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Article:
Kilian, C., Buckley, C., Lemp, J.M. et al. (6 more authors) (2025) Targeting alcohol use in high-risk population groups: a US microsimulation study of beverage-specific pricing policies. Lancet Public Health. ISSN: 2468-2667

https://doi.org/10.1016/S2468-2667(25)00165-3

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Targeting alcohol use in high-risk population groups: a US microsimulation study of beverage-specific pricing policies

Carolin Kilian, Charlotte Buckley, Julia M Lemp, Xinyi Kou, William C Kerr, Nina Mulia, Robin C Purshouse, Jürgen Rehm, Charlotte Probst

Summary

Background Raising retail prices on alcoholic beverages preferred by high-risk groups (males, those of low socioeconomic status, and those with heavy alcohol use) might selectively reduce their alcohol consumption. However, the differential impact of beverage-specific price increases on US population groups has yet to be studied. This study aimed to simulate the effect of beverage-specific price increases on alcohol use within subgroups of the adult US population defined by sex, educational attainment, and alcohol use category.

Methods An individual-level microsimulation of the US population (aged 18–79 years) was used to simulate alcohol consumption from 2000 to 2019 based on individual characteristics (ie, sex, age, race, ethnicity, and educational attainment as a proxy for socioeconomic status categorised as high school degree or less, some college, and college degree or more) and previous alcohol use. The microsimulation model was generated via integration of diverse data sources including decennial US Census data, annual data from the American Community Survey, annual data from the National Vital Statistics System, annual data from the Behavioral Risk Factor Surveillance System, and biennial, longitudinal data from the Panel Study of Income Dynamics. Policy parameters were informed by the existing literature. Four national policy scenarios were compared with a reference scenario without price change in 2019: a uniform price increase of 10% (scenario 1), a uniform price increase of 30% (scenario 2), a beverage-specific price increase of 30% for beer and spirits and 10% for wine (scenario 3), and a beverage-specific price increase of 50% for beer and spirits and 10% for wine (scenario 4). Individual-level effects on alcohol consumption were simulated using beverage-specific own-price elasticities. Sensitivity analysis assessed assumption-based correlation coefficient between alcohol consumption and the individual-level percent reduction in alcohol consumed; and the application of the beverage-non-specific own-price participation elasticity.

Findings Scenario 4 had the strongest effect on alcohol use overall and most effectively reduced consumption in high-risk groups: males and females with high alcohol use (more than 60 g of pure alcohol per day for males and 40 g of pure alcohol per day for females) and low educational attainment (high school degree or less) reduced their alcohol use by –17·30% (–17·62 g per day, credible interval [CI] –21·77 to –13·20) and –17·49% (–12·25 g per day, CI –14·72 to –9·58), respectively. In comparison, smaller relative changes were observed among groups at less risk of harm.

Interpretation Disproportionate increases in retail prices for the cheapest beverages, beer and spirits, might lead to a greater decline in consumption among high-risk groups. Pricing policies could thus be used as a powerful public health tool to mitigate the unequal alcohol-attributable burden of disease.

Funding National Institute on Alcohol Abuse and Alcoholism, National Institutes of Health.

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Lancet Public Health 2025

Published Online
August 27, 2025
https://doi.org/10.1016/S2468-2667(25)00165-3

See Online/Comment
https://doi.org/10.1016/S2468-2667(25)00189-6

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Introduction

Alcohol use is the second leading cause of death among individuals aged 15–49 years in the USA, accounting for nearly 8% of all deaths in this age group in 2021.[1] In the same year, more than 111 500 individuals of all ages died due to alcohol (age-standardised mortality rate: 22·3 per 100 000), reflecting the highest absolute number of annual deaths caused by alcohol use since 1990.[1] To address this increasing alcohol-attributable harm, there is an urgent need to strengthen effective alcohol control policies in the USA. Across different policy areas, measures that increase the retail prices of alcoholic beverages such as alcohol taxation are recommended as the most cost-effective policies to lower population-level alcohol use.[2] However, with very few exceptions, alcohol excise taxes have not been increased in most US states since 1991 or have effectively decreased due to the lack of inflation adjustment, making alcoholic beverages more affordable over time.[3] Increasing alcohol affordability in the USA has been mirrored by a rise in alcohol per capita consumption by about 16% since 1995.[4]

Alcohol pricing policies might affect consumer groups differently, as suggested by the very few studies that have looked into subgroup-specific effects.[2,5,6] One mechanism through which price changes might address alcohol use by high-risk alcohol users, including males and people with very high alcohol consumption, is to increase the prices of alcoholic beverages prevalent in these groups,[5]

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Research in context

Evidence before this study

According to the 2022 umbrella review on alcohol price responsiveness from Guindon and colleagues, few studies have investigated the effect of alcohol price changes on alcohol consumption across population groups defined by socioeconomic status and sex. We conducted a PubMed search on Dec 11, 2024, using search terms (alcohol use OR alcohol consumption AND price OR tax*) AND (socioeconomic status OR income OR education OR sex) and identified 31 research reports that have been published since Jan 1, 2022. Subgroup-specific effects of uniform price changes on alcohol consumption were investigated in three reports, none of which were from the USA. Based on the limited evidence available, however, it is highly likely that increases in alcohol beverage prices impact alcohol consumption differently across population groups.

