BMJ Open

Differential impact of minimum unit pricing on alcohol consumption between Scottish men and women: controlled interrupted time series analysis

Jürgen Rehm,[1] Amy O'Donnell ,[2] Eileen F S Kaner,[2] Eva Jane LLopis,[3,4] Jakob Manthey ,[5] Peter Anderson [2]

To cite: Rehm J, O'Donnell A, Kaner EFS, *et al*. Differential impact of minimum unit pricing on alcohol consumption between Scottish men and women: controlled interrupted time series analysis. *BMJ Open* 2022;**12**:e054161. doi:10.1136/bmjopen-2021-054161

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-054161).

Received 07 June 2021
Accepted 25 March 2022

For numbered affiliations see end of article.

Correspondence to
Dr Peter Anderson;
peteranderson.mail@gmail.com

ABSTRACT

Objective To assess the immediate impact of the introduction of minimum unit pricing (MUP) in Scotland on alcohol consumption and whether the impact differed by sex, level of alcohol consumption, age, social grade and level of residential deprivation of respondents.

Design Primary controlled interrupted time series analysis and secondary before-and-after analysis of the impact of introducing MUP in Scotland using alcohol consumption data for England as control.

Setting Data from Kantar Worldpanel's Alcovision survey, a continuous retrospective online timeline follow-back diary survey of the previous week's alcohol consumption.

Participants 53 347 women and 53 143 men.

Interventions Introduction of a minimum price of 50 pence per UK unit (6.25 pence/g) for the sale of alcohol in Scotland on 1 May 2018.

Main outcome measures Number of grams of alcohol consumed per week, in total, in off-trade (eg, at home) and in on-trade (eg, in pubs, restaurants).

Results Primary interrupted time series analyses found that the introduction of MUP was associated with a drop in reported weekly total alcohol consumption of 5.94 g (95% CI 1.29 to 10.60), a drop in off-trade consumption of 3.27 g (95% CI −0.01 to 6.56) and a drop in on-trade consumption of 2.67 g (95% CI −1.48 to 6.82). Associated reductions were larger for women than for men and were greater among heavier drinkers than for lighter drinkers, except for the 5% of heaviest drinking men for whom an associated increase in consumption was found. Secondary before-and-after analyses found that reductions in consumption were greater among older respondents and those living in less deprived areas. The introduction of MUP was not associated with a reduction in consumption among younger men and men living in more deprived areas.

Conclusions Greater policy attention needs to be addressed to the heaviest drinking men, to younger men and to men who live in more deprived areas.

Strengths and limitations of this study

- ⇒ The study uses a large commercial dataset surveying the previous week's alcohol consumption of 106 490 adults in Scotland and England.
- ⇒ The study uses location-controlled interrupted time series analyses of the potential impact of the introduction of minimum unit pricing (MUP) in Scotland, with the alcohol consumption of residents of England (and, in sensitivity analysis, residents of Northern England) as control.
- ⇒ The study assesses how the potential impact of MUP might differ by sex, level of alcohol consumption, age, social grade and level of residential deprivation of respondents.
- ⇒ The sample of respondents is not a random sample but rather a quota sample and cannot claim full representativeness of all adult residents in Scotland and England.
- ⇒ The study only assesses the immediate rather than the long-term impact of the introduction of MUP.

INTRODUCTION

The use of alcohol is one of the major risk factors for burden of disease and mortality found in global and European comparative risk analyses.[1 2] Alcohol control policies are put in place to reduce this attributable harm. The WHO has identified the three so-called 'best buys' as the most effective, cost-effective and easy-to-implement policies: (1) policies to increase the price of alcohol via taxation increases or via floor pricing; (2) restrictions on availability of alcohol; and (3) bans on marketing of alcohol.[3] Despite the demonstrated effectiveness of the best buy policies,[4] other policies such as drink-driving or educational campaigns seem to be preferred by governments in Europe[5] and elsewhere. However, following the lead of Scotland and some Eastern European countries (including Armenia, Belarus and Russia), floor-pricing policies (ie, policies where alcoholic beverages cannot be sold under a threshold price)

are currently gaining support.[6 7] Therefore, an evaluation of current policies and their impact is crucial to inform governments in other countries that are planning to institute such policies.[8–10]

This paper aims to evaluate the impact of a specific floor-pricing policy, the introduction of a minimum unit price (MUP) for all alcohol products in Scotland below which they cannot legally be sold. The MUP was set to be 50 GB pence per unit (8 g) of pure alcohol (ethanol) sold (6.25 pence/g) beginning on 1 May 2018.[6] The rationale for introducing MUP as part of a larger national alcohol strategy in Scotland was to reduce hazardous and harmful alcohol consumption, targeting drinkers at the greatest risk of harm, those who tend to consume the cheapest alcohol, often purchased off-premise in supermarkets and shops where prices are comparatively lowest. Prior econometric modelling studies[11] suggested that a MUP is likely to produce greater reductions in alcohol-related inequalities than either taxation on a volumetric basis (based on product strength/ethanol content) or an ad valorem basis (proportionate to product value). Part of this effect relies on preventing producers and retailers from absorbing some of the tax increases by further reducing prices, especially at the lower price points.[12]

While the evaluations of the Scottish MUP thus far have been positive, showing a general decrease in alcohol purchases, use and heavy drinking,[8–10] many of the evaluations are based on alcohol sales or household expenditures which did not, or could not, differentiate by the sex of the drinker. However, such differentiation is necessary to determine if the underlying assumption of an appropriately targeted policy holds true, especially since a lot of the modelling before implementation was based on sex-unspecific price elasticities or general assumptions. Only very recently has sex-specific modelling of MUP been undertaken, which predicted larger reductions in men than in women.[13] For example, a 0.5 pence MUP was predicted to lead to a 5.3% reduction in consumption and a 4.1% reduction in hospital admissions for men, but to a 0.7% reduction in consumption and a 1.6% reduction in hospitalisations for women. The Kantar Worldpanel (KWP) Alcovision survey,[14] a continuous retrospective online timeline follow-back (TLFB) diary survey, allows us to specifically investigate the gender-based impact of MUP in Scotland using England as a control group. In addition to allowing us to disaggregate consumption by sociodemographic characteristics, a further strength of the Alcovision survey, which has been used in previous alcohol-policy related analyses,[15 16] is its large sample size—approximately 30 000 different respondents from Great Britain (England, Scotland and Wales) each year.

Based on current empirical evidence and modelling-based assumptions, we would expect the following:

1. The introduction of the MUP in Scotland would lead to a reduction in overall consumption.
2. The reduction in consumption would be more pronounced for heavy drinkers with scarce resources; in Scotland this would be men from lower socioeconomic strata who would be most affected by MUP.

METHODS

Study design

As a primary analysis we undertook location-controlled interrupted time series regression of the short-term associated impact of the introduction of MUP on the off- and on-trade alcohol consumption of Scottish men and women using consumption of English men and women as controls. We analysed immediate and level changes in consumption rather than changes in trends (slopes), in line with the findings of our previous analyses.[9 10] We undertook a sensitivity analysis, repeating the interrupted time series regression using men and women resident in Northern England as control, rather than all of England, noting that residents in Northern England are more likely than residents from all of England to have a similar drinking culture to residents in Scotland. As a secondary analysis we undertook before-and-after analyses to investigate in more detail the potential impact of MUP by individual age of respondent and by individual residential deprivation ranking of where the respondent lived.

Data sources

Our data source is the KWP Alcovision survey,[14] an ongoing cross-sectional online TLFB diary survey of the previous week's alcohol consumption, with an annual sample of approximately 30 000 individuals aged 18+ years in Great Britain. Participants provide detailed data on their drinking occasions during the previous 7 days, including details on brands and volumes drunk, and whether these are consumed off-trade (eg, at home) or on-trade (eg, in a bar, pub or restaurant) for each occasion. Participants complete the survey only once, without repeated surveys. Quota samples based on age, sex, social grade and geographical region are drawn from Kantar's managed access panel.[14] Invitations to participate are sent out on set dates and timed such that completion dates of the survey occur during every month, and each day of the year is represented in the data. Weights based on age-sex groups, social grade and geographical region are constructed using UK census data. Based on client requests, Kantar oversamples residents from Scotland and those aged 18–34 years from both England and Scotland (see online supplemental figures 1 and 2, page 1). In the dataset we analysed, drink diaries were completed by 106 490 respondents from England and Scotland during the 4 years from 2015 to 2018, with an average of 512 diaries per week (SD 173), a rate which remained stable over the 4-year period (F=0.544, p=0.462).

We received truncated postal code data, which we used to identify respondents as being residents of Scotland, England or Northern England (regions of North-West England, North-East England, and Yorkshire and Humber). We used the English[17] and the Scottish[18] Indices of Multiple Deprivation to group respondents into levels

of residential deprivation (for details see online supplemental pages 2–5 and online supplemental figures 3–7).

The number of drinks consumed were recorded separately for on- and off-trade, with information given on serving sizes in millilitres (mL). In the dataset analysed we had records of all drinks consumed during the 7-day time period but not specified by day of week. Drinks were categorised within 19 categories, which we collapsed, grouped and coded as beers, ciders, wines, spirits, fortified wines and ready-to-drink products. In the dataset we analysed detailed product description was provided for beers, including alcohol-free beers, but not for other beverages. For non-beer products, the alcohol by volume (ABV) averages of the categories obtained from household purchase data over the same 4 years (2015–2018) were used.[19] For beer products, the brand-specific ABVs from the household purchase data were used.[19] Volume was combined with ABV to calculate grams of alcohol (1 mL alcohol=0.79 g pure alcohol). We summed consumption into grams of alcohol by drink group per week for each individual survey respondent.

In addition to the five deprivation groups, we also grouped individuals into: (1) four age groups (18–24, 25–44, 45–64 and 65+ years) and (2) four occupation-based social grade groups (AB ('highest'), C1, C2, DE ('lowest')) based on the National Readership Survey.[20]

For the interrupted time series analyses we prepared weekly data by averaging consumption across all respondents for each of the 208 weeks in the study period, separately for men and women, and separately for total consumption, off-trade consumption and on-trade consumption. We plotted the seasonally adjusted total consumption over time (study week) by England and Scotland (online supplemental figure 8, page 6). We observed parallel trends between England and Scotland prior to the introduction of MUP, illustrating the appropriateness of England as a control area (tests for parallel trends, see online supplemental table 1, page 6).

To analyse the potential impact of MUP in reducing alcohol consumption by levels of consumption, we calculated, separately for men and women and for each country (Scotland and England) and for each week (from week 1 to week 208), the average consumption for separate percentiles of consumption ranging from 5% to 95% within 5% intervals.

Statistical analyses

Primary interrupted time series analyses

As primary analyses, interrupted time series regressions[21] were undertaken with the weekly consumption data averaged across all respondents, and separately for men and women, over the full 208 weeks, where week 1 is the first week of 2015 and week 208 is the last week of 2018. As with our previous analyses,[9 10] we created three new dependent variables of Scotland minus England (net effect) for each of the weeks for: (1) the average consumption of all grams of all alcohol per week, separately for men and women; (2) the average consumption of all grams of all alcohol per week consumed off-trade (eg, at home), separately for men and women; and (3) the average consumption of all grams of all alcohol per week consumed on-trade (eg, in pubs, bars or restaurants), separately for men and women.

For each of the three dependent variables, we examined the distribution visually and with Q–Q plots and found all variables, being the differences Scotland minus England (net effect) for the means of consumption by respondent for each of the 208 weeks, to be normally distributed (see online supplemental figure 9, page 7). We adjusted the dependent variables for any seasonality using the ratio-to-moving-average method.[22] Based on Durbin–Watson tests[23] (range 1.53–2.18), there was no evidence of autocorrelation, and based on augmented Dickey–Fuller tests,[24] the series were found to be stationary (see table 1). We examined the immediate and permanent level changes due to the event, the introduction of MUP in Scotland, at week 174. The event variable was entered as a dummy variable, coded with 0 for each week before the event and with 1 for each week from the event forwards. Thus, in our generalised linear regression models, which we ran separately for men and for women, the dependent variables were the difference in reported consumption of grams of alcohol between Scotland and England (net effect). The independent variables were the dummy variable event and time (each week from 1 to 208). Interrupted time series regression equation 1 and SPSS syntax is presented in online supplemental box 1, page 8.

To test if MUP had an associated differential impact by sex of respondent we re-ran interrupted time series regression equation 1 for the total sample (both men and women), adding sex of respondent and the interaction term sex*introduction of MUP to the model (see online supplemental box 1, page 8).

We repeated interrupted time series regression equation 1 separately for each of the four age groups, four social grade groups and five deprivation groups (thus, comparing the same groups in England and Scotland). For these analyses, we transformed the continuous variables into their z-scores and used the z-scores as the dependent variables, so that the results could be compared between groups in terms of SD rather than original units. This allowed us to compare the relative importance of the regression coefficients, and thus changes, across the sociodemographic characteristics of the respondents.

For the analyses by the separate consumption percentiles, for each separate percentile we also created a difference in consumption by subtracting the mean consumption, Scotland minus England. We repeated interrupted time series regression equation 1 separately for each of the 19 percentiles (from 5% to 95%) and plotted the coefficient and 95% CIs associated with the event (introduction of MUP) by the percentile, separately for men and women.

