li> <li>- grey literature: yes</li> <li>- year of last search: 2017</li> <li>- no. of studies included: 7 reviews (LMIC: 0)</li> <li>- duplicate study selection and data extraction: yes</li> </ul>	Four ROBIS (Risk of Bias Assessment Tool for Systematic Reviews) domains were used (i) study eligibility criteria; (ii) identification and selection of studies; (iii) data collection and study appraisal; and (iv) synthesis and findings. Only broad scores are presented (high, low or uncertain) without any details.	<ul style="list-style-type: none"> <li>Only broad results presented.</li> <li>- The evidence for 'increased pricing and taxation' was assessed as 'possibly beneficial,' with a recommendation for 'revision with adequate quality assessment, meta-analysis and regression where possible to account for the potential confounders, and integration of the overall quality into the interpretation of the results.' Unclear what was meant by 'beneficial.'</li> <li>- The evidence for 'price only (minimum unit pricing)' was</li> </ul>	<ul style="list-style-type: none"> <li>Small number of reviews included; included studies limited to those reported between 2006 and 2017; limited reporting of quality assessment of individual studies; overly broad presentations of results; no clear conclusion reported; limited generalizability to LMIC.</li> </ul>

(Continues)

TABLE 1 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
			assessed, based on a single review as 'possibly beneficial' with recommendations that further implementation of minimum unit pricing occur within a monitoring environment.	

## Initiation, cessation

Reviews generally did not discuss the effect of price/tax on drinking initiation. In the context of LMICs, one review specifically searched for studies that examined the effect of price/tax interventions on drinking initiation and failed to identify a single study [24]. Two umbrella reviews briefly discussed the effect of price or tax on alcohol initiation. One review stated that policies that increase alcohol prices delay the onset of drinking [14]. The sole reference provided, however, presents no direct support for this statement [48]. A second review identified one study that used United States (US) data collected in the early 1970s, which suggested that a \$0.30 increase in the price of spirits was associated with a decrease in the number of youths who drank spirits by 23% [15].

## Heavy episodic drinking, heavy drinking

A recent umbrella review found that pricing was an effective intervention to address heavy drinking and that minimum pricing selectively targeted heavy drinkers [18]. An older umbrella review concluded that there was very strong evidence for the effectiveness of alcohol taxes in targeting heavy drinkers [33]. Two additional reviews agreed that heavy drinkers were price responsive [32, 35]. A meta-analysis estimated from 10 US studies found a significant own-price elasticity of binge drinking, but of lower magnitude compared to overall drinking [20]. The total mean own-price elasticity for heavy alcohol use was  $-0.28$ , suggesting that a 1% increase in price would lead to a 0.28% reduction of demand for alcohol among heavy drinkers. A review of Chinese studies identified one study that found that an alcohol tax reduction in Hong Kong was counter-intuitively associated with a decrease in binge drinking [39].

## Differences in own-price responsiveness by subgroups

- SES. Too few reviews commented on socioeconomic differences in price responsiveness to make conclusive statements.
- Sex. Few reviews discussed if alcohol price responsiveness differed by sex. A meta-regression did not find any meaningful differences between males and females [28].
- Age. The available evidence on how price responsiveness differed by age was mixed. A recent umbrella review found that young people were no more or less responsive to price changes than older people [17]. By contrast, another, albeit older, umbrella review reported that young people seemed to prefer cheaper drinks, potentially indicative of heightened price responsiveness [15]. An older review similarly argued that youths were especially price-responsive and were likely to exhibit decreased consumption when faced with higher prices [33]. None of the above reviews provided estimates for the magnitude of the effect of price on youth alcohol demand. A meta-regression found that teens and young adults were, perhaps counterintuitively, substantially less responsive to



**TABLE 2** Reviews: study characteristics, main findings and limitations

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Ornstein, 1980 [29]; - Narrative review Ornstein, Levy, 1983 [30]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: unclear - grey literature: unclear - year of last search: not reported - no. of studies included: 23 (LMIC: 0) - duplicate study selection and data extraction: no	To some extent; the quality of individual studies was generally discussed throughout; some studies dismissed because of quality concerns. No formal quality assessment approach/tool used; useful critical review of econometric techniques used in individual studies, with suggestion to interpret results cautiously.	Total own-price elasticities: - beer: -0.3 to -0.9, all statistically significant; - wine: wide variation between countries; generally inelastic; - spirits: most studies generally weak; best estimate, unitary elastic; cross-price elasticities: - no consistency in findings across studies.	Search strategy not described; criteria for quality assessment could be more explicit; limited generalizability to LMIC.
Leung and Phelps, 1993 [31]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: unclear - grey literature: unclear - year of last search: not reported - no. of studies included: 21 (LMIC: 0) - duplicate study selection and data extraction: no	To some extent; the quality of individual studies was generally discussed throughout. No formal quality assessment approach/tool used; useful critical review of data, study design, and econometric techniques used in individual studies.	Total own-price elasticities*: - beer: -0.3 - wine: -1 - spirits: -1.5 *based on studies that used aggregate data; studies that used individual-level data tended to find higher total own-price elasticities Cross-price elasticities: - no consistency in findings across studies; Too few studies reported participation and consumption elasticities or elasticities between groups to make any conclusive statements.	Search strategy not described; criteria for quality assessment could be more explicit; limited generalizability to LMIC.
Edwards, Anderson <i>et al.</i> , 1994 [32]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: no - grey literature: unclear - year of last search: not reported - no. of studies included: 46 (LMIC: 1) - duplicate study selection and data extraction: no	None	Only broad results presented: No average results provided; a description of the main results were discussed by countries and range of elasticities were provided: - English-speaking countries had a demand for beer that was less price elastic than the one for wines and spirits; - Heavy and dependent drinkers were at least as responsive to price as moderate drinkers; - Cross-price elasticities between beverage type were generally small.	No quality assessment of included studies; no account for differing types of price elasticities (e.g. short-run, long-run, participation, consumption); no search strategy or proper discussion of results; results of the review do not support some of the proposed policy recommendations; limited generalizability to LMIC.