Added value of this study

To the best of our knowledge, this is the first study to describe the potential effect of increased alcohol beverage prices on alcohol consumption on different population groups in the USA at national level. By way of integrating diverse empirical data sources into one coherent microsimulation model, our study outlines, for the first time, a specific strategy on how to leverage pricing policies for improving US health and health inequities. Specifically, the simulation of beverage-specific pricing policy that emphasises price increases for beer and spirits suggested most pronounced changes among males, people with lower educational attainment, and alcohol users with an average daily intake of more than 40 g of pure alcohol per day for females and 60 g of pure alcohol per day for males—population groups bearing the greatest alcohol-attributable health burden.

Implications of all the available evidence

Increasing the prices of alcoholic beverages is a very effective tool to lower alcohol consumption in the population at low cost, as has been demonstrated in previous investigations. Our study now expands the available evidence by revealing the untapped potential of pricing policies to tackle high-risk population groups in the USA. Raising the prices for alcoholic beverages, especially for the cheapest and most popular drinks, beer and spirits, might not only address the high and unequally distributed health burden attributable to alcohol use, but can also generate substantial state revenue. Given the progressive liberalisation of alcohol regulations in the USA, which has led to persistently low prices for beer and spirits and greater affordability of alcoholic beverages over the past three decades, our findings support implementation of increased alcohol pricing as evidence-based and cost-effective policy that improves public health.

that is, beer and spirits.[7] In the USA, the average retail prices per standard drink of alcohol (defined as 14 g of pure alcohol) are the lowest for beer and spirits compared with that of wine.[8] As these alcoholic beverages (beer and spirits) are also the most prevalent beverages consumed by individuals with low educational attainment,[7] increasing their prices might also contribute to lowering the unequally distributed and high alcohol-attributable health burden in this group.[9] This hypothesis is supported by empirical data from observational studies conducted in Finland, Lithuania, Wales, and Scotland, where decreases in alcohol affordability were associated with reduced socioeconomic inequalities in mortality.[10–12]

See Online for appendix

In this study, we aimed to simulate the effect of beverage-specific price increases on alcohol use within subgroups of the adult US population defined by sex, educational attainment, and alcohol use category. Beverage-specific considerations are typical for excise taxation of alcohol, as they allow to specifically target the types of alcohol most associated with harm in a country.[13] By modelling mechanisms on the individual level, our approach allows unique insights into the potential public health benefits of pricing policies aimed at alcohol users from groups currently bearing the highest alcohol-related health burden in the USA, namely, males, individuals with low educational attainment, and people drinking at high levels.

Methods

Study design and operationalisations

The current study is part of the Simulation of Alcohol Control Policies for Health Equity (SIMAH) project.[14] All study procedures adhere to GATHER.[15] SIMAH has been reviewed and approved by the Centre for Addiction and Mental Health Research Ethics Board (number 115/2020). Policy effect estimates are generated by a computer model, which has been developed and documented using the overview, design concepts and details protocol (appendix pp 3–22), a recognised reporting standard for simulation models.[16]

The study design is based on a dynamic, individual-level microsimulation to model alcohol use for the years 2000–19 (appendix p 6).[14] The individuals in the microsimulation constitute a synthetic population that is representative of the real US population aged 18–79 years at the national level. The policy under consideration is implemented in the year 2019 and different scenarios are compared to a reference scenario without the policy.

In the model, individuals are described by four demographic variables: educational attainment (used as a proxy for socioeconomic status, denoted education), race and ethnicity, age, and sex (male or female in line with categories used in the underlying data). Education is categorised as high school degree or less, some college (1–3 years of college, not graduated; associate degree), and college degree or more (appendix p 11). Race and ethnicity

are categorised as non-Hispanic White, non-Hispanic Black, Hispanic, and other (appendix p 23).

Alcohol use as the outcome of interest is simulated based on each individual's characteristics. We consider changes in two outcome measures, given their different public health implications: (1) average alcohol consumption in average grams of pure alcohol per day and (2) alcohol consumption categories defined by WHO based on the grams of pure alcohol per day: abstainers (past 12 months), category 1 with up to 20 g per day for females and up to 40 g per day for males, category 2 with more than 20 g per day up to 40 g per day for females and more than 40 g per day up to 60 g per day for males, and category 3 with more than 40 g per day for females and more than 60 g per day for males.

Policy scenarios

Four policy scenarios were modelled (table). In the first two scenarios, the retail prices per standard drink for beer, wine, and spirits were increased by 10% and 30% compared with reference. In the third and fourth scenario, retail prices per standard drink for beer and spirits were increased by 30% and 50%, respectively, whereas the retail price per standard drink for wine was raised by 10%. Scenario 3 and scenario 4 were chosen to study the effect of differential price increases on alcohol consumption in population subgroups with the highest alcohol-related health burden (ie, males, individuals with high school degree or less, and category 3 drinkers). These policy scenarios are comparable with previous modelling studies,[17,18] and account for the very low average retail price per standard drink for beer and spirits compared with that of wine.

Data sources

Microsimulation parameters were informed by US data sources and existing research (appendix pp 3–22). In brief, population estimates for each subgroup (defined by education, race and ethnicity, age, and sex if not indicated otherwise) were based on decennial US Census data,[19] and the annual American Community Survey (ACS);[20] transitions between levels of education by subgroup (race and ethnicity, age, and sex) were informed by data from the Panel Study of Income Dynamics;[21] and mortality within each subgroup was based on individual death records obtained from the National Vital Statistics System.[22] Individual-level data to inform alcohol exposure in each subgroup were retrieved from the annual Behavioral Risk Factor Surveillance System (BRFSS), 2000–19.[23]