Table 1 Unstandardised coefficients from interrupted time series analyses (95% CI) for all respondents and for men and women separately by total consumption, off-trade consumption and on-trade consumption with Durbin–Watson statistic (value should be near 2.0) and augmented Dickey–Fuller test (p value should be <0.05) of models added

		All respondents	Men	Women
Total consumption	Durbin–Watson statistic	1.94	2.18	1.86
	Augmented Dickey–Fuller test: t; t-critical; p value	−19.59; −3.43; <0.01	−7.10; −3.43; <0.01	−8.38; −3.43; <0.01
	Intercept	−5.134 (−8.049 to −2.219)	−10.388 (−14.735 to −6.042)	0.120 (−3.466 to 3.706)
	Level change associated with MUP	−5.944 (−10.603 to −1.285)	−3.303 (−10.250 to 3.644)	−8.585 (−14.317 to −2.854)
	Time in weeks	0.00 (−0.026 to 0.032)	0.020 (−0.023 to 0.063)	−0.014 (−0.050 to 0.022)
Off-trade consumption	Durbin–Watson statistic	1.65	2.22	1.53
	Augmented Dickey–Fuller test: t; t-critical; p value	−6,82; −3.43; <0.01	−11.87; −3.43; <0.01	−3.83; −3.43; <0.02
	Intercept	−5.410 (−7.467 to −3.353)	−10.523 (−13.483 to −7.563)	−0.297 (−2.492 to 1.899)
	Level change associated with MUP	−3.274 (−6.561 to 0.014)	−1.317 (−6.047 to 3.414)	−5.231 (−8.740 to −1.721
	Time in weeks	0.004 (−0.017 to 0.024)	0.009 (−0.020 to 0.039)	−0.002 (−0.023 to 0.020)
On-trade consumption	Durbin–Watson statistic	1.92	1.93	1.94
	Augmented Dickey–Fuller test: t; t-critical; p value	−12.70; −3.43; <0.01	−11.53; −3.43;<0.01	−3.55; −3.43;<0.05
	Intercept	0.276 (−2.319 to 2.872)	0.135 (−2.422 to 2.692)	0417 (−4.058 to 4.892)
	Level change associated with MUP	−2.671 (−6.819 to 1.478)	−1.986 (−6.074 to 2.101)	−3.355 (−10.507 to 3.797)
	Time in weeks	−0.001 (−0.027 to 0.025)	0.011 (−0.015 to 0.036)	−0.012 (−0.057 to 0.032)

The level change is the estimated net reduction in consumption of grams of alcohol per week (Scotland minus England) associated with the introduction of MUP.
MUP, minimum unit pricing.

Sensitivity analysis

We repeated interrupted time series regression equation 1 using men and women resident in Northern England as control for Scotland, rather than residents from all of England.

Secondary before-and-after analyses

The secondary before-and-after analyses were done with individual respondent 7-day consumption data summed across each week separately for men and women to better understand variation in the associated impact of MUP by age and deprivation, for each individual age and each individual deprivation score rather than by the four age groups and the five deprivation groups used in the interrupted time series analyses. For these analyses, we did not compute a new dependent variable (Scotland minus England) but rather used the original data by country. We examined the distribution of the dependent variables and found them to be highly dispersed (see online supplemental figures 10 and 11, page 11). We excluded all respondents with zero consumption during the previous week and then took the natural log of the consumption data, resulting in a normal distribution of the natural logged data (see online supplemental figures 12 and 13, page 12). In our models the independent variables were: the event variable (introduction of MUP), coded as a dummy variable as above for the interrupted time series analysis; country as a factor (England or Scotland); age as a dummy coded variable for each individual age year; deprivation as a dummy coded variable for each deprivation score rounded to an integer; and time (weeks) as a covariate. For each of the dependent variables we ran two separate models, one for age and one for deprivation score. Before-and-after analysis regression equation 2 and the SPSS syntax are presented in Supplement Box 2, pages 8–9.

From the results of the regression model and for each individual age and for each individual deprivation score, we took the difference in the marginal means (and the 95% CI of the differences) [Scotland*MUP*age / or/ deprivation score] minus [England*MUP*age / or/ deprivation score], this difference representing the added associated impact of MUP in Scotland over and above that in England for each individual age and for each individual deprivation score. We plotted the differences

of the marginal means as above (with their 95% CIs) by each age and each integer deprivation ranking respectively, for men and women separately. We extracted the mean values of the changes (y-axes) from the plots and performed a linear regression of these values respectively by age and deprivation score, separately for men and women, to test how the differences in the marginal means between Scotland and England (net effect) differed by age and deprivation score. The before-and-after analysis regression equation 3 and SPSS syntax are presented in Supplement Box 3, page 9. We tested the difference in slopes between men and women for total consumption by repeating regression equation 3 for the total sample (both men and women), adding the interaction term sex*age/or/deprivation score as an additional independent variable to the model. Finally, given the relationship between age and deprivation score (Supplement Figure 9, page 5), we also tested if any relationship between changes in alcohol consumption associated with MUP and age of the respondent differed by deprivation group. We tested this by adding an interaction term age*deprivation group to the regression model (see Supplement Box 4, page 10).

Sensitivity analysis

We repeated before-and-after analysis regression equation 2 using a root-normal model, taking the square root instead of the log to normalise the consumption data. We tested if any relationship between changes in alcohol consumption associated with MUP and age and deprivation score of the respondent differed by the method of normalising the data. We tested this by adding an interaction term 'type of normalisation (natural log or square root)'*age/or/deprivation score to the regression model (see online supplemental box 5, page 10).

Power calculations are reported in the online supplemental, page 13.

Analyses were performed with SPSS v26 (IBM Corp, 2019).[25] For our regression models we used generalised linear models, procedure GENLIN.

Patient and public involvement

The research was done without public involvement. The public was not consulted to develop the research questions, nor was it involved in identifying the study design or outcomes. We did not invite the public to participate in the interpretation of results, nor in the writing or editing of this paper. There are no plans to directly involve the public in the dissemination of the research findings.

RESULTS

Overall, 106 490 respondents (53 347 women and 53 143 men) contributed to the dataset (for details of numbers of respondents by country before and after the introduction of MUP and by sociodemographic characteristics, see Supplement Table 2, page 14). Although there were small differences prior to MUP between Scotland and England (proportion of female respondents and age and mean deprivation score of male respondents), these differences remained the same following MUP, except for the mean age of women (see Supplement Tables 3–5, pages 15–17). Whereas Scottish women in the sample were on average a little younger than English women before MUP, they were on average a little older than English women after MUP (Supplement Table 4, page 16).

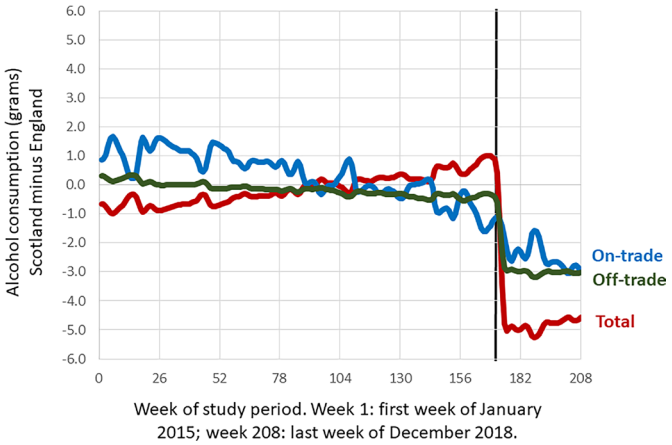

Figure 1 Plots of average weekly alcohol consumption Scotland minus England (net effect) for all respondents by week of study period for total alcohol consumption, off-trade consumption (eg, at home) and on-trade consumption (eg, in pubs, bars and restaurants) with T4253H smoothing.[58] Black vertical line shows introduction of minimum unit pricing. Data used for primary interrupted time series analyses.

For all respondents (English and Scottish), the mean reported consumption per week was 125.8 g for men (66.4% consumed off-trade) and 71.3 g for women (71.3% consumed off-trade; for details see Supplement Table 6, page 18). Consumption decreased with age similarly for both sexes, by 5.1 g per every 10 years of increasing age (95% CI 4.4 to 5.7) (see Supplement Figure 14, page 19). Consumption decreased by only a small amount with decreasing deprivation, similarly for both sexes, by 1.1 g per every 10 points (within a scale 1–100) of decreasing deprivation (95% CI 0.8 to 1.4) (see Supplement Figure 15, page 19).

Interrupted time series analyses: main findings

Figure 1 plots the differences in consumption of alcohol (g) Scotland minus England (net effect) for each of the 208 weeks, 2015–2018. Table 1 shows the results of the associated impact of MUP on alcohol consumption changes for all respondents and for men and women separately. For all respondents and for total consumption, the introduction of MUP was associated with a net drop in consumption (Scotland minus England) of 5.9 g per week (95% CI 1.3 to 10.6) (a 6.2% drop from the mean pre-MUP level in Scotland, 95% CI 2.3% to 8.4%). The reductions in consumption are largely driven by women (a reduction of 8.6 g per week, 95% CI 2.9 to 14.3) rather than by men (a reduction of 3.3 g per week, 95% CI –3.6 to 10.4). Supplement Table 7, page 20 gives the results of the models with the interaction terms (sex of

Table 2 Sensitivity analysis using Northern England as a control for Scotland

		All respondents	Men	Women
Total consumption	Intercept	−7.910 (−9.991 to −5.828)	−10.937 (−13.723 to −8.152)	−4.882 (−7.875 to −1.890)
	Level change associated with MUP	−5.886 (−9.212 to −2.559)	−4.285 (−8.737 to 0.167)	−7.487 (−12.269 to −2.704)
	Time in weeks	0.009 (−0.012 to 0.030)	0.022 (−0.005 to 0.050)	−0.005 (−0.0035 to 0.025)
Off-trade consumption	Intercept	−10.475 (−12.000 to −8.950)	−13.783 (−15.651 to −11.915)	−7.168 (−9.262 to −5.073)
	Level change associated with MUP	−3.028 (−5.466 to −0.591)	0.658 (−2.328 to 3.643)	−6.715 (−10.062 to −3.367)
	Time in weeks	0.022 (0.007 to 0.037)	0.025 (0.006 to 0.043)	0.019 (0-.002 to 0.040)
On-trade consumption	Intercept	2.565 (−0.034 to 5.165)	2.846 (−0.667 to 6.358)	2.285 (−1.512 to 6.082)
	Level change associated with MUP	−2.857 (−7.012 to 1.297)	−4.943 (−10.557 to 0.672)	−0.772 (−6.841 to 5.297)
	Time in weeks	−0.013 (−0.039 to 0.013)	−0.002 (−0.037 to 0.033)	−0.024 (−0.062 to 0.014)

Unstandardised coefficients from interrupted time series analyses (95% CIs) for all respondents and separately for men and women by total consumption, off-trade consumption and on-trade consumption. The level change is the estimated net reduction in consumption of grams of alcohol per week (Scotland minus Northern England) associated with the introduction of MUP.
MUP, minimum unit pricing.

respondent*event, the introduction of MUP). Based on the coefficient of the interaction term, women showed a greater reduction in consumption associated with MUP than men of 8.8 g per week (95% CI 1.9 to 15.7).

Interrupted time series analyses: sensitivity analyses

Table 2 shows the results of the sensitivity analyses using respondents from Northern England as control. For all respondents and for total consumption, the introduction of MUP was associated with a net drop in consumption of 5.9 g per week (95% CI 2.6 to 9.2) (Scotland minus England), a very similar finding to that when using all of England as a control (table 1). Based on the model with the interaction terms (sex of respondent*event, the introduction of MUP), women showed a greater reduction in consumption associated with MUP than men of 6.0 g per week (95% CI 1.0 to 11.0), a slightly lower level to that when using all of England as a control (see Supplement Table 8, page 20).

Associated changes in consumption following the introduction of MUP by characteristics of respondents

Figure 2 plots the associated changes in the difference in alcohol consumption (Scotland minus England) following the introduction of MUP by drinking percentile distribution of total alcohol consumption (for mean consumption by percentile see Supplement Figure 16, page 21, and for numerical data of figure 2 see Supplement Table 9, page 22, in which a footnote adds the average number of respondents per percentile). Up to the 45th percentile there was no associated reduction in alcohol consumption. From the 45th to the 85th percentile there were reductions in alcohol consumption associated with MUP, with the magnitudes of reduction greater for women than for men (regression coefficient (RC) 2.8 g per 5 percentile, 95% CI 2.0 to 3.6). For the 95th percentile the introduction of MUP was associated with an increase in consumption for men of 13.8 g (95% CI 5.8 to 21.5), but not for women (4.8 g, 95% CI −4.0 to 13.7).

Figure 3 shows the associated changes in the difference in consumption following the introduction of MUP by age group (top graph), social grade (middle graph) and deprivation group (bottom graph), plotting standardised coefficients, allowing for relative rather than absolute comparisons across the groups (for numerical data, see Supplement Tables 10–12, pages 23–25).

By age group (figure 3, top graph), there was a pattern of greater associated drops in all consumption and in off-trade consumption for both men and women with increasing age. For younger men there was an increase in off-trade consumption, which was offset by decreases in on-trade consumption in the same group. There appeared to be no clear or consistent discernible pattern by social

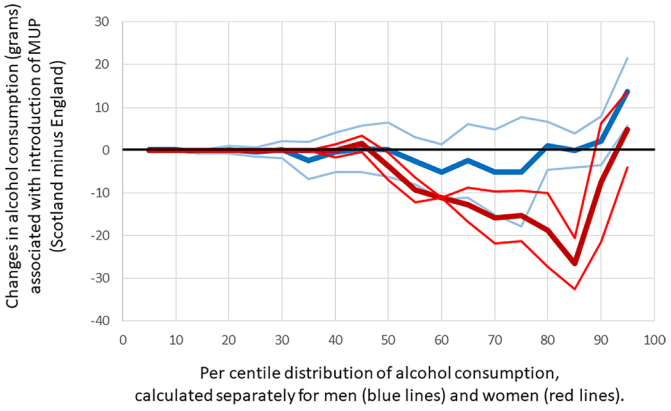

Figure 2 Associated changes in the difference in consumption (Scotland minus England, net effect) following the introduction of minimum unit pricing (MUP) by drinking percentile distribution of total consumption. Blue lines: men; red lines: women. Thicker lines: means; thinner lines: 95% CIs. Horizontal black line set at zero (ie, no change). Results from primary interrupted time series analysis.