(Continues)

TABLE 2 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Fogarty, 2006 [27]; - Narrative review; meta-regression - Effectiveness of pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: no - grey literature: unclear - year of last search: not reported - no. of studies included: 44 (LMIC: 1) - duplicate study selection and data extraction: no	None	Mean (95% CI); median total own-price elasticities: - beer: -0.38 (-0.46, -0.30); -0.28 - wine: -0.77 (-0.89, -0.65); -0.59 - spirits: -0.70 (-0.84, -0.56), -0.59 Mean and median own-price elasticities appear to be calculated without any distinction between price- and tax-elasticities, between short- and long-run price elasticities and include multiple estimates from the same studies.	Non-systematic search strategy; study characteristics not presented; no quality assessment of included studies; no account for differing types of price elasticities (e.g. short-run, long-run, participation, consumption); limited generalizability to LMIC.
Gallet, 2007 [28]; - Narrative review; meta-regression - Effectiveness of advertising and pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: unclear - grey literature: yes - year of last search: not reported - no. of studies included: unclear (132 studies that examined price, income or advertising elasticities) (LMIC: 1) - duplicate study selection and data extraction: no	No quality assessment approach/tool used. Information collected on several common traits of studies, which covered a broad range of attributes, including the type of elasticity estimate, the beverage to which the elasticity applied, serial correlation, heteroscedasticity, the specification of demand, the nature of the data, estimation techniques used, year of publication and quality of the publication outlet. A criticism for some of these study traits were discussed	Total median own-price elasticities - all, short-run: -0.52 - all, long-run: -0.82 - beer: -0.36 - wine: -0.70 - spirits: -0.68 - alcohol (composite of beer, wine, spirits): -0.50 No specific distinction made by type of own-price elasticities, and between subgroups; unable to disentangle policy-relevant effects. Tax elasticities appear to be treated as own-price elasticities.	Poorly described search strategy; study characteristics not clearly presented; no formal quality assessment of included studies; limited generalizability to LMIC.
Booth, Brennan, et al., 2008 [33]; - Narrative review - Effectiveness of advertising and pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: unclear - grey literature: yes - year of last search: 2008 - no. of studies included: 2 reviews [20, 28] + 15 additional individual studies (LMIC: 0 (from additional 15 studies) - duplicate study selection and data extraction: unclear	Quality assessment was discussed but no information was provided as to how it was operationalized. Limitations for each study were provided.	Only broad results presented. - own-price elasticity estimates highly variable, but consistently negative; - stronger effect for cheaper drinks; - scattered evidence suggests that price policies have a similar or stronger effect for at-risk groups (young, young adult binge drinkers and heavy drinkers).	Only broad presentation of results (focus on direction of effect); unclear how quality assessment was operationalized; limited generalizability to LMIC.
Wagenaar, Sabois, Komro, 2009 [20]; - meta-analysis - Effectiveness of pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: not reported	No quality assessment approach/tool used. As a quality inclusion criterion, authors excluded from analysis empirical studies that did	Pooled standardized effect sizes (95%CI) - aggregate-level: - alcohol -0.44 (-0.54, -0.34)	No quality assessment of included studies; no account for differing types of price elasticities (e.g. short-run, long-run, participation, consumption) (Continues)



TABLE 2 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Elder, Lawrence <i>et al.</i> , 2010 [34]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use and related harms	- no. of studies included: unclear (112 but only 105 references could be identified) (LMIC: 1) - duplicate study selection and data extraction: no	not provide sufficient data for calculating some form of numerical estimate of effect and estimate of its standard error. Sensitivity and robustness analyses to evaluate consistency of estimates across study characteristics were conducted.	<ul style="list-style-type: none"> <li>- beer: -0.17 (-0.22, -0.12)</li> <li>- wine: -0.30 (-0.36, -0.23)</li> <li>- spirits: -0.29 (-0.34, -0.23)</li> <li>- individual-level</li> <li>- alcohol -0.03 (-0.05, -0.02)</li> <li>- beer: -0.12 (-0.22, -0.02)</li> <li>- wine: -0.14 (-0.26, -0.01)</li> <li>- spirits: -0.10 (-0.17, -0.02)</li> <li>- heavy drinking: -0.01 (-0.03, 0.00)</li> </ul> <p>Total simple mean own-price elasticities:</p> <ul style="list-style-type: none"> <li>- alcohol -0.51</li> <li>- beer: -0.46</li> <li>- wine: -0.69</li> <li>- spirits: -0.80</li> <li>- heavy drinking: -0.28</li> </ul> <p>Standardized effect sizes at aggregate-level were calculated from total own-price elasticities and combined short- and long run estimates. Unclear if standardized effect sizes at individual-level refer to participation or consumption own-price elasticities, or both; tax elasticities treated as own-price elasticities.</p>	consumption); pooled elasticity estimates not reported; limited generalizability to LMIC.
	- 'a priori' design: unclear - search comprehensive: yes - grey literature: yes - year of last search: 2005 - no. of studies included: 46 (LMIC: 0) - duplicate study selection and data extraction: unclear	Quality of study execution was assessed using a 9-point scale, reflecting the total number of limitations to internal or external validity (study population and intervention descriptions, sampling, exposure and outcome measurement, data analysis, interpretation of results, and other biases). Studies with 0 or 1 limitation were categorized as having good execution, those with 2 to 4 limitations as fair execution, and those with 5 or more were categorized as having limited execution.	<p>Total own-price elasticities, median (interquartile interval):</p> <ul style="list-style-type: none"> <li>- beer: -0.50 (-0.91, -0.36)</li> <li>- wine: -0.64 (-1.03, -0.38)</li> <li>- spirits: -0.79 (-0.90, -0.24)</li> <li>- ethanol: -0.77 (-2.00, -0.50)</li> </ul> <p>Prices/taxes were associated with a lower prevalence of excessive alcohol consumption;</p> <p>Median estimates presented without any distinction between price- and tax-elasticities, and between short- and long-run price elasticities.</p>	No account for differing types of price elasticities (e.g. short-run, long-run); limited generalizability to LMIC.