Policy scenarios were implemented by applying USA-specific and beverage-specific own-price elasticities based on Fogarty.[24] These data were preferred over the most recent elasticities published by Nelson[25,26] given alcohol industry involvement in the latter.[2] As own-price elasticities reported by Fogarty represent changes in average alcohol consumption only (henceforth: consumption elasticities), we obtained USA-specific own-price elasticity estimates for beverage-non-specific drinking participation (ie, how many people might stop drinking alcohol entirely given higher retail prices; henceforth: participation elasticities) from Ruhm and colleagues.[27] We refrained from implementing cross-price elasticities, which capture how changes in the price of alcoholic beverages might affect the demand of other products, given mixed evidence of their presence in the USA and elsewhere.[2,28]

	Reference	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Beer	$0·93	$1·02	$1·21	$1·21	$1·40
Wine	$2·23	$2·45	$2·90	$2·45	$2·45
Spirits	$0·56	$0·62	$0·73	$0·73	$0·84

Reference: 2019 retail price per standard drink where average retail prices were obtained from the 2019 National Alcohol Beverage Control Association Research's Report on Alcohol Beverage Revenue and Taxes.[8] Scenario 1: 10% increase for beer, wine, and spirits. Scenario 2: 30% increase for beer, wine, and spirits. Scenario 3: 30% increase for beer and spirits and 10% increase for wine. Scenario 4: 50% increase for beer and spirits and 10% increase for wine. Prices are in US dollars.

Table: **Overview of average beverage-specific retail prices per US standard drink of 14 g of pure alcohol in 2019 under different policy scenarios of price increases**

Statistical analysis

The development of the microsimulation model is reported in the SIMAH protocol (appendix pp 3–22).[14] Briefly, the microsimulation model simulates life course changes in education and alcohol use stratified by education (for alcohol use only), race and ethnicity, age, and sex. The baseline year of the microsimulation is 2000 and the synthetic population progresses forward in time steps of one year until 2019. Every year, individuals are added to the population through births (aged 18 years) and inward migration and removed through mortality and outward migration. Individual-level changes in education are simulated using transition probabilities obtained from Markov models, using biennial data from the Panel Study of Income Dynamics, 2005–2019, whereas changes in alcohol use categories are informed by ordinal logistic regression modelling of pseudo-longitudinal BRFSS data (2000–10).

A Bayesian probabilistic framework was used to calibrate and validate the microsimulation model in two steps (appendix pp 3–22). In this approach, the estimated model parameters for education (ie, transition probabilities; step 1) and alcohol use category (ie, regression coefficients; step 2) were interpreted as previous beliefs about their true values. Posterior beliefs about the parameters were then estimated using a Bayesian history matching approach,[29] which compared simulated outputs for education and alcohol use category prevalences with independently observed target data from ACS 2000–10 (step 1) and BRFSS 2011–15 (step 2), setting aside target data for validation. Parameter values were retained as part of the posterior

beliefs if considered non-implausible based on the comparison (having a mean implausibility metric <3).[29] The calibrated model was then validated using reserved data from ACS 2011–19 (step 1) and BRFSS 2016–19 (step 2).[20,23]

The calibrated model was used to quantify changes in alcohol use categories and alcohol consumption by education and sex, accounting for stochasticity and parameter uncertainty (ie, posterior beliefs of the calibrated education and alcohol models, as well as uncertainty of the policy effect). Specifically, 60 unique combinations of parameter settings from the calibrated education and alcohol models were paired with distinct beverage-specific mean consumption elasticities drawn from the effect distribution (appendix pp 19–21). Each combination was simulated ten times with varying random seeds and averaged across these iterations to account for stochasticity, resulting in a total of 600 simulation runs and 60 effect estimates per policy scenario. Mean effect estimates were calculated by averaging across these 60 effect estimates. Credible intervals (CIs), reflecting parameter uncertainty, were derived based on the minimum and maximum effect estimates across these combinations (appendix pp 24–26).

All policies were implemented in the model in 2019. In a first step, participation elasticity was applied by proportionally sampling the number of past-year alcohol users to stop drinking alcohol by alcohol use category, accounting for their probability of transitioning to abstinence. Consequently, individuals in categories with a higher likelihood of becoming abstainers (eg, category 1 alcohol use) were more likely to be sampled to stop drinking. Next, among those who continue to drink alcohol, we simulated individual-level changes in beverage-specific alcohol consumption based on beverage-specific own-price elasticities and each individual's current alcohol use. On account of the available evidence, we assumed a U-shaped association between alcohol consumption and individual-level price elasticities at a medium correlation (r=0·60).[30] This resulted in higher price responsiveness in individuals with medium consumption, whereas those with very low and very high consumption were less likely to change their behaviour due to price shifts. To apply beverage-specific own-price elasticities, we sampled the probability of drinking beer, wine, and spirits according to each individual's alcohol use category and demographic characteristics (appendix pp 3–22). The policy effect on the prevalence of alcohol use categories and average alcohol consumption under each policy scenario was quantified and compared to a reference scenario without policy implementation in 2019, reflecting the effect of a 1-year policy change. In addition to descriptive comparisons across scenarios, we calculated the distributions of reductions in alcohol consumption to assess whether policy effects differed systematically by education within sex under the most impactful policy scenario (ie, most pronounced changes in alcohol use).