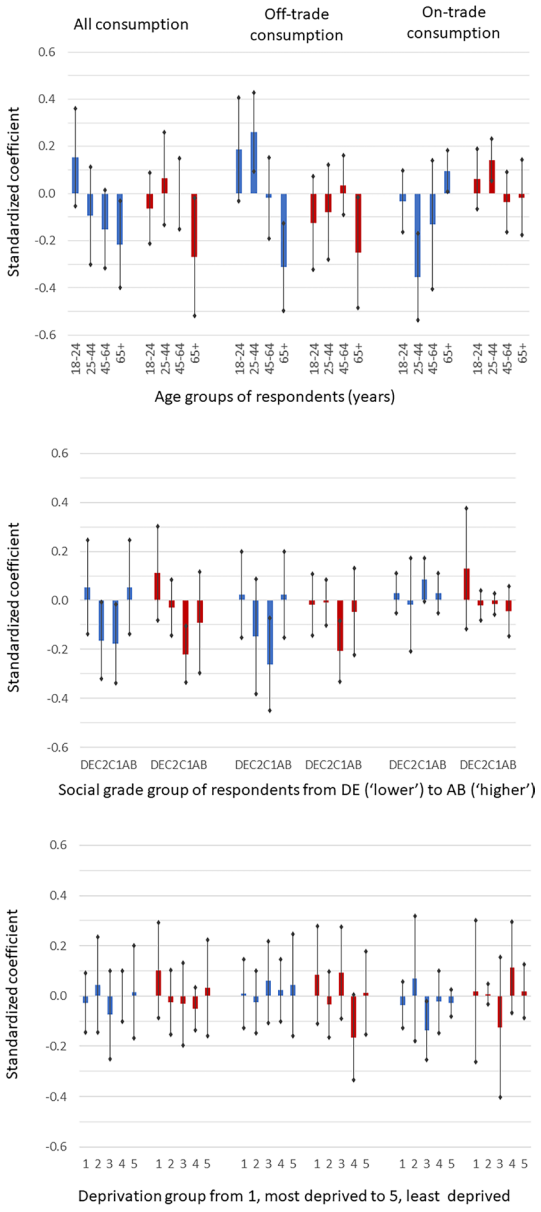

Figure 3 Associated changes in consumption following introduction of minimum unit pricing (MUP) for all consumption, off-trade consumption and on-trade consumption (Scotland minus England, net effect) by age group (top graph), social grade group (middle graph) and deprivation group (bottom graph) for men (blue) and women (red). Consumption changes are standardised coefficients (units of SD) from primary interrupted time series analyses with 95% CIs.

grade (figure 3, middle graph) or by deprivation group (figure 3, bottom graph). The secondary before-and-after analyses provide more detail of the associated impact of MUP by individual age and deprivation ranking.

Secondary before-and-after analyses

Figure 4 plots the associated changes in alcohol consumption (in grams of alcohol) following introduction of MUP for all consumption, off-trade consumption and on-trade consumption by gender and individual age. For men, reductions in consumption following the introduction of MUP became greater with increasing age for both total

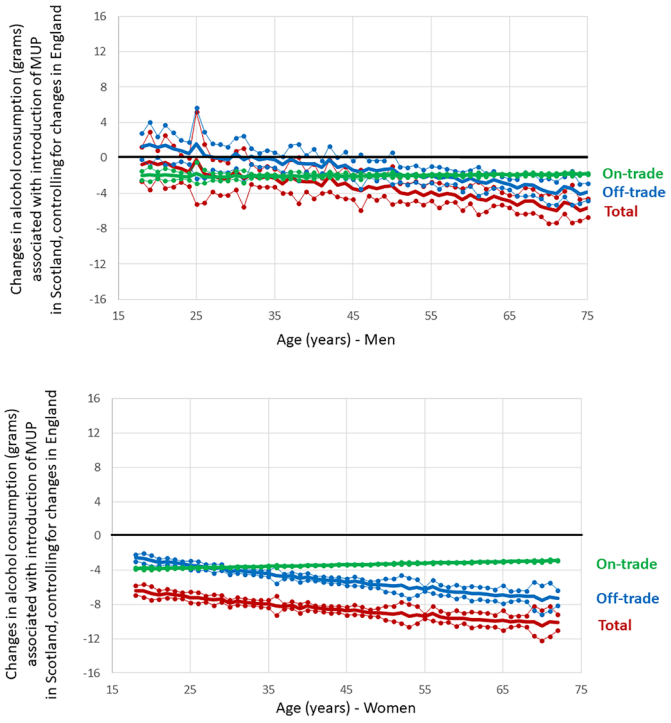

Figure 4 Plots of the changes in alcohol consumption (g/week, with 95% CIs) associated with the introduction of minimum unit pricing (MUP) in Scotland, controlling for changes in England for each age year. Plots of men and women for total consumption, off-trade consumption and on-trade consumption. Thicker lines: means; thinner lines: 95% CIs. Horizontal black line set at zero (ie, no change). The changes are derived from the secondary before-and-after analysis regression equation 2. They represent, for each age, the difference in the marginal means (and 95% CIs of the differences) for [Scotland*event (introduction of MUP) *age (dummy coded variable for each age)] minus [England*event (introduction of MUP) *age (dummy coded variable for each age)].

consumption (linear RC across age −0.088, 95% CI −0.094 to −0.083) and off-trade consumption (RC −0.092, 95% CI −0.097 to −0.088). For on-trade consumption, reductions in consumption became very slightly smaller with increasing age (RC 0.0038, 95% CI 0.0026 to 0.0050). For younger men (those aged <30 years), the introduction of MUP was not associated with a decrease in consumption, more so the younger the age, as upper 95% CIs were greater than zero. For women a similar pattern emerged, with reductions in consumption across all ages. Reductions in both total (RC −0.070, 95% CI −0.072 to −0.067) and off-trade consumption became slightly greater with increasing age (RC −0.087, 95% CI −0.090 to −0.085), whereas reductions in on-trade consumption became very slightly smaller with increasing age (RC 0.0179, 95% CI 0.0176 to 0.0182). The coefficient for the interaction term, sex*age (with women as reference category) was −0.019 (95% CI −0.025 to −0.013), indicating that the reduction in consumption was slightly greater with increasing age for men than for women.

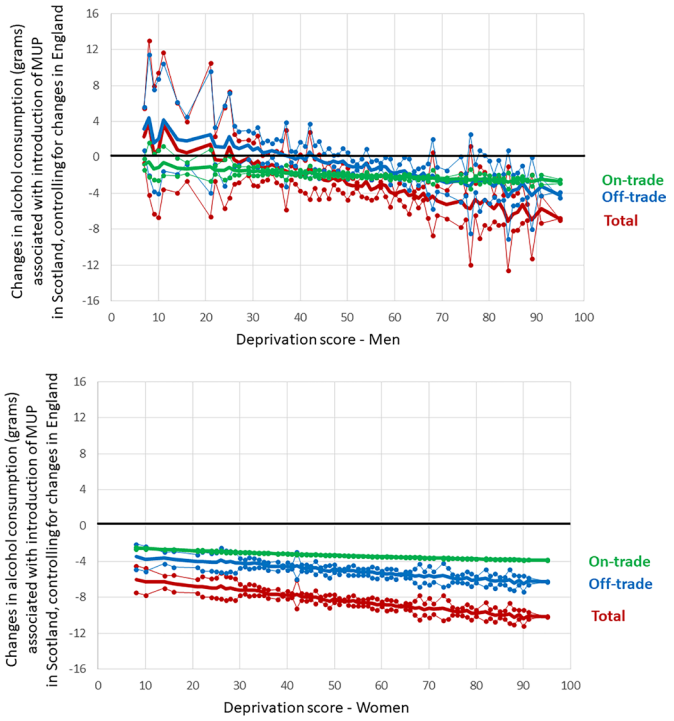

Figure 5 Plots of the changes in alcohol consumption (g/week, with 95% CIs) associated with the introduction of minimum unit pricing (MUP) in Scotland, controlling for changes in England for each deprivation score (on a 100% scale). Plots of men and women for total consumption, off-trade consumption and on-trade consumption. Thicker lines: means; thinner lines: 95% CIs. Horizontal black line set at zero (ie, no change). The changes are derived from the secondary before-and-after analysis regression equation 2. They represent for each deprivation score (the higher the deprivation score, the less deprived) the difference in the marginal means (and 95% CIs of the differences) for [Scotland*event (introduction of MUP) *deprivation score (dummy coded variable for each deprivation score)] minus [England*event (introduction of MUP) *deprivation score (dummy coded variable for each deprivation score)].

Figure 5 plots the associated changes in alcohol consumption (in grams of alcohol) following the introduction of MUP for all consumption, off-trade consumption and on-trade consumption by gender and individual deprivation ranking. For men, reductions in consumption following the introduction of MUP became greater with less deprivation, more so for total consumption (RC −0.102, 95% CI −0.108 to −0.097) and off-trade consumption (RC −0.082, 95% CI −0.087 to −0.078) than for on-trade consumption (RC −0.020, 95% CI −0.022 to −0.019), with an indication that those living in the most deprived areas (bottom two-fifths) showed no decrease in consumption, more so the greater the deprivation (as upper 95% CIs were greater than zero). For women, a similar pattern emerged, with reductions in consumption across all deprivation scores. Reductions in consumption following the introduction of MUP became larger with less deprivation for total consumption (RC −0.050, 95% CI −0.051 to −0.049), off-trade consumption (RC −0.035, 95% CI −0.036 to −0.034) and on-trade consumption (RC −0.0151, 95% CI −0.01550.107 to −0.0147). The coefficient for the interaction term sex*deprivation score (with women as reference category) was −0.053 (95% CI −0.059 to −0.046), indicating that the reduction in consumption was slightly greater with less deprivation for men than for women.

The age-related patterns in figure 4 were independent of deprivation. Before-and-after analysis regression equation 4 found no interaction between age in years and deprivation group in the changes in total alcohol consumption (Scotland minus England, net effect) associated with the introduction of MUP: for men, the coefficient for the interaction was -2.2^{-5} (95% CI -5.5^{-3} to 5.4^{-3}) and, for women, the coefficient was 1.6^{-3} (95% CI -1.1^{-3} to 4.2^{-3}). In other words, the slopes between changes in alcohol consumption by age for men and women plotted in figure 4 were almost identical across the five deprivation groups.

Before-and-after analyses: sensitivity analyses

We repeated the before-and-after analyses using the square root (as opposed to logged) grams of alcohol consumption as the dependent variable, with similar patterns of findings to Figures 4 and 5 (see Supplement Figures 17 and 18, pages 26–27). There were, however, differences in the slopes. For total consumption, before-and-after analysis regression equation 5 found, with age, that the slope for logged grams of alcohol was slightly steeper for men (RC of interaction term 'type of normalization*age' −0.017, 95% CI −0.025 to −0.008), but slightly less steep for women (RC of the interaction term 0.082, (95% CI 0.078 to 0.087) than the slope for the square root of consumption. There were similar findings in the differences in slopes for dependence score, the slope for logged grams of alcohol being slightly steeper for men (RC of interaction term 'type of normalization*dependence score' −0.059, 95% CI −0.068 to −0.050) and slightly less steep for women (RC of the interaction term 0.040, 95% CI 0.038 to 0.043).

DISCUSSION

We found that the introduction of MUP in Scotland was associated with a change in overall reported alcohol consumption in line with the predicted direction. Compared with respondents from England, Scottish respondents reported a 6.2% drop in alcohol consumption (95% CI 2.3% to 8.4%) associated with MUP. Sensitivity analyses using respondents from Northern England, with more similar drinking levels to Scotland than England as a whole,[26] found an almost identical associated drop in alcohol consumption. The drop in consumption was larger for heavier drinkers than for lighter drinkers, with the exception of the top 5% of heaviest drinking men for whom there was an increase in consumption associated with the introduction of MUP.

Against expectations, we found that associated drops in consumption were greater for women than for men, both in the main (using all of England as a control) and in the sensitivity (using Northern England as a control) analyses. Men and women also responded differently by age. Based on both the interrupted time series analysis and the before-and-after analysis, the size of the associated drop in consumption for men became smaller with decreasing age, with younger men showing no associated decrease in consumption. For women, the associated drop in consumption also became smaller with decreasing age, although less so than for men.

We included two potential measures of socioeconomic disadvantage: social grade and an index of residential deprivation based on multiple measures of income, employment, education, health, crime, access to housing and environmental quality,[17 18] noting that the risk of alcohol-related harm increases both the more socioeconomically disadvantaged the individual is, and over and above that, the more socially disadvantaged the residential area in which the individual resides.[27] It should be noted that estimates of the indices of residential deprivation differ between Scotland and England and thus, in absolute terms, they may not be the same. However, in our analyses we compare relative deprivation; for example, comparing the bottom fifth of deprivation of Scotland with the bottom fifth of deprivation of England, noting that relative deprivation itself is a key determinant of ill health.[28] Based on the interrupted time series analyses, for both men and women there was no discernible pattern by social grade or deprivation group. However, based on the secondary before-and-after analyses (both main and sensitivity), the size of the associated drop in consumption for men became smaller with increasing deprivation, with men living in the most deprived areas having no associated decrease in consumption. For women, the associated drop in consumption also decreased slightly with decreasing deprivation score, although less so than for men.

The drop in consumption of 6.2% is a little lower than the 7.6% drop we found in our previous analysis of household purchase data in both the short[9] and medium term.[10] As with the present study based on survey data, our previous analyses of household purchase data also found that drops in consumption were greater among households with higher rather than lower usual purchases of alcohol.[9 10] However, with our previous analyses of household purchase data, we could not test the impact of MUP on purchases by age or gender as the purchase data were for the household as a whole and not attributable to individual household family members. Nor did those analyses report the impact of MUP by the social grade of the household or the level of deprivation in which the household was located. The findings presented in this paper thus provide a more nuanced understanding of the differential impact of MUP on different population subgroups. Specifically, what we identified in the present analysis is the top 5% of heavy drinking men did not reduce their consumption in association with MUP; rather, our results suggest an increase in associated consumption among this group. For women, there was an upturn in changes in alcohol consumption in the heaviest drinking percentiles (figure 2); that the lower 95% CI for women did not cross zero could be due to the relatively small numbers of respondents in each of the 19 consumption percentiles (Supplement Table 9, page 22).

We do not know why, for both younger men (those aged <32 years) and for those living in residential areas in the bottom two-fifths of deprivation, there was no decrease in consumption associated with MUP compared with older men and those living in less deprived areas. It has been suggested that some very heavy drinkers (as we found for the top 5% of heavy drinking men) would be less prone to the potential impact of MUP,[29] and in potential need of additional support to cope with the impact of MUP.[30] Responses to MUP might vary by individual and psychosocial factors including socioeconomic disadvantage, which may interact with the situational availability of alcohol.[31] This is clearly an area for further study.