(Continues)

TABLE 2 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Fogarty, 2010 [21]; - Meta-analysis; meta-regression - Effectiveness of pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: no - grey literature: unclear - year of last search: not reported - no. of studies included: 106 (LMIC: 1) - duplicate study selection and data extraction: no	No quality assessment approach/tool used. As a quality inclusion criterion, author excluded from analysis empirical studies that did not provide sufficient data for calculating some form of numerical estimate of effect and estimate of its standard error. Sensitivity and robustness analyses to evaluate consistency of estimates across study characteristics were conducted.	Pooled total own-price elasticities - Fixed effects: - beer: -0.26 - wine: -0.83 - spirits: -0.38 - Random effects: - beer: -0.36 - wine: -0.57 - spirits: -0.5 Significance levels not reported; all estimates were statistically significantly different than 0. Pooled estimates calculated without any distinction between price- and tax-elasticities, and between short- and long-run price elasticities.	Non-systematic search strategy; no quality assessment of included studies; no account for differing types of price elasticities (e.g. short-run, long-run); limited generalizability to LMIC.
Patra, Giesbrecht et al., 2012 [35]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use and related harms	- 'a priori' design: unclear - search comprehensive: yes - grey literature: no - year of last search: 2011 - no. of studies included: 26 (LMIC: 0) - duplicate study selection and data extraction: yes	The quality of individual articles was assessed based on 4 domains: comparability of subjects, exposure, outcome measurement, and funding/sponsorship. For some studies, some limitations were reported (albeit extremely briefly) along study characteristics.	Only broad results were provided. Changes in price or taxes of alcohol were found to have had an impact on drinking patterns, including high risk drinking.	Limited quality assessment of included studies; overly broad presentation of results (focus on direction of effect); limited generalizability to LMIC.
Sompaisarn, Shield et al., 2013 [24]; - Meta-analysis - Effectiveness of pricing policies at reducing alcohol use and related harms in LMIC	- 'a priori' design: unclear - search comprehensive: yes - grey literature: no - year of last search: 2011 - no. of studies included: 12 (LMIC: 12) - duplicate study selection and data extraction: yes	Minimum quality criteria for inclusion were used: (i) a longitudinal study had to have enough time points to provide a meaningful result; and (ii) the results were not confounded by any other large changes in alcohol control policies that were not taken into account. - minimal and broad data limitation for each study were highlighted; - authors stated that 'problems with statistical analysis' were assessed; however, no such assessment was presented.	Pooled total own-price elasticities (95% CI): - total alcohol: -0.64 (-0.80, -0.48) - beer: -0.50 (-0.78, -0.22) - other alcoholic beverages: -0.79 (-1.09, -0.49) - all studies: -0.66 (-0.82, -0.51) Pooled estimates calculated without any distinction between price and tax elasticities, between short- and long-run price elasticities and between types of own-price elasticities (participation, or consumption elasticities). Only broad results presented:	Relatively small number of studies included; relatively vague quality assessment criteria; non-English or Thai studies or reports excluded.
van Walbeek, Blecher, 2014 [38]; - Narrative review	- 'a priori' design: no - search comprehensive: unclear	None	Only broad results presented:	Non-systematic search strategy; no quality assessment; only very (Continues)