To emulate and reduce real-world complexity, the microsimulation model is based on three global assumptions: (1) the data used to inform synthetic population and model parameters are valid and generalisable to the adult US population and its subgroups across time;[7,14] (2) the structure of the Markov and ordinal model used to inform transition processes in education and alcohol use, respectively, are reasonable representations of the corresponding population dynamics;[31] and (3) the implemented policy mechanisms provide a valid approximation of real-world price policy effects (appendix pp 3–22).[5]

Sensitivity analyses

The effect of alternative policy parameter settings was investigated in two sensitivity analyses. Specifically, we investigated: the assumption-based correlation coefficient between alcohol consumption and the individual-level percent reduction in alcohol; and the application of the beverage-non-specific own-price participation elasticity. In a first sensitivity analysis, we assumed a closer relationship between alcohol consumption and the individual-level percent reduction in alcohol with r=0·8 and no participation elasticities. This analysis was expected to yield a smaller policy effect compared with the main model (more conservative setting). In a second sensitivity analysis, a looser relationship between alcohol consumption and the individual-level percent reduction in alcohol was assumed with r=0·4 while retaining the participation elasticity, which was expected to result in a larger policy effect (less conservative setting).

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

In the reference scenario, the scenario without policy in place, average alcohol consumption in the population (including non-drinkers) slightly decreased between 2000 and 2019 among males, whereas it increased among females. Changes in average alcohol consumption under the different policy scenarios and by population subgroup are depicted in figure 1 (appendix p 27).

A 10% price increase across beverages (scenario 1) resulted in an immediate reduction in alcohol consumption between –5·85% (–0·81 g per day, CI –0·95 to –0·66) for males with high school degree or less and –6·40% (absolute change –0·95 g per day, –1·07 to –0·83) for males with college degree or more and between –6·26% (–0·37 g per day, –0·42 to –0·32) for females with high school degree or less and –6·44% (–0·43 g per day, –0·48 to –0·37) for females with some college (appendix p 27). Declines in alcohol consumption were substantially larger in policy scenarios with steeper price increases, with the most pronounced decline observed under

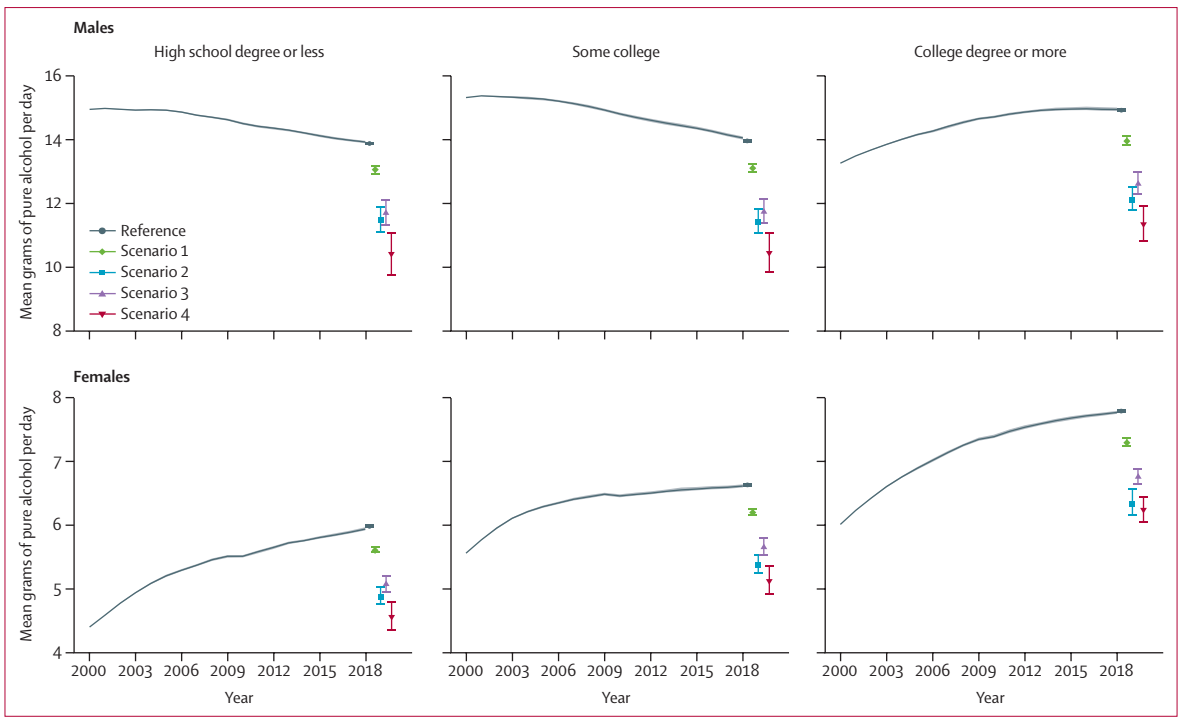

Figure 1: **Simulated average alcohol consumption under different pricing policy scenarios within population subgroups (including abstinent individuals)**
Reference: no price change. Scenario 1: 10% increase for beer, wine, and spirits. Scenario 2: 30% increase for beer, wine, and spirits. Scenario 3: 30% increase for beer and spirits and 10% increase for wine. Scenario 4: 50% increase for beer and spirits and 10% increase for wine. Price changes are being introduced in 2019. Error bars represent credible intervals based on the minimum and maximum values across 60 unique parameter combinations.