Before we discuss the implications of the results, it is important to mention potential strengths and limitations of our study. We based our analysis on a large sample of 53 347 women and 53 143 men from England and Scotland which— apart from the oversampling of 18–34 year-olds—was, in general, representative of the sex and age structure of the population (Supplement Figures 1 and 2, page 1). The sample was neither more nor less deprived than the population of England or Scotland as a whole (Supplement Figure 3, page 3). A strength of the interrupted time series analyses is the large number of data points (weekly consumption) before (n=173) and from the introduction of MUP onwards (n=25), considered more than sufficient for interrupted time series analyses.[22] A second strength overall and for the before-and-after analyses is the large sample size (88 894 respondents prior to the introduction of MUP and 17 596 respondents thereafter). A third strength is the use of a location control, both all of England and Northern England in the sensitivity analysis. Location controls allow for other extraneous factors beyond the intervention to be controlled for, such as an unusual heat wave during the months of June, July and August that affected all Great Britain.[32]

For limitations, first, all results are based on subjective reports of drinking. While such subjective reports tend to underestimate consumption as measured by sales or other recorded data in general in all European countries,[33] there is no reason to believe that under-reporting should differ by country or region or before or after the introduction of the MUP. The timeline follow-back survey method has been criticised for the limited time period of drinking it covers, thus missing heavy episodic drinking occasions among participants with a low frequency of such occasions. This limitation for classifying individuals is actually a strength when it comes to the characterisation of population averages; however, the shorter the time period, the smaller the biases due to memory and

the more accurate the population average.[34] Second, as with all survey-based research on alcohol, this research cannot claim full representativeness.[35] Statistical theory stipulates such representativeness needs to be based on probabilistic sampling design (ie, all residents from England and Scotland need to be assigned a probability >0) combined with high response rates unaffected by systematic non-response.[36] However, these conditions can no longer be reached in modern surveys involving alcohol, no matter which methodology is used.[35 37–39] Instead, post-stratification based on sex, age, social grade and geographical region was used to allow for generalisations to be made for the general population. The quota sample was derived from Kantar's managed access panel. Data were not available and not attainable on the number of respondents approached to achieve the 30 000 respondents surveyed each year, and this information is not mentioned in existing publications based on the Alcovision survey, for example.[15 16] Unlike the household purchase data which record purchases wherever they are made and thus account for cross-border purchases, we are unable to account for any cross-border purchasing or drinking the respondents might have engaged in. If this was significant (and a study on licensing compliance would suggest that it is not[40]), one might hypothesise that the estimated sizes of the associated impact with MUP in reducing alcohol consumption would differ between using Northern England or all of England as a control, which was not the case. Finally, as we only had data to the end of 2018, we have been unable to examine the impact of MUP beyond the immediate term.

In our analysis we used both interrupted time series analysis and before-and-after analyses. With the interrupted time series analysis, we used England (or Northern England) as a location control, creating new dependent variables, the differences between Scotland and England. Interrupted time series analysis is an appropriate methodology for investigating the impact of a newly introduced natural experiment (the introduction of MUP) that takes into account seasonal variation and autocorrelation of the data over time.[22] The before-and-after analysis is simply comparing the means before and after the introduction of MUP. Results of before-and-after analyses are often presented along with interrupted time series analyses, as we have done previously with household purchase data.[9] While we add in an interaction term of country*event (introduction of MUP), which should take into account common events outside of MUP that occurred in both Scotland and England, our analyses are unable to control for seasonal variation when comparing the longer time period before the introduction of MUP and the 8-month period following the introduction of MUP.

Externally validated indicators[35 39] using sales[41 42] or household purchasing data as the basis[9 10] corroborate our results that, in comparison with England over the same and longer time periods, the introduction of the MUP was associated with a decrease in alcohol consumption. Finally, the reductions in alcohol consumption in Scotland were part of an overall national strategy or framework for alcohol policy, where all measures had already been extensively covered in the press. It cannot be excluded that the actual reductions may have been due in part to the media reports surrounding the introduction of the MUP rather than to the floor pricing itself (for an example of an alcohol policy measure where the media impact seems to be stronger, see Møller[43]). However, it is highly unlikely that media reports would produce exactly this abrupt and permanent pattern—that is, a drop in consumption starting exactly at the date of introduction of MUP and lasting for the time period studied, in comparison to a control group.

Despite these potential limitations, most research corroborates the results of our study that the MUP resulted in a reduction of overall alcohol consumption compared with England or Northern England.[9 10 41 42] Overall, research was based on a number of designs including purchasing data from households or sales records. Our results here were based on a control group design, where the intervention was only introduced in one group, thus strengthening our confidence in a real effect.[44]

When the Minister for Public Health, Sport and Wellbeing introduced the 2018 alcohol policy framework,[6] he emphasised that the implementation of the MUP was strongly motivated by an interest in decreasing health inequalities through a reduction in alcohol consumption among the heaviest and most vulnerable drinkers. Our results indicate that this goal may not be fully realised: first, we found that women, who are less heavy drinkers in our data and in almost all surveys worldwide to date,[45] reduced their consumption more than men; second, the 5% of heaviest drinking men had an increase in consumption associated with MUP; and, third, younger men and men living in more deprived areas had no decrease in consumption associated with MUP. These results are surprising as modelling studies would have suggested otherwise.[11 14]

We can only speculate about the reasons for the increase in the 5% of the heaviest drinking men. Several studies have found that overall, heavier drinkers—including people with alcohol use disorders—react less to price than the general population (ie, they react more price inelastic and their consumption is determined by other factors[46 47]). However, while this may explain lower reductions, it cannot explain an increase in consumption. Such a polarisation with increasing consumption of the heaviest drinkers in overall decreasing consumption levels has now been observed in several studies, often in adolescents and young adults.[48 49] These studies indicate that such polarisation means a deviation from the standard collective theory of all subgroups changing in the same direction,[50] but fall short on good explanations as to why this is the case.

The results may also imply a diminished impact on alcohol-attributable hospitalisations and mortality, which have been shown to be strongly associated with heavy drinking in men and in those of lower socioeconomic

status.[51–54] Indeed, a large controlled study on emergency department visits following the introduction of MUP did not show any reduction in alcohol-related emergency department visits.[55]

Before any further conclusions can be drawn, we need to corroborate our sex-, age-, heavy drinking- and socioeconomic status-related findings in different studies. This seems important as different conclusions about the impact of MUP may result for other countries. If indeed the findings of our study are corroborated, then additional and/or different pricing mechanisms may need to be considered to reduce alcohol-attributable hospitalisations and mortality. For instance, several harms from alcohol use are specifically linked to on-trade drinking, such as public disorder and violence.[56] Recent experiences in Lithuania have shown substantial reductions in all-cause mortality following a taxation increase, which mainly affected men.[57]

Author affiliations
[1]Social and Epidemiological Research, CAMH, Toronto, Ontario, Canada
[2]Population Health Sciences Institute, Newcastle University, Newcastle upon Tyne, UK
[3]Department of Health Promotion, Maastricht University, Maastricht, Limburg, The Netherlands
[4]ESADE Business School, Ramon Llull University, Barcelona, Spain
[5]Institute of Clinical Psychology and Psychotherapy, Technische Universität Dresden, Dresden, Sachsen, Germany

Twitter Jakob Manthey @JakobManthey

Acknowledgements We thank Kantar Worldpanel for providing the raw data and reviewing the method description as it describes the data collection. Kantar Worldpanel provided the raw data at no cost to Newcastle University under a direct contract. Through its own contracted work as a market research company, Kantar Worldpanel received reimbursement from AB InBev to cover the costs of the data. Kantar Worldpanel has similar commercial relationships with other customers who pay to have data collected on food and non-food items available for sale in supermarkets and other retail outlets covered by the WorldPanel. Kantar Worldpanel and no other entity had any role in the study design, data analysis, data interpretation or writing of the manuscript. Professor Kaner, supported by a National Institute for Health Research (NIHR) Senior Investigator award, is Director of the NIHR Applied Research Collaboration, North East and North Cumbria. Dr O'Donnell is a National Institute for Health Research (NIHR) Advanced Fellow. The views expressed in this article are those of the authors and not necessarily those of NIHR or the Department for Health and Social Care.

Contributors JR conceptualised the paper and prepared the initial draft of the introduction and discussion. PA undertook the analyses and prepared the draft of the methods and results and submitted the paper. PA, AO'D, EJ-L, JR, JM and EK refined the various versions of the full paper and approved the final manuscript for submission. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. All authors had access to the data used for analyses, and PA, AO'D and EJ-L verified the raw data sets received from Kantar WorldPanel and are the guarantors for the data used for the analyses.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare no support from any organisation for the submitted work within the previous five years. PA declares receipt of funds from AB InBev Foundation to provide evidence-based public health comment on the proposed content and evaluation of the Foundation's global drinking goals, outside of the submitted work. The remaining authors declare no financial relationships with any organisations in the previous five years that might have an interest in the submitted work. All authors declare no other relationships or activities that could appear to have influenced the submitted work.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Ethical approval was not required as our analyses are based on a publicly available commercial dataset.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Kantar WorldPanel data cannot be shared due to licensing restrictions.

ORCID iDs
Amy O'Donnell http://orcid.org/0000-0003-4071-9434
Jakob Manthey http://orcid.org/0000-0003-1231-3760
Peter Anderson http://orcid.org/0000-0003-4605-9828

REFERENCES

1 GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020;396:1223–49.
2 Rehm J, Imtiaz S. A narrative review of alcohol consumption as a risk factor for global burden of disease. *Subst Abuse Treat Prev Policy* 2016;11:37.
3 World Health Organization. 'Best buys' and other recommended interventions for the prevention and control of noncommunicable diseases, 2017. Available: http://www.who.int/ncds/management/best-buys/en/ [Accessed 21 Jun 2018].
4 Chisholm D, Moro D, Bertram M, *et al*. Are the "best buys" for alcohol control still valid? An update on the comparative cost-effectiveness of alcohol control strategies at the global level. *J Stud Alcohol Drugs* 2018;79:514–22.
5 World Health Organization Regional Office for Europe. *Making the WHO European region safer: developments in alcohol control policies, 2010-2019*. Geneva: WHO, 2021. file:///C:/Users/richa/Downloads/Alcohol%20SAFER%20EN%2016.pdf
6 Scottish Government. Alcohol framework 2018: updated framework setting out our national prevention aims on alcohol, 2018. Available: https://www.gov.scot/publications/alcohol-framework-2018-preventing-harm-next-steps-changing-relationship-alcohol/ [Accessed 21 Mar 2021].
7 Neufeld M, Bobrova A, Davletov K, *et al*. Alcohol control policies in former Soviet Union countries: a narrative review of three decades of policy changes and their apparent effects. *Drug Alcohol Rev* 2021;40:350–67.
8 Public Health Scotland. Overview of evaluation of MUP, 2021. Available: https://www.gov.scot/publications/alcohol-framework-2018-preventing-harm-next-steps-changing-relationship-alcohol/ [Accessed 21 Feb 2021].
9 O'Donnell A, Anderson P, Jané-Llopis E, *et al*. Immediate impact of minimum unit pricing on alcohol purchases in Scotland: controlled interrupted time series analysis for 2015-18. *BMJ* 2019;366:l5274.
10 Anderson P, O'Donnell A, Kaner E, *et al*. Impact of minimum unit pricing on alcohol purchases in Scotland and Wales: controlled interrupted time series analyses. *Lancet Public Health* 2021;6:e557–65.
11 Meier PS, Holmes J, Angus C, *et al*. Estimated effects of different alcohol taxation and price policies on health inequalities: a mathematical modelling study. *PLoS Med* 2016;13:e1001963.