TABLE 2 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
- Effectiveness of pricing policies at reducing alcohol use and related harms in LMIC	- grey literature: no - year of last search: not reported - no. of studies included: 83 (LMIC: 7) - duplicate study selection and data extraction: no		- a 10% increase in the price of alcohol reduced alcohol consumption by ~4% to 8% in most low- and middle-income countries.	broad results presented, which limit usefulness of review; despite focus on LMIC small number of studies included, which limits generalizability to LMIC.
Li, Babor <i>et al.</i> , 2015 [39]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use and related harms in China	- 'a priori' design: no - search comprehensive: unclear - grey literature: yes - year of last search: not reported - no. of studies included: 1 (LMIC: 0) - duplicate study selection and data extraction: unclear	Study quality was evaluated on a scale of 1–5 according to the Maryland Scale of Scientific Methods. Equity Checklist for Systematic Reviews to assess equity and gender sensitivity of actions was also used.	One study concluded that an alcohol tax reduction in 2007 and 2008 in Hong Kong was associated with increased alcohol use (as well as decreased binge drinking)	Only one study included that examined the impact of prices/taxes on alcohol use; study's conclusion not based on included studies; limited generalizability to LMIC.
Chen, Ahler <i>et al.</i> , 2016 [26]; - Meta-analysis - Food Demand Elasticities in China	- 'a priori' design: no - search comprehensive: yes - grey literature: unclear - year of last search: 2012 - no. of studies included: 11 (LMIC: 11) - duplicate study selection and data extraction: unclear	None	Total own-price elasticity: - alcohol, mean: -0.77 - alcohol, predicted: -0.65 - Predicted cross-price elasticities - tobacco: 0.12 - rice: 0.13 - wheat: 0.26 - vegetables: 0.03 Statistical significance not reported.	No quality assessment of studies; unclear if all studies included measured alcohol similarly; statistical significance of pooled results not reported.
Scott, Muirhead <i>et al.</i> , 2017 [42]; - Narrative review - Effectiveness of marketing (price, promotion, product attributes and place of sale/availability) on key drinking outcomes (initiation, continuation, frequency and intensity) in young people.	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: 2015 - no. of studies included: 2 (LMIC: 0) - duplicate study selection and data extraction: yes	The Effective Public Health Practice Project (EPHPP) Quality Assessment Tool was used to assess the quality of individual studies. Quality assessment of individual studies not provided; only broad scores presented (weak, moderate, strong).	- Drinking continuation: one study found that alcohol discounts had a significant effect on alcohol consumption among young people ages 14–17 in the Netherlands. - Drinking intensity: one study, using 2 datasets, found that binge drinking among US adolescents (mean age: 15 years) decreased as price increased (data set 1: price elasticity: -0.18 (95% CI, -0.30, -0.06); data set 2: price elasticity: -0.73 (95% CI, -1.51, 0.05)). The reported price elasticities for drinking intensity were past 2-week binge participation elasticities.	Very small number of studies included limits the usefulness of the review; complete quality assessment not reported.
Boniface, Scannell, Marlow, 2017 [41];	- 'a priori' design: yes - search comprehensive: yes	The Effective Public Health Practice Project (EPHPP) Quality	There was very little evidence that minimum alcohol prices were not	Limited discussion of effect sizes; complete quality assessment not reported (Continues)

TABLE 2 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
<ul style="list-style-type: none"> <li>- Narrative review</li> <li>- Effectiveness of minimum unit pricing policies at reducing alcohol use and related harms</li> </ul>	<ul style="list-style-type: none"> <li>- grey literature: unclear</li> <li>- year of last search: 2017</li> <li>- no. of studies included: 35 (LMIC: 3)</li> <li>- duplicate study selection and data extraction: yes</li> </ul>	<p>Assessment Tool was used to assess the quality of individual quantitative studies. Quality assessment of individual studies not provided; only broad scores presented (weak, moderate, strong).</p>	<p>associated with consumption or subsequent harms. Results were presented with respect to the Bradford Hill criteria for causality:</p> <ul style="list-style-type: none"> <li>- Strength of the association: reasonably good support;</li> <li>- Consistency: very strong support;</li> <li>- Specificity: very strong support;</li> <li>- Temporality: very strong support;</li> <li>- Dose-response/biological gradient: strong support, although the relationship is difficult to quantify;</li> <li>- Plausibility: strong support;</li> <li>- Coherence: strong support;</li> <li>- Experiment: tentative support;</li> <li>- Analogy: very strong support.</li> </ul>	<p>reported; limited generalizability to LMIC.</p>

price changes than adults [28]. The available evidence on the effect of price/tax interventions on binge drinking by age was mixed. A recent review found that binge drinking in youth with a median age of 15 years decreased as price increased, although the mean elasticities varied widely from approximately  $-0.20$  to  $-0.75$  [42]. By contrast, an older review found mixed results and was unable to conclude whether young binge drinkers were more or less price responsive than older binge drinkers [33].

# LMICs.

Few reviews discussed the own-price elasticities of alcohol use in the context of LMICs. Two reviews examined LMICs broadly and two reviews focused specifically on China. One meta-analysis identified 12 studies and concluded that the own-price elasticities for alcohol in LMICs were similar to those in high-income countries; they estimated own-price elasticities for beer, non-beer alcoholic beverages and total alcohol consumption to be  $-0.5$  (95% CI,  $-0.8$ ,  $-0.2$ ),  $-0.8$  (95% CI,  $-1.1$ ,  $-0.5$ ) and  $-0.6$  (95% CI,  $-0.8$ ,  $-0.5$ ) [24]. Another review similarly focused on LMICs and concluded that a 10% increase in the price of alcohol reduced alcohol consumption by 4% to 8% in most LMICs [38]. However, of 83 included studies, only seven were actually conducted in LMICs. A meta-analysis of food demand elasticities in China, based on 19 studies, found a pooled own-price elasticity for alcohol of  $-0.65$ , comparable to the own-price elasticities seen in high-income countries [26]. Last, a broader review of health promotion interventions and policies addressing excessive alcohol use in China identified a single study from Hong Kong (a high-income administration region of China) and consequently provides no useful evidence to the context of LMICs [39]. Overall, the 30 reviews included a total of 36 LMIC studies conducted between 1984 and 2013. A list of all LMIC studies is provided in the Appendix.

# ICAP—Jon Nelson's reviews

As all other reviews, Nelson found that higher alcohol prices and taxes were associated with lower beer, wine, spirits and alcohol consumption [22, 23, 25]. Depending on specifications, pooled total own-price elasticities ranged from  $-0.20$  to  $-0.35$  for beer,  $-0.34$  to  $-0.63$  for wine,  $-0.48$  to  $-0.67$  for spirits and  $-0.46$  to  $-0.58$  for alcohol [22, 23, 25]. As most reviews, Nelson seldom commented on participation, consumption, initiation or cessation own-price elasticities. In one review, Nelson indicated that, based on few studies, price might be important for drinking participation for younger adults [37] and that price was an important factor for young adults' drinking participation and consumption [36].