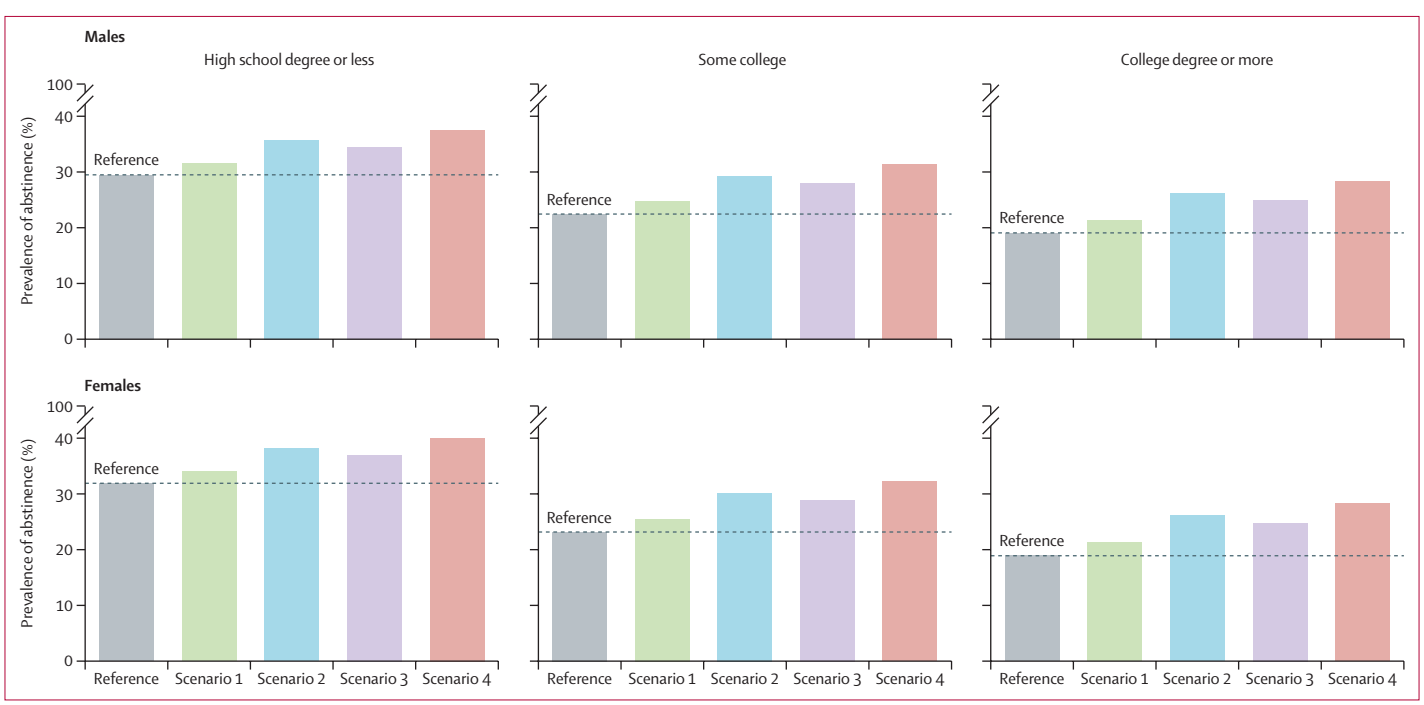

Figure 2: **Simulated prevalence of alcohol abstinence under different pricing policy scenarios within population subgroups**
Reference: no price change. Scenario 1: 10% increase for beer, wine, and spirits. Scenario 2: 30% increase for beer, wine, and spirits. Scenario 3: 30% increase for beer and spirits and 10% increase for wine. Scenario 4: 50% increase for beer and spirits and 10% increase for wine. Reference scenario without changes is shown in grey. Alcohol beverage prices are increased in 2019.

scenario 4 (50% increase for beer and spirits and 10% for wine). In this scenario, average consumption among males decreased by –25·16% (–3·51 g per day, CI –4·11 to –2·87) for those with some college, –24·92% (–3·46 g per day, –4·12 to –2·76) for those with high school degree or less, and –23·96% (–3·57 g per day, –4·09 to –3·00) for those with college degree or more (appendix p 28). Among females, alcohol consumption in relative terms declined most among those with high school degree or less (–23·73%; –1·42 g per day, CI –1·64 to –1·17), followed by those with some college (–22·70%, –1·50 g per day, –1·72 to –1·27) and college degree or more (–19·89%; –1·55 g per day, –1·75 to –1·34; appendix p 28).

Figure 2 depicts changes in the prevalence of alcohol abstinence under the different policy scenarios. In 2019, in the reference scenario, alcohol abstinence in males was most prevalent among those with high school degree or less (29·54%, CI 29·48–29·59), followed by those with some college (22·50%, 22·42–22·60) and college degree or more (19·12%, 19·07–19·19%). Among females, the prevalence of abstaining from alcohol was 31·91% (CI 31·85–32·01), 23·17% (23·10–23·27), and 18·92% (18·85–19·00) for the groups high school degree or less, some college, and college degree or more, respectively (appendix pp 33–34).

A 10% price increase (scenario 1) corresponded to an increase in the prevalence of alcohol abstinence in the same year (2019) of 2·06 percentage points (CI 2·05–2·08; high school degree or less), 2·29 percentage points (2·27–2·31; some college), and 2·37 percentage points (2·35–2·40; college degree or more) in males and 2·06 percentage points (2·05–2·08; high school degree or less), 2·32 percentage points (2·30–2·34; some college), and 2·40 percentage points (2·38–2·43; college degree or more) in females (appendix p 33). Under policy scenario 4, the prevalence of abstaining from alcohol increased between 8·06 percentage points (8·04–8·09; high school degree or less) and 9·28 percentage points (9·22–9·32; college degree or more) in males and 8·09 percentage points (8·05–8·13; high school degree or less) and 9·41 percentage points (9·37–9·44; college degree or more) in females (appendix pp 33–34).