12 Ally AK, Meng Y, Chakraborty R, *et al*. Alcohol tax pass-through across the product and price range: do retailers treat cheap alcohol differently? *Addiction* 2014;109:1994–2002.
13 Meier PS, Holmes J, Brennan A, *et al*. Alcohol policy and gender: a modelling study estimating gender-specific effects of alcohol pricing policies. *Addiction* 2021;116:2372–84.
14 KANTAR. Panels and audiences, 2021. Available: https://www.kantar.com/expertise/research-services/panels-and-audiences [Accessed 22 Mar 2021].
15 Stevely AK, Holmes J, Meier PS. Combinations of drinking occasion characteristics associated with units of alcohol consumed among British adults: an event-level decision tree modeling study. *Alcohol Clin Exp Res* 2021;45:630–7.
16 Stevely AK, de Vocht F, Neves RB, *et al*. Evaluating the effects of the Licensing Act 2003 on the characteristics of drinking occasions in England and Wales: a theory of change-guided evaluation of a natural experiment. *Addiction* 2021;116:2348–59.
17 GOV.UK. National statistics: English indices of deprivation 2019, 2019. Available: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019 [Accessed 22 Mar 2021].
18 Gov.scot. Scottish index of multiple deprivation (SIMD) 2020 technical notes, 2020. Available: https://www.gov.scot/publications/simd-2020-technical-notes/ [Accessed 21 Mar 2021].
19 Anderson P, Jané Llopis E, O'Donnell A, *et al*. Impact of low and no alcohol beers on purchases of alcohol: interrupted time series analysis of British household shopping data, 2015-2018. *BMJ Open* 2020;10:e036371.
20 National Readership Survey. Social grade London: national readership survey, 2019. Available: http://www.nrs.co.uk/ nrs-print/lifestyle-and-classification-data/social-grade/ [Accessed 10 Jul 2019].
21 Beard E, Marsden J, Brown J, *et al*. Understanding and using time series analyses in addiction research. *Addiction* 2019;114:1866–84.
22 Makridakis S, Wheelwright SC, McGee VE. *Forecasting: methods and applications*. New York: John Wiley and Sons, 1983.
23 Durbin J, Watson GS. Testing for serial correlation in least squares regression. II. *Biometrika* 1951;38:159–78.
24 Fuller WA. *Introduction to statistical time series*. New York: John Wiley and Sons, 1976.
25 IBM Corp. *IBM SPSS Statistics for Windows, version 26.0*. Armonk, NY: IBM Corp, 2019.
26 Beard E, Brown J, West R. Is the emergence of a healthier central England replacing the traditional north-south divide? Analysis of national survey data on smoking and high-risk drinking. *BMJ Open* 2017;7:e014210.
27 Anderson P, Baumberg B. Alcohol in Europe, a public health perspective, 2006. Available: https://ec.europa.eu/health/archive/ph_determinants/life_style/alcohol/documents/alcohol_europe_en.pdf
28 Wilkinson RG, Pickett KE. The problems of relative deprivation: why some societies do better than others. *Soc Sci Med* 2007;65:1965–78.
29 Gill J, Black H, Rush R, *et al*. Heavy drinkers and the potential impact of minimum unit pricing: no single or simple effect? *Alcohol Alcohol* 2017;52:722–9.
30 Public Health Scotland. Interim report on the impact of minimum unit pricing (MUP) among people who are alcohol dependent and accessing treatment services – briefing paper, 2021. Available: https://www.publichealthscotland.scot/media/8201/the-impact-of-mup-among-people-who-are-alcohol-dependent-and-accessing-treatment-services-briefing.pdf
31 Kwasnicka D, Boroujerdi M, O'Gorman A, *et al*. An n-of-1 study of daily alcohol consumption following minimum unit pricing implementation in Scotland. *Addiction* 2021;116:1725–33.
32 British Isles heat wave, 2018. Available: https://en.wikipedia.org/wiki/2018_British_Isles_heat_wave
33 Kilian C, Manthey J, Probst C, *et al*. Why is per capita consumption underestimated in alcohol surveys? Results from 39 surveys in 23 European countries. *Alcohol Alcohol* 2020;55:554–63.
34 Stockwell T, Zhao J, Chikritzhs T, *et al*. What did you drink yesterday? Public health relevance of a recent recall method used in the 2004 Australian National Drug Strategy Household Survey. *Addiction* 2008;103:919–28.
35 Rehm J, Kilian C, Rovira P, *et al*. The elusiveness of representativeness in general population surveys for alcohol. *Drug Alcohol Rev* 2021;40:161–5.
36 Kruskal W, Mosteller F. *Representative sampling, III: The current statistical literature*. International Statistical Review/Revue Internationale de Statistique, 1979: 245–65.
37 Stedman RC, Connelly NA, Heberlein TA, *et al*. The end of the (research) world as we know it? Understanding and coping with declining response rates to mail surveys. *Soc Nat Resour* 2019;32:1139–54.
38 Habermann H, Kennedy C, Lahiri P. A conversation with Robert Groves. *Statist Sci* 2017;32:128–37.
39 Rehm J, Kilian C, Manthey J. Future of surveys in the alcohol field. *Drug Alcohol Rev* 2021;40:176–8.
40 Dickie E, Mellor R, Myers F, *et al*. *Minimum unit pricing (MUP) evaluation: compliance (licensing) study*. Edinburgh: NHS Health Scotland, 2019. http://www.healthscotland.scot/media/2660/minimum-unit-pricing-for-alcohol-evaluation-compliance-study-english-july2019.pdf
41 Giles L, Richardson E, Beeston C. *Using alcohol retail sales data to estimate population alcohol consumption in Scotland: an update of previously published estimates*. Edinburgh: Public Health Scotland, 2021. https://publichealthscotland.scot/media/2994/using-alcohol-retail-sales-data-to-estimate-population-alcohol-consumption-in-scotland-an-update-of-previously-published-estimates.pdf
42 Robinson M, Mackay D, Giles L, *et al*. Evaluating the impact of minimum unit pricing (MUP) on off-trade alcohol sales in Scotland: an interrupted time-series study. *Addiction* 2021;116:2697–707.
43 Møller L. Legal restrictions resulted in a reduction of alcohol consumption among young people in Denmark. In: Room R, ed. *The effects of Nordic alcohol policies: what happens to drinking when alcohol controls change?* Helsinki: Nordic Council for Alcohol and Drug Research, 2002: 93–9.
44 Shadish WR, Cook TD, Campbell DT. *Experimental and quasi-experimental designs for generalized causal inference*. New York: Houghton Mifflin Company, 2002.
45 Manthey J, Shield KD, Rylett M, *et al*. Global alcohol exposure between 1990 and 2017 and forecasts until 2030: a modelling study. *Lancet* 2019;393:2493–502.
46 Wagenaar AC, Salois MJ, Komro KA. Effects of beverage alcohol price and tax levels on drinking: a meta-analysis of 1003 estimates from 112 studies. *Addiction* 2009;104:179–90.
47 Nelson JP. Does heavy drinking by adults respond to higher alcohol prices and taxes? A survey and assessment. *Econ Anal Policy* 2013;43:265–91.
48 Loy JK, Seitz N-N, Bye EK, *et al*. Trends in alcohol consumption among adolescents in Europe: do changes occur in concert? *Drug Alcohol Depend* 2021;228:109020.
49 Holmes J, Ally AK, Meier PS, *et al*. The collectivity of British alcohol consumption trends across different temporal processes: a quantile age-period-cohort analysis. *Addiction* 2019;114:1970–80.
50 Skog OJ. The collectivity of drinking cultures: a theory of the distribution of alcohol consumption. *Br J Addict* 1985;80:83–99.
51 Probst C, Kilian C, Sanchez S, *et al*. The role of alcohol use and drinking patterns in socioeconomic inequalities in mortality: a systematic review. *Lancet Public Health* 2020;5:e324–32.
52 Probst C, Roerecke M, Behrendt S, *et al*. Socioeconomic differences in alcohol-attributable mortality compared with all-cause mortality: a systematic review and meta-analysis. *Int J Epidemiol* 2014;43:1314–27.
53 Probst C, Roerecke M, Behrendt S, *et al*. Gender differences in socioeconomic inequality of alcohol-attributable mortality: a systematic review and meta-analysis. *Drug Alcohol Rev* 2015;34:267–77.
54 Jones L, Bates G, McCoy E, *et al*. Relationship between alcohol-attributable disease and socioeconomic status, and the role of alcohol consumption in this relationship: a systematic review and meta-analysis. *BMC Public Health* 2015;15:1–14.
55 So V, Millard AD, Katikireddi SV, *et al*. Intended and unintended consequences of the implementation of minimum unit pricing of alcohol in Scotland: a natural experiment. *Public Health Res* 2021;9:1–210.
56 Room R, Babor T, Rehm J. Alcohol and public health. *The Lancet* 2005;365:519–30.
57 Štelemėkas M, Manthey J, Badaras R, *et al*. Alcohol control policy measures and all-cause mortality in Lithuania: an interrupted time-series analysis. *Addiction* 2021;116:2673–84.
58 Velleman PF. Robust nonlinear data smoothers: definitions and recommendations. *Proc Natl Acad Sci U S A* 1977;74:434–6.

SUPPLEMENT

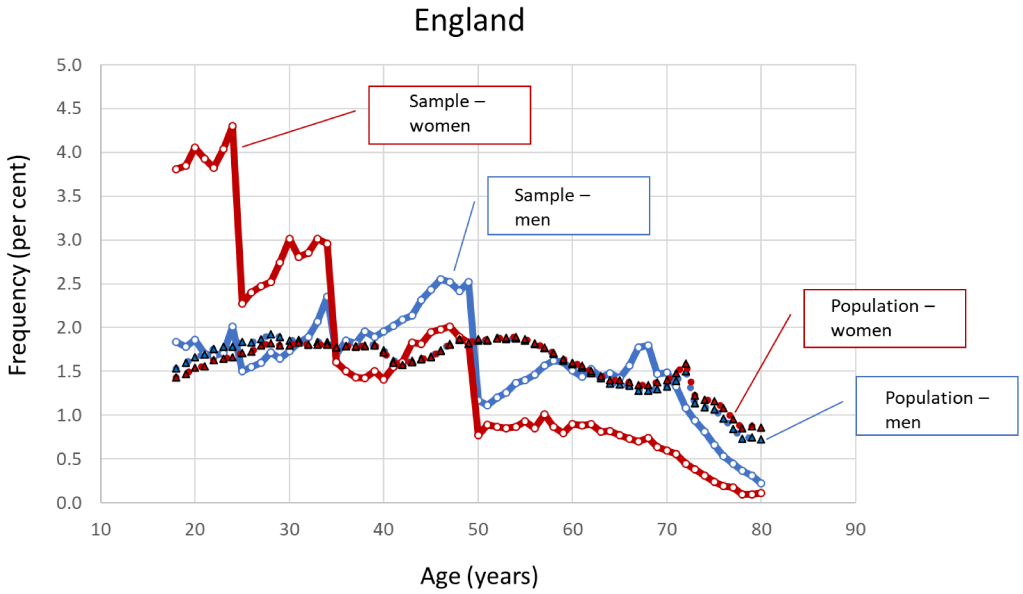

Figure 1 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for range 18-80 years), England. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and Northern Ireland, for 2018: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland.

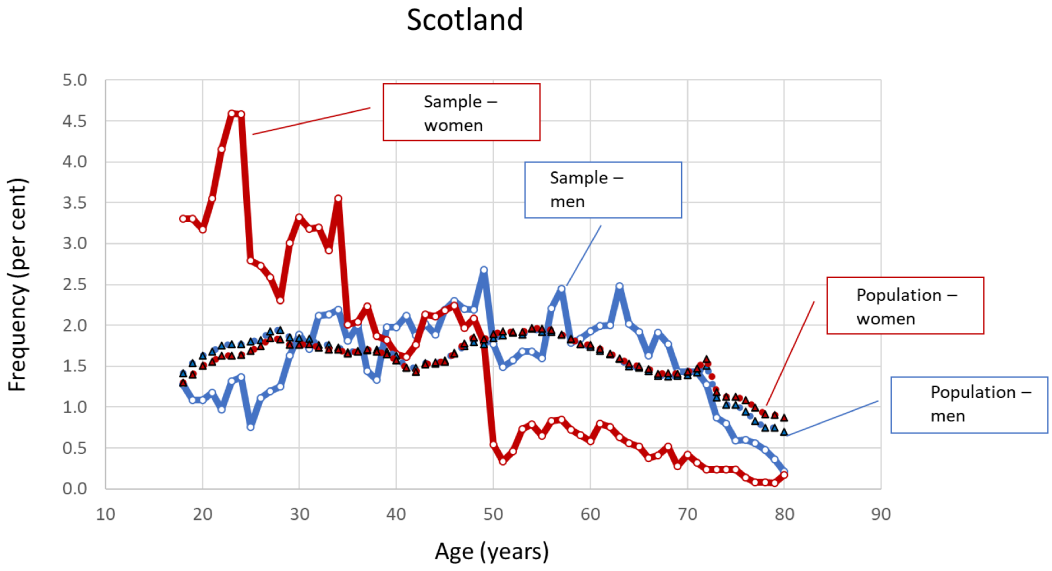

Figure 2 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for age range 18-80 years), Scotland. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and Northern Ireland, for 2018: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland.

Calculation of indices of deprivation, England and Scotland

The indices are calculated differently for England and Scotland. In England, the index is estimated at Lower-Layer Super Output Areas, data areas which are a standard statistical geography designed to be of a similar population size, with an average of approximately 1,500 residents or 650 households. In Scotland, 6,976 'data zones', small areas with roughly equal populations, are used. Each local data zone is then ranked according to its deprivation index within all data zones from lowest (most deprived) to highest (least deprived). Data for each data zone can be matched to a full postal code (e.g., OX3 8DT). However, to preserve anonymity, the data set we analysed included truncated postal codes (e.g., OX3), which cover a larger geographical area. Thus, for each truncated postal code, we averaged the full postal code using matched data zone rankings, which, for Scotland, ranged from 472 to 6,493, and for England, ranged from 243 to 31,354; in each jurisdiction the lower the number, the most deprived. The distributions of the rankings of our sample and of the total population were similar for both England and Scotland (see Supplement Figure 3, page 3 below). We rescaled the rankings based on the adjustment of the highest number (i.e., least deprived) in each of England and Scotland to 100. To assess the difference between the original deprivation index at data zone level and the aggregated deprivation index at the truncated postal code level, we checked the dispersion of the aggregated and re-scaled data (see Supplement, Figures 4 and 5, page 4 below). The absolute average difference between the original ranking at data zone level, and the average at the truncated postal code level showed a curvilinear relationship, increasing from the most deprived levels to the mid-range and then decreasing to the least deprived level. In relative terms, the dispersion decreased with decreasing deprivation, overall averaging 0.25 for Scotland and 0.33 for England (being higher in England, as the original score ranges were larger). In Scotland, for example, this means that, on average, the ranking at the truncated postal code level included data zone level rankings that could be, on average, 25% higher or 25% lower. The re-scaled rankings at truncated postal code level were grouped into five deprivation groups (1-20, 21-40, 41-60, 61-80, 81-100) from the most deprived (1) to the least deprived (5). Respondents in the social grade groups AB (relatively 'higher') were more likely to be in deprivation group 5 (least deprived), and those in social grade groups DE ('lower') were more likely to be in deprivation group 1 (most deprived), (see Supplement Figure 6, page 5 below). There was a J-shaped relationship between mean deprivation ranking score and age, with, after the age of 30 years, less deprivation with increasing age (see Supplement, Figure 7, page 5 below).

Rehm J, *et al. BMJ Open* 2022; 12:e054161. doi: 10.1136/bmjopen-2021-054161

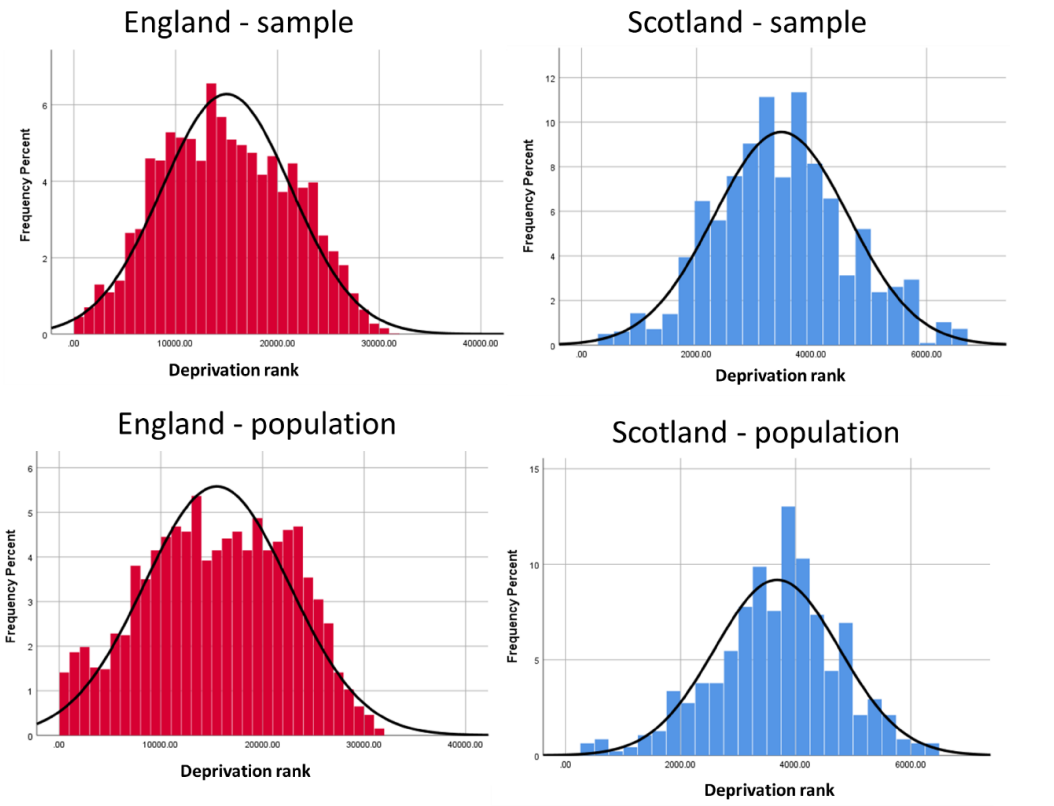

Figure 3 Per cent distribution (vertical axes) for analyzed sample and total population by deprivation rank (horizontal axes), England and Scotland. Data for total population from GOV.UK. National Statistics: English indices of deprivation 2019. https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019; Gov.scot. Scottish Index of Multiple Deprivation (SIMD) 2020 technical notes. 2020. Available from: https://www.gov.scot/publications/simd-2020-technical-notes/.