In four reviews, Nelson argued that existing evidence suggested that the effect of price/tax interventions on binge drinking was not statistically significant and that such policies were unlikely to be effective in reducing heavy drinking [36, 37, 43, 44]. In response, Ludbrook *et al.* [52] pointed out that Nelson's review, which only included studies reporting sex-specific elasticities, made claims outside the original scope regarding the price responsiveness of heavy drinkers in general

**TABLE 3** International Center for Alcohol Policies (ICAP)—Jon Nelson's reviews: study characteristics, main findings and limitations

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Nelson, 2013 - Health Econ Rev [22]; - Meta-analysis - Price and income elasticities for alcohol beverages (beer, wine, spirits)	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: 2012 - no. of studies included: 182 (LMIC: 16) - duplicate study selection and data extraction: no	Some studies excluded because of poor reporting (e.g. missing standard errors), or poor methods 'linear model or poor data'; quality of included studies not generally assessed (no formal quality assessment approach/tool used); unclear which study was excluded and why.	Pooled total own-price elasticities, trimmed samples (95% CI) - fixed effects: - beer: -0.26 (-0.46, -0.06) - wine: -0.34 (-0.54, -0.14) - spirits: -0.49 (-0.69, -0.29) - alcohol: -0.46 (-0.66, -0.26) - random effects - beer: -0.35 (-0.39, -0.31) - wine: -0.58 (-0.64, -0.52) - spirits: -0.64 (-0.70, -0.58) - alcohol: -0.58 (-0.64, -0.52) Total own-price elasticities, full samples, medians - beer: -0.32 - wine: -0.57 - spirits: -0.67 - alcohol: -0.54	Substantial overlap with Nelson, 2013 - Journal of Wine Economics and Nelson, 2014 - J Health Econ [23, 25]. No formal quality assessment conducted; opaque selection of individual studies' estimates; unclear if short-run and long-run estimates have been pooled together; heterogeneity not formally assessed; efforts to minimize the potential effect of alcohol prices on alcohol use apparent; data/results do not support all conclusions.
Nelson, 2013 - J Wine Econ [23]; - Meta-analysis; meta-regression - Price and income elasticities for wine and spirits	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: 2012 - no. of studies included: 125 (LMIC: 6) - duplicate study selection and data extraction: no	Some studies excluded because of poor reporting (e.g. missing standard errors), or poor methods 'linear model or poor data'; quality of included studies not generally assessed (no formal quality assessment approach/tool used); unclear which study was excluded and why.	Pooled total own-price elasticities, full samples (95% CI) - Fixed effects: - wine: -0.63 (-0.65, -0.61) - spirits: -0.48 (-0.50, -0.46) - Random effects: - wine: -0.62 (-0.74, -0.50) - spirits: -0.65 (-0.73, -0.57) Pooled total own-price elasticities, trimmed samples - same as Nelson, 2013 (Health Econ Rev)	Substantial overlap with Nelson, 2013 - Health Econ Rev [22]. No formal quality assessment conducted; opaque selection of individual studies' estimates; unclear if short-run and long-run estimates have been pooled together; heterogeneity not formally assessed; efforts to minimize the potential effect of alcohol prices on alcohol use apparent; data/results do not support all conclusions.
Nelson, 2014 - J Health Econ [25]; - Meta-analysis; meta-regression - Price and income elasticities for beer	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: 2012 - no. of studies included: 114 (LMIC: unclear) - duplicate study selection and data extraction: no	None	Pooled total own-price elasticities (95% CI) - fixed effects: - beer, full sample: -0.23 (-0.24, -0.22) - beer, trimmed sample: -0.20 (-0.39, -0.31) - random effects: - beer, full sample: -0.35 (-0.21, -0.19) - beer, trimmed sample: -0.23 (-0.27, -0.19)	Substantial overlap with Nelson, 2013 - Health Econ Rev [22]. No formal quality assessment conducted; opaque selection of individual studies' estimates; unclear if short-run and long-run estimates have been pooled together; heterogeneity not formally assessed; efforts to minimize the potential effect of alcohol prices on alcohol use

(Continues)

TABLE 3 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Nelson, 2013 - Econ Anal Pol [36]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use and related harms in heavy drinkers	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: 2012 - no. of studies included: 19 (LMIC: 1) - duplicate study selection and data extraction: no	Some limitations were generally discussed. No formal quality assessment approach/tool used.	Only broad results presented. Results generally not clearly synthesized. - heavy drinking unlikely to be associated with prices or taxes (2/19 studies found statistically significant and substantial price/tax response by heavy drinking adults); - prices/taxes likely associated with moderate drinking; - prices/taxes possibly associated with heavy drinking among youth.	apparent; data/results do not support all conclusions.  No formal quality assessment conducted; no differentiating between types of elasticities; tax and price interventions not separated; limited generalizability to LMIC.
Nelson, 2014 - Health Econ [37]; - Narrative review - Effectiveness of pricing policies at reducing alcohol use by sex	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: 2012 - no. of studies included: 21 (LMIC: 5) - duplicate study selection and data extraction: no	Some limitations were generally discussed. No formal quality assessment approach/tool used.	Results not clearly synthesized. Study's conclusion: - adult men had less elastic demands compared with women; - there was little or no price response by heavy-drinking adults, regardless of sex; - although the sample was small, price might be important for drinking participation for younger adults; - results were mixed but strongly suggested that heavy drinking by young adults, regardless of sex, was not easily dissuaded by higher prices.	No formal quality assessment conducted; unclear exclusion criteria; data/results do not support all conclusions; limited generalizability to LMIC.
Nelson, 2015 - Health Econ Rev [43]; - Narrative review - Effectiveness of pricing policies at reducing binge drinking by age	- 'a priori' design: no - search comprehensive: yes - grey literature: yes - year of last search: 2012 - no. of studies included: 65 (LMIC: 0) - duplicate study selection and data extraction: no	Some limitations were generally discussed. No formal quality assessment approach/tool used.	Effects of prices/taxes on binge drinking, among youth, young adult and adult population varied between studies. Overall, very heterogeneous and mixed evidence: - for youth 3/18 studies found statistically significant protective effects on heavy drinking from price/tax interventions, 10 null results, and others mixed; - for young adults 1/5 studies that pooled men and women found statistically significant protective	No formal quality assessment conducted; unclear exclusion criteria; data/results do not support all conclusions; limited generalizability to LMIC.