Changes in alcohol consumption were further mapped by alcohol use category. Alcohol use category was based

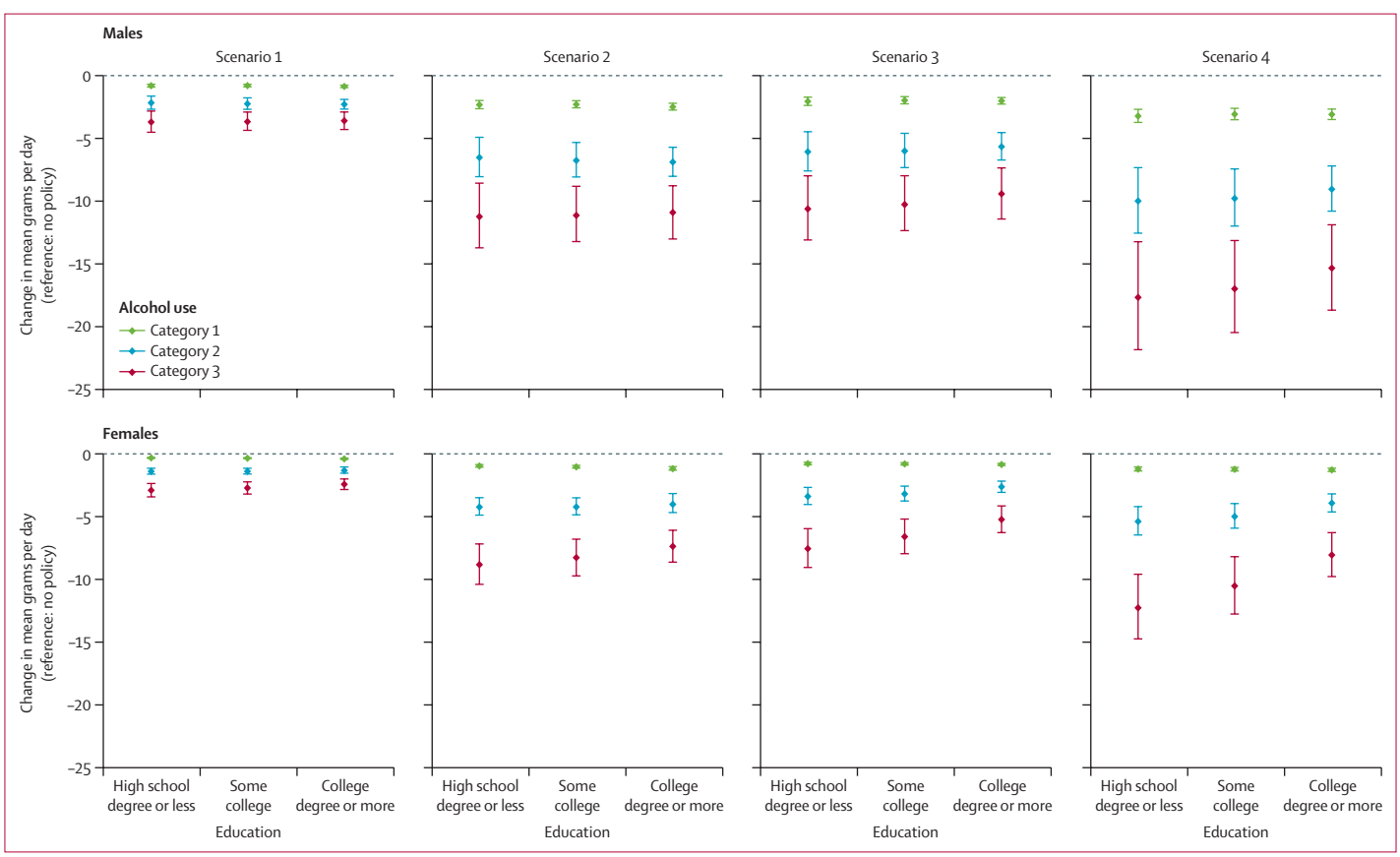

Figure 3: **Change in simulated average alcohol consumption in grams per day by alcohol use category in reference to 2018 under different pricing policy scenarios withing population subgroups**

Reference: no price change. Scenario 1: 10% increase for beer, wine, and spirits. Scenario 2: 30% increase for beer, wine, and spirits. Scenario 3: 30% increase for beer and spirits and 10% increase for wine. Scenario 4: 50% increase for beer and spirits and 10% increase for wine. Alcohol use category 1: up to 20 g per day for females and up to 40 g per day for males. Alcohol use category 2: more than 20 g per day up to 40 g per day for females and more than 40 g per day up to 60 g per day for males. Alcohol use category 3: more than 40 g per day for females and more than 60 g per day for males. Alcohol beverage prices are increased in 2019. Error bars represent credible intervals based on the minimum and maximum values across 60 unique parameter combinations.

on each individual's alcohol use as of 2018, ie, the year before the policy. Increasing alcohol beverage prices by 10% (scenario 1) led to declines in the average consumption across alcohol use categories, especially in category 3. In this group, consumption dropped by –3·94% (–3·59 g per day, CI –4·28 to –2·89), –3·80% (–3·66 g per day, –4·35 to –2·90), and –3·63% (–3·69 g per day, –4·50 to –2·82) in males with college degree or more, some college, and high school degree or less, respectively. In females, alcohol consumption decreased by –4·16% (high school degree or less; –2·92 g per day, –3·44 to –2·37), –4·19% (some college; –2·73 g per day, –3·21 to –2·25), and –4·08% (college degree or more; –2·44 g per day, –2·85 to –2·02; appendix pp 39–42).