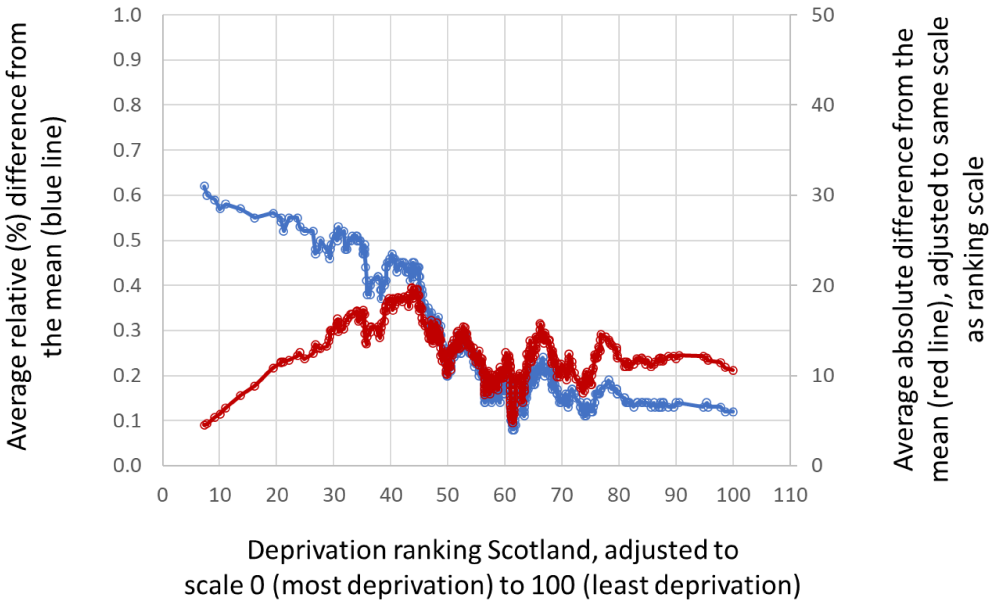

Figure 4 Dispersion of aggregated deprivation ranking, Scotland. The horizontal axis is the ranking from 0 (most deprived) to 100 (least deprived). The red line (right vertical axis) is the average absolute difference of the original ranking at local data zone level from the mean calculated at the truncated postcode level, adjusted to the same scale as the horizontal axis. Thus, for example, at a deprivation ranking of 30 on the horizontal axis, the average absolute difference is 15, a relative difference of 0.5. The blue line (left vertical axis) plots these relative differences (essentially, the right vertical axis divided by the horizontal axis).

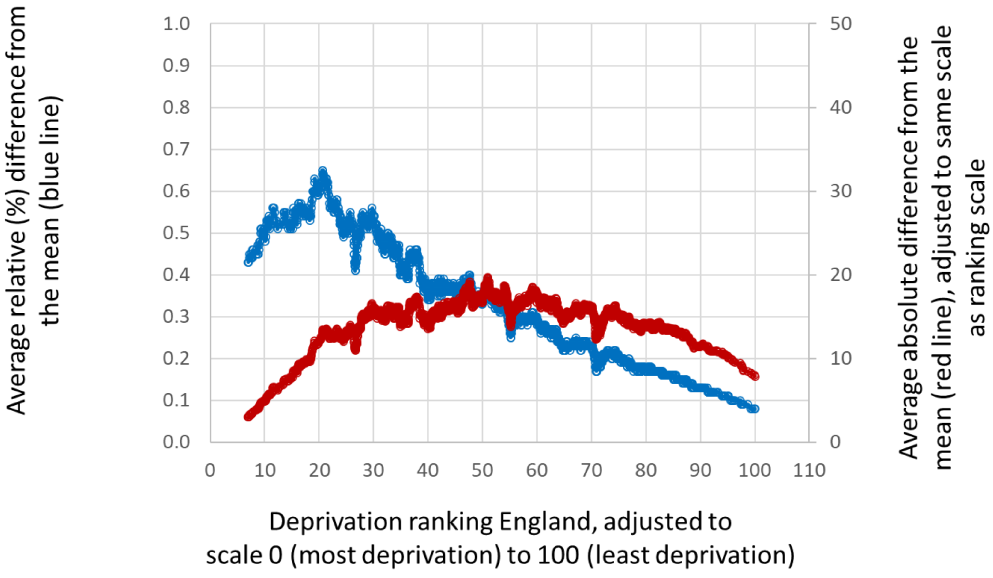

Figure 5 Dispersion of aggregated deprivation ranking, England. For explanation, see legend to Figure 4.

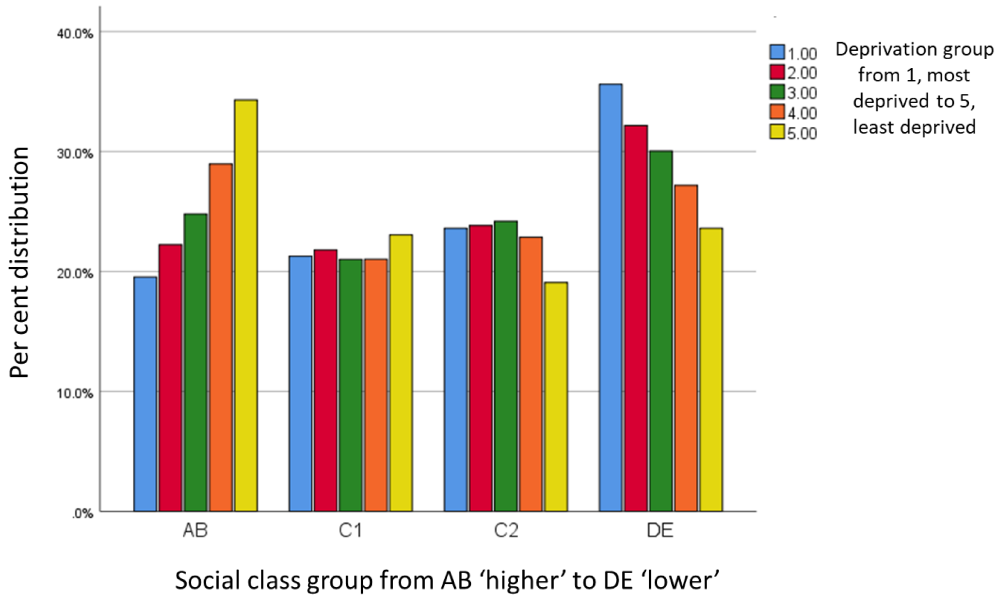

Figure 6 Distribution of deprivation group (from 1, most deprived to 5, least deprived) within social class groupings from AB, relatively higher to DE, relatively lower. Social class groups based on National Readership Survey; 2019. http://www.nrs.co.uk/ nrs-print/lifestyle-and-classification-data/social-grade/.

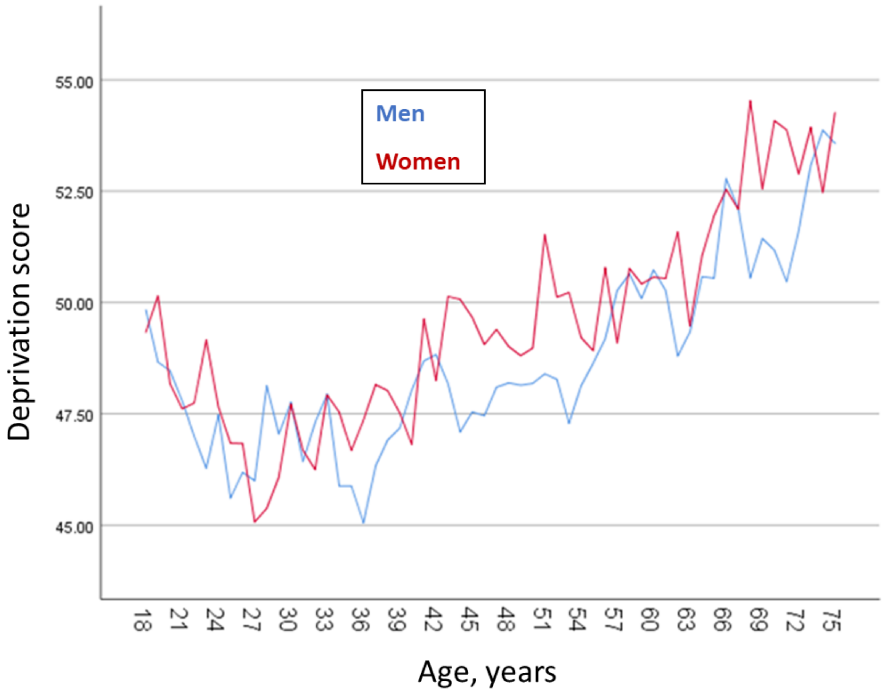

Figure 7 Plot of mean deprivation score (higher the score, the least deprived) by age and gender.

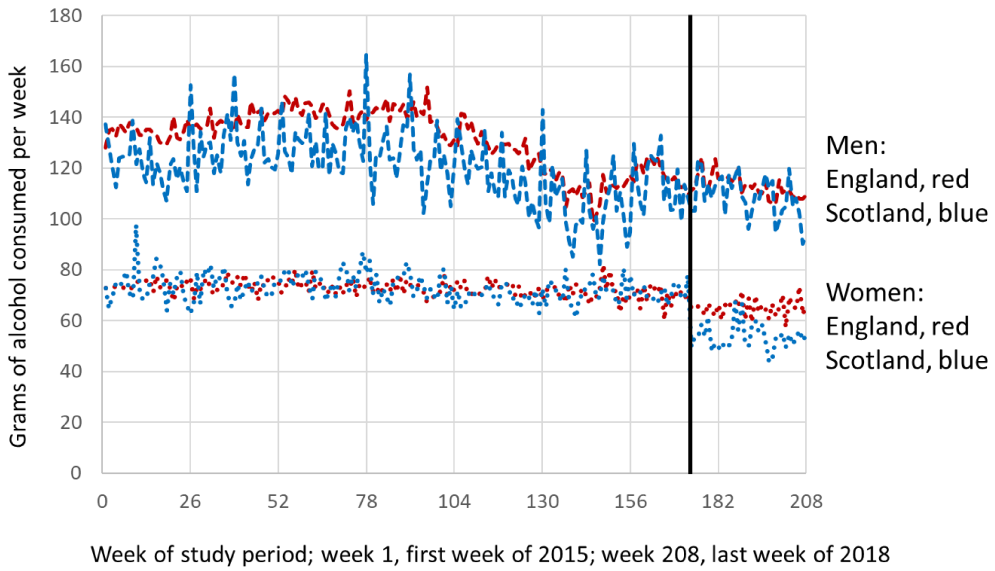

Figure 8 Plots of adjusted dependent variables (grams of alcohol consumed per week), seasonally adjusted using the ratio-to-moving-average method, over time (study week) by England and Scotland for men and women. Vertical black line: introduction of MUP.

Table 1 shows the results testing for parallel lines between Scotland and England prior to the introduction of MUP, separately for men and women; the coefficient for the interaction term, country*time indicates that the plots are parallel.

Table 1 Results of separate regression analyses for men and women (coefficients and 95% CI; and p values) for the time period prior to the introduction of MUP. Dependent variable: grams of alcohol consumed per week. Independent variables: country (Scotland or England); time (weeks of study period); and interaction, country* time)

	Men		Women	
	B (95% CI)	P value	B (95% CI)	P value
(Intercept)	131.411 (128.334 to 134.488)	.000	75.622 (74.314 to 76.929)	.000
Scotland	-13.948 (-18.300 to -9.597)	.000	0.601 (-1.249 to 2.450)	.524
England (reference category)	0[a]	.	0[a]	.
Time (Weeks)	-0.129 (-0.160 to -0.099)	.000	-0.034 (-0.047 to -0.021)	.000
Scotland * Time	0.033 (-0.010 to 0.076)	.135	-0.007 (-0.026 to 0.011)	.429
England * Time (reference category)	0[a]	.	0[a]	.