(Continues)



TABLE 3 (Continued)

Author, year; review type, research question	'a priori' design; search; study selection; data extraction	Quality assessment	Main findings	Limitations/risks of bias
Nelson, McNall, 2017 - Eur J Health Econ [44]; - Narrative review - Evidence from natural experiments on the effectiveness of pricing policies at reducing alcohol use	- 'a priori' design: no - search comprehensive: no - grey literature: yes - year of last search: not reported - no. of studies included: 29 (LMIC: 0) - duplicate study selection and data extraction: yes	Some limitations were generally discussed. No formal quality assessment approach/tool used.	effects, 2/7 found significant protective effects for men, and 2/4 found significant protective effects for women; - for adults 5/19 studies indicated statistically significant protective effects and 4/19 suggest mixed results.  The review assessed the impact of tax/price policy changes in five countries (Denmark, Finland, Hong Kong, Sweden, and Switzerland). Results not clearly synthesized; little to no discussion of effect sizes; of the 29 studies included, 13 used Nordic Tax Study (NTS) data: - binge drinking was reduced in 4/18 studies included; young adults and youth responded to changes in 4/14 studies, and changes seemed to have had little effect on older adults.	Search strategy not comprehensive; no formal quality assessment conducted; poorly justified or unclear exclusion criteria; data/ results do not support all conclusions; limited generalizability to LMIC.

**TABLE 4** Summary of key results: own-price effects

Total alcohol consumption
Higher alcohol taxes and prices were associated with lower total alcohol consumption [14–16, 18–21, 24, 26–35, 38];
Own-price $\eta$ , alcohol:
– Wagenaar <i>et al.</i> , 2009: $\approx -0.51$ [20];
– Gallet, 2007: short-run $\approx -0.52$ ; long-run $\approx -0.82$ [28];
By beverage type: beer, wine, spirits
Price responsiveness varied by beverage type [14,20,21,24,27–31,34];
Own-price $\eta$ , beer:
– Fogarty, 2010: $\approx -0.26$ (FE), $-0.36$ (RE) [21];
– Elder <i>et al.</i> , 2010: $\approx -0.50$ [34];
– Wagenaar <i>et al.</i> , 2009: $\approx -0.46$ [20];
– Gallet, 2007: $\approx -0.36$ [28];
– Fogarty, 2006: $\approx -0.38$ [27];
– Leung <i>et al.</i> , 1993: $\approx -0.30$ [31];
– Ornstein, 1980; Ornstein, Levy, 1983: $\approx -0.30$ to $-0.90$ [29,30];
Own-price $\eta$ , wine:
– Fogarty, 2010: $\approx -0.83$ (FE), $-0.57$ (RE) [21];
– Elder <i>et al.</i> , 2010 $\approx -0.64$ [34];
– Wagenaar <i>et al.</i> , 2009: $\approx -0.69$ [20];
– Gallet, 2007: $\approx -0.70$ [28];
– Fogarty, 2006: $\approx -0.77$ [27];
– Leung <i>et al.</i> , 1993: $\approx -1.00$ [31];
Own-price $\eta$ , spirits:
– Fogarty, 2010: $\approx -0.38$ (FE), $-0.50$ (RE) [21];
– Elder <i>et al.</i> , 2010: $\approx -0.79$ [34];
– Wagenaar <i>et al.</i> , 2009: $\approx -0.80$ [20];
– Gallet, 2007: $\approx -0.68$ [28];
– Fogarty, 2006: $\approx -0.70$ [27];
– Leung <i>et al.</i> , 1993: $\approx -1.50$ [31];
Heavy episodic drinking, heavy drinking
Own-price $\eta$ , heavy drinking:
– Wagenaar <i>et al.</i> , 2009: $-0.28$ [20];
Low- and middle-income countries: total and by beverage type
Own-price $\eta$ , total alcohol:
– Sornpaisarn <i>et al.</i> , 2013: $\approx -0.64$ [24];
– Chen <i>et al.</i> , 2016 (China) $\approx -0.65$ [26];
Own-price $\eta$ , beer:
– Sornpaisarn <i>et al.</i> , 2013: $\approx -0.50$ [24];
International Center for Alcohol Policies (ICAP) reviews: total and by beverage type
Own-price $\eta$ , alcohol
– Nelson, 2013: $\approx -0.46$ (FE), $-0.58$ (RE) [22];
Own-price $\eta$ , beer:
– Nelson, 2014: $\approx -0.23$ (FE), $-0.35$ (RE) [25];
– Nelson, 2013: $\approx -0.26$ (FE), $-0.35$ (RE) [22];
Own-price $\eta$ , wine:
– Nelson, 2013: $\approx -0.34$ (FE), $-0.58$ (RE) [22];
– Nelson, 2013: $\approx -0.63$ (FE), $-0.62$ (RE) [23];
Own-price $\eta$ , spirits:
– Nelson, 2013: $\approx -0.49$ (FE), $-0.64$ (RE) [22];
– Nelson, 2013: $\approx -0.48$ (FE), $-0.65$ (RE) [23];

Note: Price elasticity estimates are presented in reverse chronological order; see Tables 2–3 for study characteristics, limitations and main findings of included reviews and, when applicable, uncertainty intervals. Abbreviations:  $\eta$ , elasticity; FE, fixed effects; RE, random effects.