Increasing beverage-specific prices by 50% for beer and spirits and 10% for wine (scenario 4) resulted in subgroup-specific changes in alcohol consumption, which were most pronounced for category 3 alcohol use (figure 3). In this group, consumption decreased by –17·57% (–16·94 g per day, CI –20·41 to –13·10), –17·30% (–17·62 g per day, –21·77 to –13·20), and –16·81% (–15·30 g per day, –18·63 to –11·85) in males with some college, high school degree or less, and college degree or more, respectively. In females with category 3 alcohol use, consumption declined by –17·49% (high school degree or less; –12·25 g per day, CI –14·72 to –9·58), –16·13% (some college; –10·51 g per day, –12·74 to –8·19), and –13·47% (college degree or more; –8·06 g per day, –9·77 to –6·28; appendix p 42).

Figure 4 depicts the differences in the change in grams per day by alcohol use category under the most impactful policy scenario (scenario 4) across education groups and by sex. Individuals with high school degree or less and category 2 or category 3 alcohol use consistently displayed larger reductions in alcohol consumption compared with their counterparts with college degree or more, with 95% CIs excluding zero in all comparisons. Among males with high school degree or less, consumption decreased by –0·94 g per day (95% CI –1·92 to –0·18) and –2·33 g per day (–3·85 to –1·11) more compared with males with college degree or more in category 2 and category 3, respectively. Among females with high school degree or less, consumption decreased by –1·46 g per day (–1·85 to –1·06) and –4·20 g per day (–5·19 to –3·19) more compared with females with college degree or more in category 2 and category 3, respectively (appendix p 51).

The simulation results under the alternative model specifications are shown in the appendix (pp 29–32, 35–38, 43–50). In sensitivity analysis 1, the more conservative model setting (ie, higher correlation coefficient and no participation elasticity), the policy effect was considerably less pronounced than in the main analysis, with declines in average alcohol consumption ranging between –4·82% (females with some college, –0·32 g per day, CI –0·37, –0·26) and –4·07% (males with high school degree or less, –0·56 g per day, –0·69 to –0·43) under scenario 1 and –18·67% (males with some college, –2·61 g per day, –3·20 to –1·97) and –14·23% (females with college degree or more, –1·11 g per day, –1·31 to –0·89) under scenario 4 (appendix pp 29–30). Applying a less conservative model setting (sensitivity analysis 2; ie, lower correlation coefficient and participation elasticity) resulted in slightly larger policy effects. Declines in average alcohol consumption ranged between –6·65% (males with college degree or higher, –0·99 g per day, CI –1·11, –0·86) and –6·17% (males with high school degree or less, –0·86 g per day, –1·01 to –0·69) under scenario 1 and –26·47% (males with high school degree or less, –3·67 g per day, –4·39 to –2·91) and –20·24% (females with college degree or more, –1·58 g per day, –1·78 to –1·36) under scenario 4 (appendix pp 31–32).

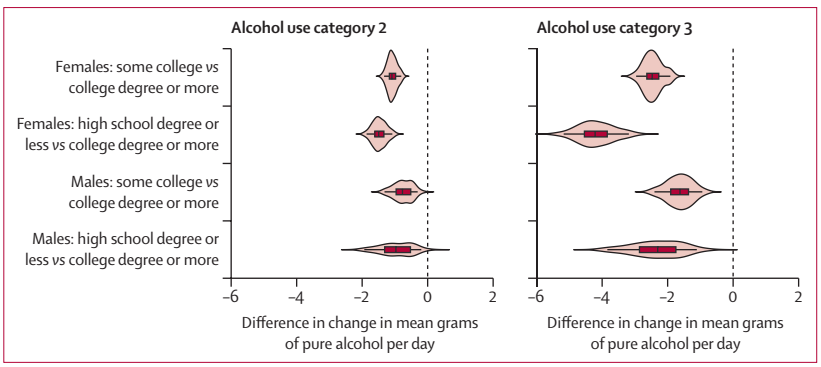

Figure 4: **Distribution of the differences in change in simulated average alcohol consumption in grams per day by alcohol use category between reference (no price change) and scenario 4: 50% increase for beer and spirits and 10% increase for wine within population subgroups**

Alcohol use category 2: more than 20 g per day up to 40 g per day for females and more than 40 g per day up to 60 g per day for males. Alcohol use category 3: more than 40 g per day for females and more than 60 g per day for males. Negative values indicate a larger reduction for the high school degree or less or the some college group following price changes compared with the college degree or more group. The whiskers of the box plot indicate the 2·5th and 97·5th percentile across 60 unique parameter combinations.

Discussion

This microsimulation modelling study provides, for the first time, evidence-informed estimates of changes in alcohol consumption in sociodemographic subgroups of the US population for several intervention scenarios of increasing retail prices on alcoholic beverages. Using the model, we demonstrate that a disproportionate increase in retail prices for the cheapest beverages, that is, beer and spirits, might lead to a greater decline in alcohol consumption among males (compared with females), those with a high school degree or less (compared with adults with college degree or more), and those drinking the most alcohol (category 3 compared with category 1 and 2 alcohol use). This is in line with real-world evidence on the overall effect and the subgroup-specific effect of pricing policies on alcohol consumption from other countries or regions, such as Lithuania[11] and Scotland (UK).[12] For example, the implementation of a minimum unit price of £0·50 per 8 g of pure alcohol in Scotland in 2018 led to an immediate drop in alcohol sales that was

most pronounced for the cheapest alcoholic beverages and among households purchasing the most alcohol.[12] Moreover, the largest reductions in alcohol-attributable hospitalisations and deaths were observed among males and individuals living in the most deprived areas.