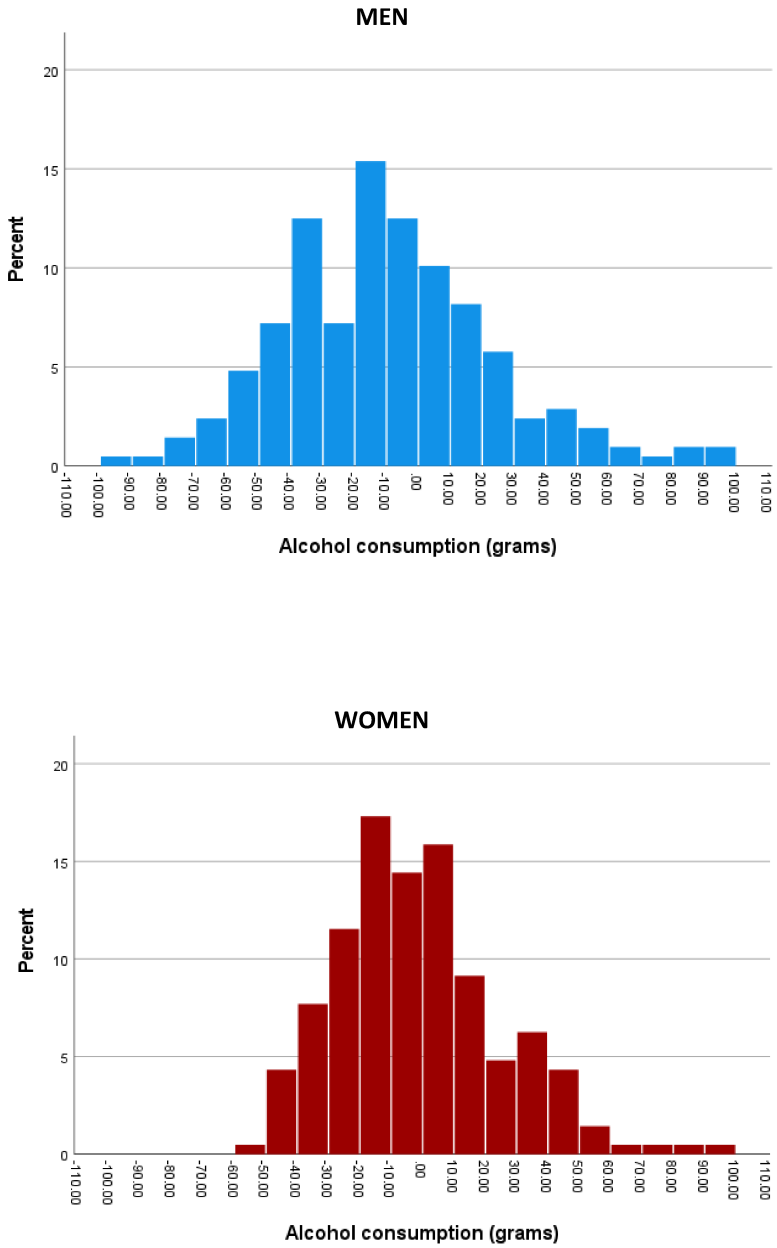

Figure 9 Plots of distributions of differences in total alcohol consumption (grams), Scotland minus England for men (top) and women (bottom).

Box 1

Primary Interrupted Time Series Analysis Regression Equation 1 to test overall impact of MUP

Difference in consumption (Scotland minus England, net effect) = intercept + time + event + error where time is weeks 1 through week 208, and the event is the dummy-coded variable for the introduction of MUP.

SPSS SYNTAX:

```
GENLIN grams (difference, Scotland minus England) WITH event week
  /MODEL event week INTERCEPT=YES
 DISTRIBUTION=NORMAL LINK=IDENTITY
  /CRITERIA SCALE=MLE COVB=MODEL PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012
ANALYSISTYPE=3(WALD)
    CILEVEL=95 CITYPE=WALD LIKELIHOOD=FULL
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```

Run separately for:

Total consumption, off-trade consumption, and on-trade consumption for total sample
Total consumption, off-trade consumption, and on-trade consumption for men
Total consumption, off-trade consumption, and on-trade consumption for women
Total consumption, off-trade consumption and on-trade consumption by each age group, social grade group, and deprivation group, separately for men and women
Total consumption by each consumption percentile, separately for men and women

SPSS SYNTAX to test for differential impact of MUP between men and women:

```
GENLIN grams (difference, Scotland minus England) by sex WITH event week
  /MODEL event sex event*sex week INTERCEPT=YES
 DISTRIBUTION=NORMAL LINK=IDENTITY
  /CRITERIA SCALE=MLE COVB=MODEL PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012
ANALYSISTYPE=3(WALD)
    CILEVEL=95 CITYPE=WALD LIKELIHOOD=FULL
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```

Box 2

Secondary Before and After Analyses Regression Equation 2 to explore in more detail impact of MUP by age and deprivation score

Natural log (consumption) = intercept + event + country + age/or/deprivation score as dummy-coded variables for each individual age and for each individual deprivation score + event*country + event*age/or/deprivation score + country* age/or/deprivation score + event*country*age/or/deprivation score + time + error,

Where:

time is weeks from 1 to 208;

event is the dummy coded variable for the introduction of MUP;

country is England or Scotland; and,

Age is the dummy coded variables for each individual age; deprivation score is the dummy coded variable for each individual deprivation score (rounded to an integer), ranging from 0 to 100.

SPSS SYNTAX

```
GENLIN grams BY country age/or/deprivationscore WITH event week
  /MODEL country event age/or/deprivationscore country*event country*age/or/deprivationscore
event*age/or/deprivationscore  country*event*age/or/deprivationscore week
INTERCEPT=YES  DISTRIBUTION=NEGBIN (1) LINK=LOG
  /CRITERIA METHOD=FISHER(1) SCALE=1 COVB=MODEL MAXITERATIONS=100 MAXSTEPHALVING=5
    PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012 ANALYSISTYPE=3(WALD) CILEVEL=95
CITYPE=WALD
    LIKELIHOOD=FULL
  /EMMEANS TABLES= country*event*age/or/deprivationscore SCALE=ORIGINAL
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```

Box 3

Before and After Analysis Regression Equation 4 to test direction and size of slopes

Differences in consumption, Scotland minus England (as derived from data of y-axes of Figures 4 and 5) = intercept + age/or/deprivation score (data from x-axes of Figures 4 and 5) + error.

SPSS SYNTAX

```
GENLIN 'differences in consumption, Scotland minus England (as derived from data of y-axes of
Figures 4 and 5)' WITH age/or/deprivationscore
  /MODEL age/or/deprivationscore/ INTERCEPT=YES
 DISTRIBUTION=NORMAL LINK=IDENTITY
  /CRITERIA METHOD=FISHER(1) SCALE=1 COVB=MODEL MAXITERATIONS=100 MAXSTEPHALVING=5
    PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012 ANALYSISTYPE=3(WALD) CILEVEL=95
CITYPE=WALD
    LIKELIHOOD=FULL
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```

SPSS SYNTAX to test if slopes differ between men and women

```
GENLIN 'differences in consumption, Scotland minus England (as derived from data of y-axes of
Figures 4 and 5)' by sex WITH age/or/deprivationscore
  /MODEL sex  age/or/deprivationscore sex*age/or/deprivation score/ INTERCEPT=YES
 DISTRIBUTION=NORMAL LINK=IDENTITY
  /CRITERIA METHOD=FISHER(1) SCALE=1 COVB=MODEL MAXITERATIONS=100 MAXSTEPHALVING=5
    PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012 ANALYSISTYPE=3(WALD) CILEVEL=95
CITYPE=WALD
    LIKELIHOOD=FULL
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```

Box 4

Before and After Analysis Regression Equation 4 to test if slopes by age differ by deprivation group
Differences in consumption, Scotland minus England (as derived from data of y-axes of Figures 4 and 5) = intercept + age + deprivationgroup + error.

SPSS SYNTAX

```
GENLIN 'differences in consumption, Scotland minus England (as derived from data of y-axes of
Figures 4 and 5)' WITH age deprivationgroup
 /MODEL age deprivationgroup age*deprivationgroup/ INTERCEPT=YES
DISTRIBUTION=NORMAL LINK=IDENTITY
 /CRITERIA METHOD=FISHER(1) SCALE=1 COVB=MODEL MAXITERATIONS=100 MAXSTEPHALVING=5
   PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012 ANALYSISTYPE=3(WALD) CILEVEL=95
CITYPE=WALD
   LIKELIHOOD=FULL
 /MISSING CLASSMISSING=EXCLUDE
 /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```

Box 5

Before and After Analysis Regression Equation, testing for differences in slopes by type of normalization (natural log or square root) of consumption data
Differences in consumption, Scotland minus England (as derived from data of y-axes of Figures 4 and 5) and Supplement Figures 17 and 18) = intercept + 'type of normalization (natural log or square root)' age/or/deprivationscore + 'type of normalization'*age/or/deprivationscore + error.