[37, 52]. Ludbrook *et al.* [52] also argued that, on closer examination, Nelson’s included primary studies revealed more complexity than was

presented. In another response, Xuan *et al.* [53] argued that, contrary to Nelson’s conclusion, there was strong evidence on the effects of prices and taxes on heavy drinking, including binge drinking and maintained that Nelson overly relied on a simple count of studies with and without  $P < 0.05$ , disregarding the magnitude of effects [43, 53].

Nelson found that male were generally less responsive to changes in alcohol prices than women, although the difference in magnitude was not clearly reported [28, 37]. One review by Nelson discussed differences in price responsiveness by sex in HED, concluding there was little price response by heavy drinkers, regardless of sex [37]. Last, Nelson found that, among studies that examined binge drinking in young adults, two of seven found a statistically significant, protective effect of higher prices or taxes against heavy drinking in young adult men, whereas two of four studies found a statistically significant, protective effect of price/tax interventions against heavy drinking in young adult women. Nelson concluded that evidence from econometric studies did not strongly support a protective effect for higher alcohol price or tax interventions on binge drinking outcomes, regardless of a drinker’s age or sex [43].

## Minimum pricing

In addition to taxes that raise the price of alcohol, minimum pricing of alcohol has been proposed as a measure to reduce alcohol use generally and harmful drinking in particular [54]. Minimum pricing can prevent low-cost selling of existing products and the introduction of new products sold at lower prices. We identified one review that specifically examined the effect of minimum unit pricing on alcohol consumption [41]. The review concluded that price-based alcohol policy interventions such as minimum unit pricing were likely to reduce alcohol consumption, however, provided little discussion of the magnitude of effects of minimum pricing and did not discuss any differential effects by subgroups.

## Cross-price effects

Evidence on the cross-price elasticities between alcohol and other goods was unclear, with estimates of the direction of cross-price elasticities mixed and magnitude relatively small. Much of the discussion in included reviews centred on substitution between different alcohol beverage types. Comparatively little evidence was available on the cross-price elasticities between alcohol and other non-alcohol goods like tobacco, psychoactive drugs or food. Reviews that discussed cross-price elasticities between different beverage types found either small cross-price elasticities or inconsistent results between studies. A recent umbrella review found no robust evidence of a relationship between alcohol prices and consumption of unhealthy substances such as tobacco or psychoactive drugs [18]. Three older reviews similarly concluded that cross-price elasticities were small and imprecisely measured [29, 31, 32].

A meta-analysis of food demand elasticities in China estimated cross-price elasticities between alcohol and non-alcoholic goods [26].

On the whole, pooled cross-price elasticities tended to be fairly small. For example, the pooled cross-price elasticity between alcohol and tobacco was 0.12 (i.e. a 1% increase in alcohol price would be expected to increase the demand for tobacco products by 0.12%) [26]. These findings are consistent with recent evidence that examined whether alcohol, tobacco, cannabis and other psychoactive drugs complemented or substituted each other. One recent review found weak evidence that increasing the price of alcohol resulted in a reduction of cannabis use in adolescents [55]. A recent general review that examined the use of excise taxes to reduce tobacco, alcohol and sugary beverage consumption concluded that there was evidence indicating substitution among alcohol beverages within a given category (e.g. between low- and high-alcohol beer), but little substitution across beverage categories (e.g. beer to wine or spirits) [56]. Last, reports by the International Agency for Research on Cancer, the World Health Organization, and the US National Cancer Institute could not conclude whether higher alcohol prices would increase or decrease the demand for tobacco products [57, 58].

### Risk of bias assessment

We found that reviews most often failed to adequately assess the quality of the evidence. For example, no formal quality assessment was conducted in any of the reviews that included the most primary studies, nor in any of Nelson's seven reviews [20–23, 25, 28, 36–38, 43, 44]. Three of six umbrella reviews used a quality assessment or risk of bias tool to assess included reviews, [16, 18, 19] although one used a tool not designed to assess reviews [18]. Only three of 24 reviews used a tool to assess the quality or risk of bias of primary studies [39, 41, 42]. Additionally, most reviews that conducted a formal quality assessment only presented broad scores without any details.

Most reviews did not report using an a priori study design, the search strategy was not always clearly described or comprehensive, it was often unclear if grey literature was searched and several studies did not select or extract studies in duplicate. Funding and potential competing interest were reported in all but four reviews [21, 26–28]. However, only one review reported funding and potential competing interest of primary studies [41]. Last, most reviews did not clearly discuss or interpret differences between price and tax elasticities, between short- and long-run price elasticities and between types of own-price elasticities.