The SIMAH microsimulation successfully integrates several large-scale data sources on population, alcohol consumption, and mortality into one coherent model, introducing dynamic changes using research-informed parameters. As a result, it accurately represents the changing demography of the USA, as well as historical trends in education and alcohol use. Uncertainty in the model inputs is quantified probabilistically and propagated to model outputs—an advance on recent comparator models where consideration of uncertainty is restricted to limited sensitivity analyses.[31] However, any modelling is based on assumptions, and some limitations need to be acknowledged. First, we implemented only one possible mechanism through which higher beverage prices can affect alcohol use, that is, through differences in beverage preference. It is possible that price elasticities also differ by other individual characteristics, such as age, education, or race and ethnicity, which we did not account for given the absence of beverage-specific price elasticities within these strata.[2] Moreover, our model did not include the location of alcohol purchases although increasing retail prices of alcoholic beverages targets off-premises alcohol intake. It was therefore not possible to account for differences in purchasing behaviour between sociodemographic and alcohol use groups. Second, we were unable to include varying beverage-specific price distributions as well as individual-level disposable income, which is the more relevant indicator of socioeconomic status for assessing consumer choice behaviour, due to scarcity of data. While it is challenging to anticipate the effect of these two constraints, we speculate that if we were to use income-specific price elasticities, the observed subgroup-specific effects would probably be more pronounced, as low-income groups are more heavily affected by price increases.[32] Third, we were unable to model the policy's long-term effects on alcohol use as price and income dynamics were not incorporated into the model and, to the best of our knowledge, there are no empirical data on long-term price elasticities in the USA.[5] Our results are therefore limited to the immediate effects of price increases on alcohol use, and it remains unclear whether the observed reductions would last, especially if new prices were levelled off by accelerating inflation. Fourth, the implemented dynamics in drinking reflect mainly non-crisis times. In crises, such as COVID-19, transitions between alcohol use categories are additionally impacted by factors such as maladaptation to stress and reduced alcohol availability, which can lead to polarisation of drinking.[33] Last, by using a national microsimulation model, we have focused on the potential effects of federal tax changes and state-level differences in retail prices of alcoholic beverages were averaged out.

Overall, despite these limitations, our analyses were able to demonstrate three points: first, microsimulation constitutes a useful tool to help predict potential effects of alcohol policy interventions; second, different subgroups of the population can and need to be taken into consideration, even when implementing broad brushed alcohol policies; and third, targeted price increases on beer and spirits lead to reductions in alcohol consumption and attributable harm overall and for the high-risk groups. Our study, therefore, adds important insights on the changes in subgroup-specific alcohol consumption that can be expected under different policy scenarios.

Overall, predicted decreases especially for people in the highest alcohol use category (category 3) were between one and two standard drinks per day for individuals with lowest education attained (high school degree or less). While these changes may seem small, this group bears the highest alcohol-attributable burden and, thus, achieving reduction in drinking would result in disproportional reduction in risk of several attributable disease consequences because the dose–response curves for alcohol are generally exponential.[34,35] Thus, even relatively small reduction of one to two standard drinks will result in meaningful improvements to public health.

The results further show that pricing policies can provide a vehicle for targeting low socioeconomic groups to reduce their disproportionately high alcohol-attributable burden, merely by accounting for differential beverage preferences and baseline prices. There are different ways to achieve the modelled price increases, depending on the specific tax design employed. In general, public health gains are largest if specific taxes are applied, ie, taxing the alcohol content of alcoholic beverages rather than taxing retail price or absolute volume regardless of the alcohol content.[31] However, in the USA, the prices per standard drink already differ substantially across beverage types, with much lower prices for spirits and beer compared with wine (table). Recognising that consumers have strong beverage-specific preferences,[7] the question is, to what degree beverage type preferences persist if the prices for preferred beverages become increasingly expensive in a relative manner, and if these cross-price elasticities differ for different subgroups in society. More information is needed on these questions to plan and implement optimal taxation designs for public health purposes.

Modern taxation for public health should be informed by evidence. It should not only aim to reduce alcohol use and attributable harm, but in addition try to reduce related inequalities. To achieve these goals, micro-simulations can be a powerful tool.

Contributors

Conceptualisation: CK and CP. Data curation: CK and CB. Formal analysis: CK and JML. Funding acquisition: CP. Investigation: CK, CB, CP, JML, and XK. Methodology: CK, CB, CP, and RCP. Project administration: CK and CP. Software: CB. Supervision: CP, WCK, NM, JR, and RCP. Data validation: CK, JML, and XK. Writing—original draft: CK. Writing—review and editing: all authors. CK, CP, JML, CB, and XK

have accessed and verified the data. All authors are responsible for the decision to submit the manuscript.

Declaration of interests

WCK has received funding and travel support from the National Alcoholic Beverage Control Association and has been paid as an expert witness regarding cases on alcohol policy issues retained by the Attorney General's Offices of the US states of Indiana and Illinois under arrangements where half of the cost was paid by organisations representing wine and spirits distributors in those states. All other authors declare no competing interests.

Data sharing

The design of the Simulation of Alcohol Control Policies for Health Equity (SIMAH) project is published elsewhere;[14] the overview, design concepts, and details are provided in the appendix (pp 3–22). Several publicly available, secondary data sources were used, all of which are described and referenced in the appendix (p 10). Model parameters, including transition probabilities for modelling changes in education over time and beta distributions for grams per day within drinking categories, are shared via figshare (https://figshare.com/s/f21a5d3a01258d5007bb; appendix p 18). The model source code used in this publication will be made publicly available via GitHub (https://doi.org/10.5281/zenodo.15641639). Mock data for running the source code will be included in the software release.

Acknowledgments

This study was supported by the National Institute on Alcohol Abuse and Alcoholism of the National Institutes of Health (NIH) under Award Number R01AA028009. The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

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