## DISCUSSION

### Main results

Overall, the 30 included reviews provide overwhelming evidence that higher alcohol prices and taxes were associated with lower total alcohol consumption and that price responsiveness varied by beverage type. Total own-price elasticities for alcohol were consistently and substantially negative to be policy meaningful. The reviews suggest

short- and long-run total own-price elasticity for alcohol of approximately  $-0.5$  and  $-0.8$  and own-price elasticities of approximately  $-0.3$  for beer,  $-0.6$  wine, and  $-0.5$  to  $-0.8$  for spirits. Limited discussion of own-price participation and consumption elasticities makes it difficult to draw strong conclusions and suggests that higher prices and taxes may affect participation and consumption equally. Reviews provided little evidence about the effect of higher prices or taxes on alcohol initiation or cessation. Other than reviews by Nelson, all reviews generally concluded that higher taxes and prices were associated with less frequent harmful drinking practices such as HED. However, the magnitudes of these associations were unclear. One meta-analysis found own-price elasticity for heavy alcohol use that was substantially lower than that of total alcohol consumption [20]. Reviews provided no evidence that alcohol price responsiveness differed by SES, mixed evidence with respect to age and sex, and limited evidence suggesting price responsiveness in LMICs was similar to high-income countries. One review focused on non-tax price strategies such as minimum pricing and concluded that such strategies were likely associated with lower alcohol consumption [41]. Last, reviews suggested some potentially policy-relevant substitution among alcohol beverages within a given category, but little substitution across beverage categories and between alcohol and other harmful products such as tobacco and psychoactive drugs.

### Limitations

First, several of our 30 included reviews were based on a similar pool of primary studies and therefore, cannot be considered independent from one another. Moreover, seven reviews were funded by the alcohol industry and authored by a long-time industry consultant [22, 23, 25, 36, 37, 43, 44]. Of the seven reviews, three had substantial overlap to be considered duplicate publications [22, 23, 25]. Although fragmented publishing may be justified, it may also contaminate and skew the literature [59]. Second, our quality assessment is based on our own interpretation of what was reported; we did not contact authors when we felt methods and/or results were unclear. Limited methodological information often rendered quality assessment difficult. Third, although we set out with an explicit focus on the context of LMICs, our findings have limited generalizability to their circumstances. Fourth, although we prepared a protocol, we did not make it publicly available before we started working on our umbrella review.

### Implications for research and policy

Several reviews focused on the direction of effects, but lacked discussion of the magnitude of the effects. This was particularly the case in reviews that specifically examined or commented on HED. Vote counting of studies with significant and non-significant results is not a reliable approach and should be avoided. The lack of distinction between price and tax elasticities, between short- and long-run price elasticities and between types of own-price elasticities in pooled

estimates and discussion is of concern and highlights the importance of involving reviewers with backgrounds in systematic review methodology, the content area and related statistical approaches used. Similarly, most reviews ignored a relevant and prolific area of economic research, demand systems, which often include alcohol as one of the goods in the estimation of own-price and cross-price elasticities.

Despite the evidence that financial conflicts of interest are associated with outcomes favourable to the funders [45–47], only one review clearly reported competing interests for individual studies [41]. Seven of the 30 included reviews reported having been supported in part by the ICAP without any explicit information that ICAP was created by alcohol producers to promote industry interests [60, 61]. Although the main results reported in the reviews funded by ICAP were generally in agreement with the rest of the literature, we found that results did not support all conclusions in six of seven review [22, 23, 25, 37, 43, 44]. A number of journals (e.g. BMJ, Heart, PLoS Medicine and Thorax) do not consider for publication any study that is partly or wholly funded by the tobacco industry [62, 63]. The Cochrane Library goes further and considers only publishing systematic reviews that are not funded by organizations with a financial interest in the outcome [45]. As most journals still consider publishing studies, including reviews, supported by the alcohol industry, it is vital that competing interests be clearly reported and that reviews pay more attention to potential competing interests in primary studies. Although early reviews conducted in the 1980s and 1990s did not follow (or at least report) modern systematic review methodological approaches, the thoughtful discussion of econometric techniques used in individual studies, with suggestion to interpret results cautiously and the progress made in the use and reporting of systematic methods to identify, select and critically appraise relevant research was impressive. However, we found that assessment and reporting of the quality and risk of bias of primary studies was still lacking in several recent reviews. The limited evidence base for LMICs warrants additional research. The weak evidence base regarding socioeconomic differences in price responsiveness warrants more research, particularly in LMICs. The mixed and contradictory evidence with respect to age and sex differences in alcohol price responsiveness also necessitates additional research.

Our findings confirm the effectiveness of taxes in reducing alcohol use. Moreover, increasing the price of alcohol through taxes can also be expected to increase tax revenue, because the demand for alcohol is inelastic. The overwhelming evidence that alcohol use causes health and social ills indicates that higher alcohol taxes can improve population health and government finances. Given that most consumption taxes are regressive, the lack of evidence of socioeconomic differences in alcohol price responsiveness suggests that alcohol tax increases may disproportionately affect lower-SES individuals if they are not more responsive to changes in alcohol prices than higher-SES individuals. Revenues generated by these taxes can, however, be used to support programs that disproportionately benefit the poor. Additionally, inasmuch as the poor consume more alcohol, their health burden is greater and tax increases will have a progressive health impact [56, 64, 65].

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## DECLARATION OF INTERESTS

None.

## AUTHOR CONTRIBUTIONS

**G Emmanuel Guindon:** Conceptualization; data curation; funding acquisition; investigation; methodology; project administration; supervision; validation; visualization. **Kevin Zhao:** Data curation; investigation; validation. **Tooba Fatima:** Data curation; investigation; validation. **Sophiya Garasia:** Data curation; investigation; validation; visualization. **Nicholas Quinn:** Data curation; investigation; validation. **N. Bruce Baskerville:** Conceptualization; data curation; funding acquisition; investigation; methodology; validation. **Guillermo Paraje:** Conceptualization; data curation; funding acquisition; investigation; methodology; validation.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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