SPSS SYNTAX

```
GENLIN 'differences in consumption, Scotland minus England BY 'type of normalization' WITH
age/or/deprivationscore
 /MODEL 'type of normalization' age/or/deprivationscore 'type of
normalization'*age/or/deprivationscore / INTERCEPT=YES
DISTRIBUTION=NORMAL LINK=IDENTITY
 /CRITERIA METHOD=FISHER(1) SCALE=1 COVB=MODEL MAXITERATIONS=100 MAXSTEPHALVING=5
   PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012 ANALYSISTYPE=3(WALD) CILEVEL=95
CITYPE=WALD
   LIKELIHOOD=FULL
 /MISSING CLASSMISSING=EXCLUDE
 /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```

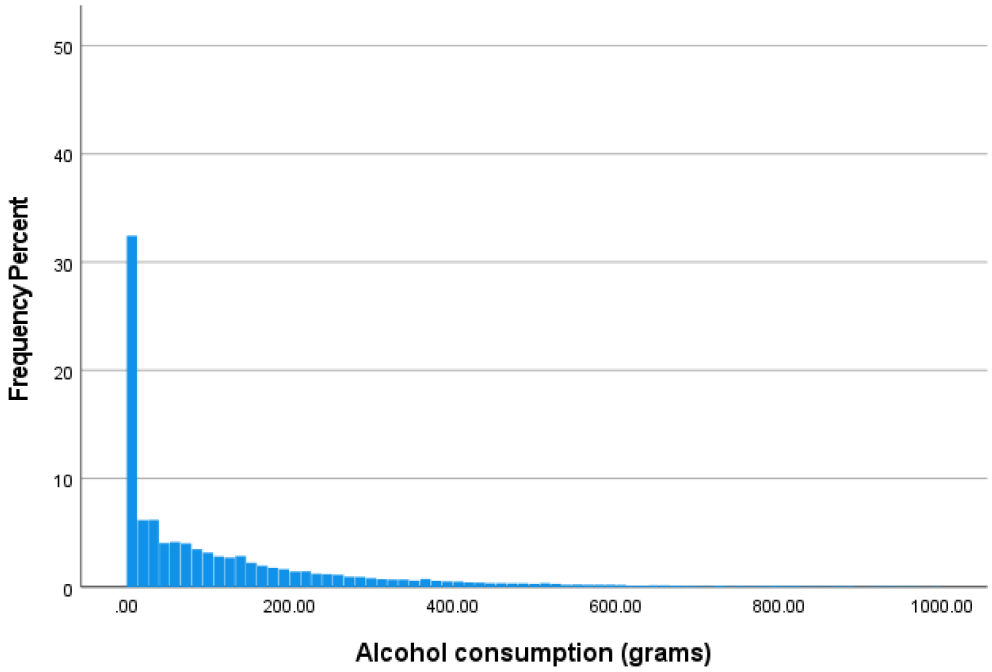

Figure 10 Distribution of weekly alcohol consumption, men.

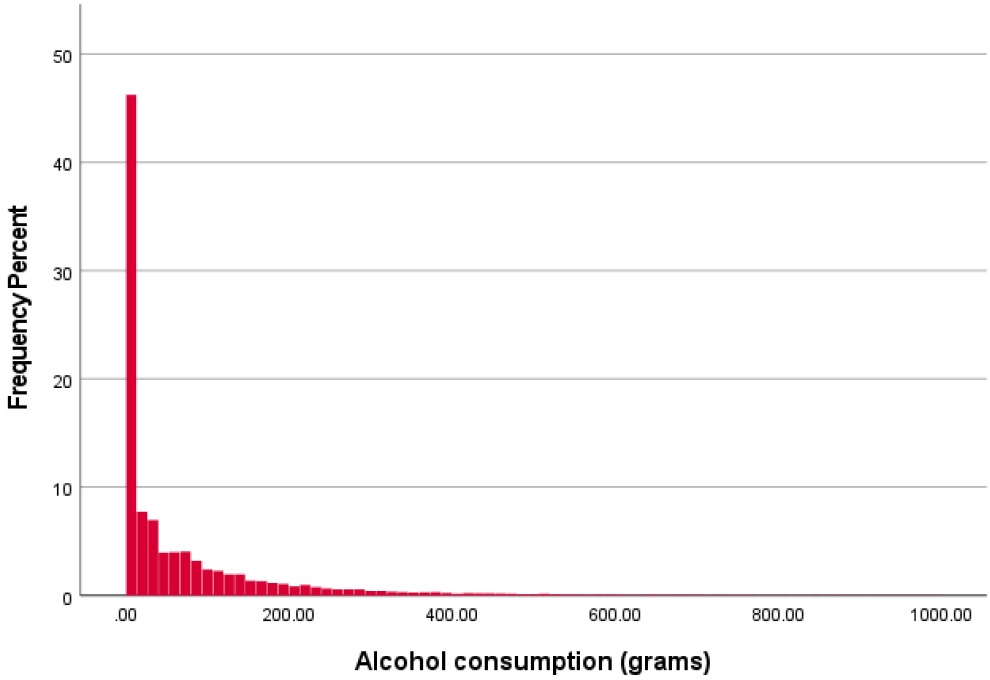

Figure 11 Distribution of weekly alcohol consumption, women.

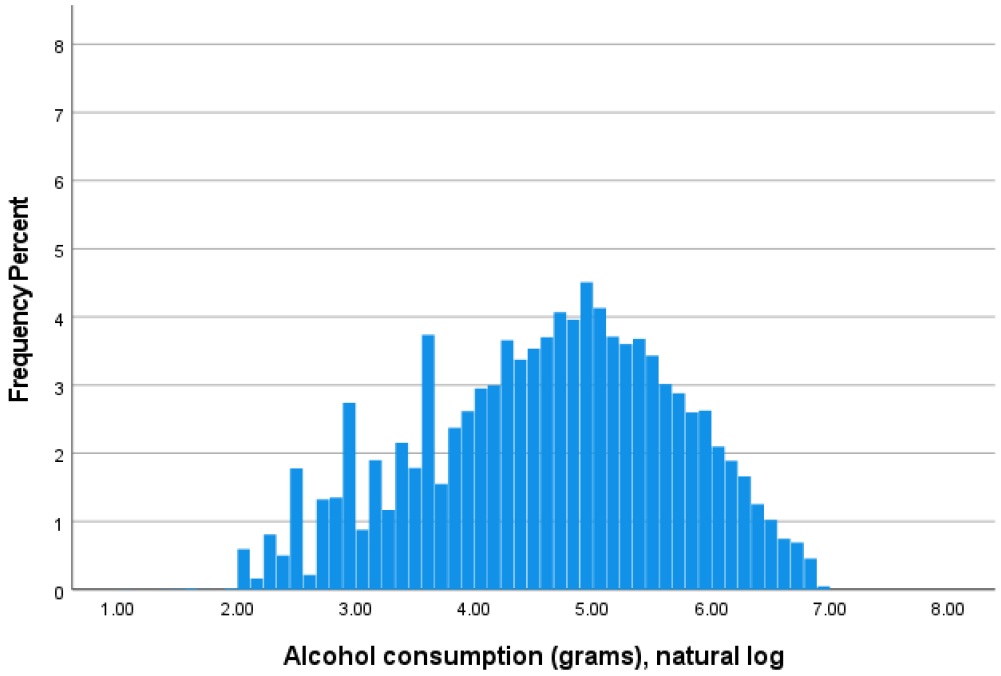

Figure 12 Distribution of weekly alcohol consumption (natural log), men who consumed alcohol during previous week.

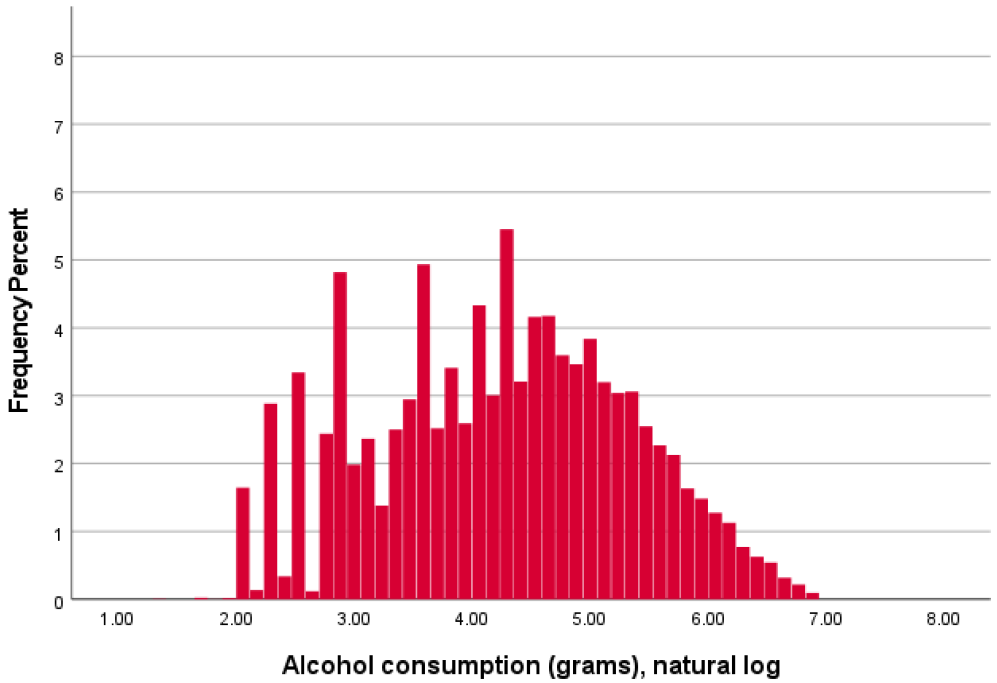

Figure 13 Distribution of weekly alcohol consumption (natural log), women who consumed alcohol during previous week.

Power calculations

For the interrupted time series analyses, we had 173 time points before and 25 time points after the intervention. The intervention was modelled as an abrupt effect with two control series. According to Beard et al.,[21] this should be more than sufficient power to detect small effects of level changes. For the before and after analyses, we used regression analyses and based the analyses on a total of 106,490 respondents. This sample size is sufficient to detect very small effect sizes in the definition of Cohen d = 0.1 with > 90% power.[24]

Table 2 Numbers of respondents by country, before and after the introduction of MUP and by socio-demographic characteristics. Drink diaries were completed by 106,490 respondents from England and Scotland during the four years from 2015 to 2018, with an average of 512 diaries per week, (SD=173), a rate which remained stable over the four-year period (F=0.544, p=0.462).

		Before introduction of MUP				Introduction of MUP and after			
		England		Scotland		England		Scotland	
		Men	Women	Men	Women	Men	Women	Men	Women
Age group	18-24	4861	10327	490	1608	878	2495	102	283
	25-44	14389	16407	2091	2870	2775	3293	364	597
	45-64	12839	9005	2442	1196	2487	1458	416	236
	65+	6359	2684	1057	269	1342	564	251	55
	Total	**38448**	**38423**	**6080**	**5943**	**7482**	**7810**	**1133**	**1171**
Social grade group	AB	10860	9197	1728	1453	878	2495	102	283
	C1	7529	8641	1179	1429	1370	2040	160	340
	C2	8607	8656	1351	1309	2274	1943	316	372
	DE	11452	11929	1822	1752	2960	1332	555	176
	Total	**38448**	**38423**	**6080**	**5943**	**7482**	**7810**	**1133**	**1171**
Deprivation group (1=most deprived; 5=least deprived)	1.00	3112	2945	191	172	618	681	30	23
	2.00	10689	10771	1254	1200	2218	2287	259	269
	3.00	12999	13252	2420	2410	2504	2572	471	484
	4.00	9326	9165	1697	1644	1729	1805	286	324
	5.00	2322	2290	518	517	413	465	87	71
	Total	**38448**	**38423**	**6080**	**5943**	**7482**	**7810**	**1133**	**1171**

Table 3 Proportion of respondents (95% confidence intervals) who are women by country and before or after introduction of MUP

Country	Event	Mean	95% Confidence Interval	
			Lower	Upper
England	Before MUP	0.500	0.496	0.503
	After MUP	0.511	0.503	0.519
Scotland	Before MUP	0.494	0.485	0.503
	After MUP	0.508	0.488	0.529

In a generalized linear regression equation, [GENLIN Proportion of respondents who are women BY event country/MODEL event country country*event INTERCEPT=YES], the coefficient of the interaction term country*event (introduction of MUP) indicated that any differences between Scotland and England in the proportion of respondents that were women before the introduction of MUP did not change following the introduction of MUP (coefficient=0.003 (95%CI=-0.021 to 0.027).

Table 4 Mean age of respondents (95% confidence intervals) by country and before or after introduction of MUP

Sex of respondent	Country	Event	Mean	95% Confidence Interval	
				Lower	Upper
Men	England	Before MUP	45.323	45.159	45.488
		After MUP	46.049	45.677	46.422
	Scotland	Before MUP	47.983	47.569	48.396
		After MUP	49.265	48.307	50.222
Women	England	Before MUP	37.171	37.020	37.322
		After MUP	35.822	35.487	36.157
	Scotland	Before MUP	35.565	35.180	35.949
		After MUP	36.450	35.585	37.315

In a generalized linear regression equation, [GENLIN Age of respondents BY event country/MODEL event country country*event INTERCEPT=YES], the coefficient of the interaction term country*event (introduction of MUP) indicated that any differences between Scotland and England in the mean age of respondents before MUP did not change for men following the introduction of MUP (coefficient=0.556 (95%CI=-0.563 to 1.675), but did for women (coefficient=2.234 (95%CI=1.219 to 3.250), indicating that, whereas Scottish women were, on average, a little younger than English women before MUP, they were a little older than English women after MUP.

Table 5 Mean deprivation score of respondents (95% confidence intervals) by country and before or after introduction of MUP

Sex of respondent	Country	Event	Mean	95% Confidence Interval	
				Lower	Upper
Men	England	Before MUP	48.014	47.814	48.215
		After MUP	47.182	46.727	47.636
	Scotland	Before MUP	53.842	53.338	54.346
		After MUP	52.644	51.476	53.812
Women	England	Before MUP	47.997	47.798	48.195
		After MUP	47.090	46.650	47.531
	Scotland	Before MUP	53.562	53.057	54.068
		After MUP	52.440	51.301	53.578

In a generalized linear regression equation, [GENLIN deprivation score of respondents BY event country/MODEL event country country*event INTERCEPT=YES], the coefficient of the interaction term country*event (introduction of MUP) indicated that any differences between Scotland and England in the mean deprivation score of respondents before MUP did not change for men (coefficient=-0.365 (95%CI=-1.731 to 1.000) or for women (coefficient=-0.217 (95%CI=-1.553 to 1.119), following the introduction of MUP.

Table 6 Alcohol consumption (grams) by sex, country and before and after introduction of MUP.

Sex	Country	phase	Proportion did not drink during previous week	Mean (total sample)	Median (total sample)
Men	England	Before MUP	0.2842	130.6012	60.8967
		After MUP	0.3142	110.9788	45.9614
	Scotland	Before MUP	0.3156	117.9299	55.3889
		After MUP	0.3575	102.5637	33.5750
Women	England	Before MUP	0.4057	72.5175	18.7625
		After MUP	0.4342	66.3174	15.1957
	Scotland	Before MUP	0.4158	72.5313	18.1157
		After MUP	0.4731	55.9706	9.0578

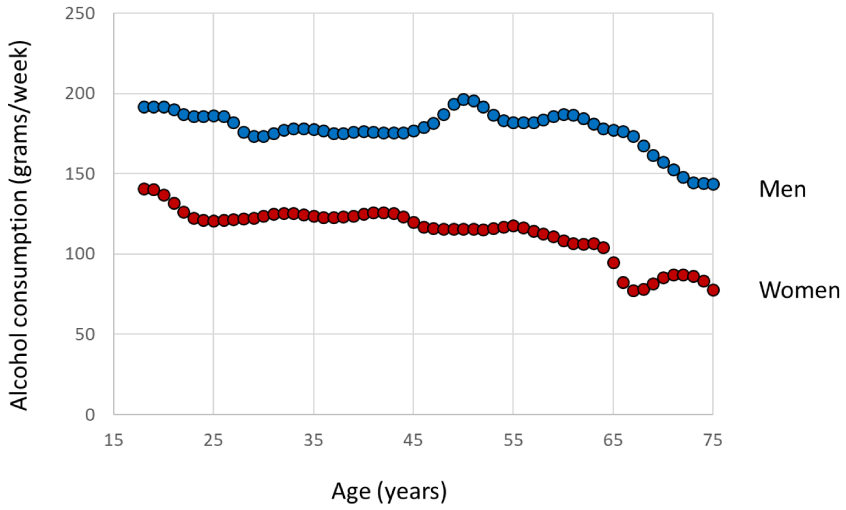

Figure 14. Mean alcohol consumption (grams per week) by age and sex, based on T4253H smoothing[1] across age**.** In a generalized linear regression equation, [GENLIN alcohol consumption with age, consumption decreased, similarly for both sexes, by 5.1 grams per every 10 years of increasing age (95% confidence interval, CI=4.4 to 5.7 grams).

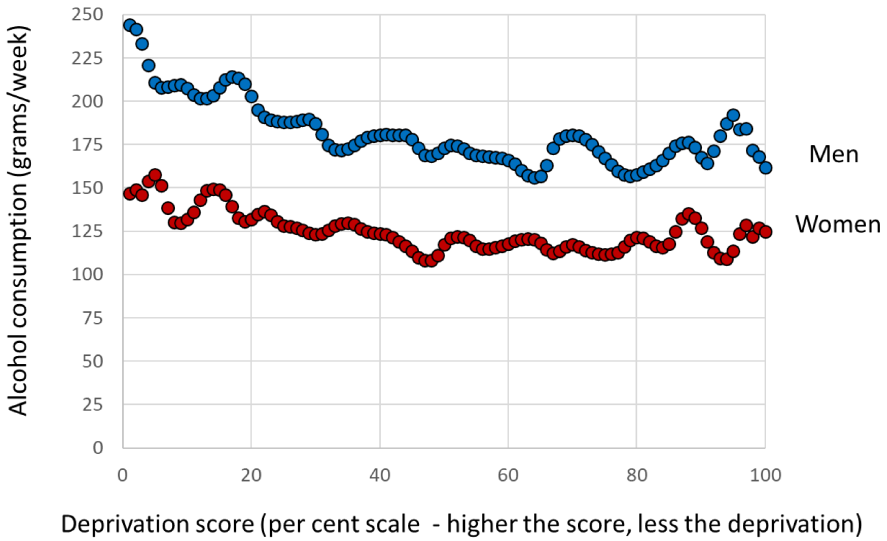

Figure 15. Mean alcohol consumption (grams per week) by deprivation score and sex, based on T4253H smoothing[1] across deprivation score**.** In a generalized linear regression equation, [GENLIN alcohol consumption with deprivation score, consumption decreased, similarly for both sexes by 1.1 grams per every 10 points (within a scale, 1-100) of decreasing deprivation (95% confidence interval, CI=0.8 to 1.4 grams).

[1] Velleman PF. Robust nonlinear data smoothers: Definitions and recommendations. *Proc Natl Acad Sci U S A*. 1977;74(2):434-436. doi:10.1073/pnas.74.2.434

Table 7 Interrupted time series analyses, main findings. Coefficients with 95% confidence intervals. Model with interaction terms by sex of respondent, which demonstrates that the drop in consumption associated with MUP was greater for women than men.

	Total consumption	Off-trade consumption	On-trade consumption
(Intercept)	-8.916 (-12.071 to -5.762)	-10.052 (-12.113 to -7.992)	1.136 (-1.747 to 4.019)
Level change associated with MUP	-1.544 (-7.214 to 4.126)	-.754 (-4.458 to 2.950)	-.790 (-5.972 to 4.393)
Time (weeks)	.003 (-.025 to .031)	.004 (-.014 to .022)	-.001 (-.027 to .025)
Women	7.565 (4.746 to 10.384)	9.285 (7.444 to 11.126)	-1.720 (-4.296 to .856)
Men (reference group)	.000 (. to .)	.000 (. to .)	.000 (. to .)
Women*event (introduction of MUP)	-8.801 (-15.672 to -1.930)	-5.039 (-9.527 to -.551)	-3.762 (-10.042 to 2.518)
Men*event (introduction of MUP) (reference group)	.000 (. to .)	.000 (. to .)	.000 (. to .)

Table 8 Interrupted time series analyses, sensitivity analysis, with Northern England as control. Coefficients with 95% confidence intervals. Model with interaction terms by sex of respondent, which demonstrates that the drop in consumption associated with MUP was greater for women than men.

	Total consumption
(Intercept)	-9.757 (-12.047 to -7.468)
Level change associated with MUP	-2.875 (-6.990 to 1.240)
Time (weeks)	.009 (-.012 to .029)
Women	3.695 (1.649 to 5.741)
Men (reference group)	.000 (. to .)
Women*event (introduction of MUP)	-6.022 (-11.009 to -1.035)
Men*event (introduction of MUP) (reference group)	.000 (. to .)

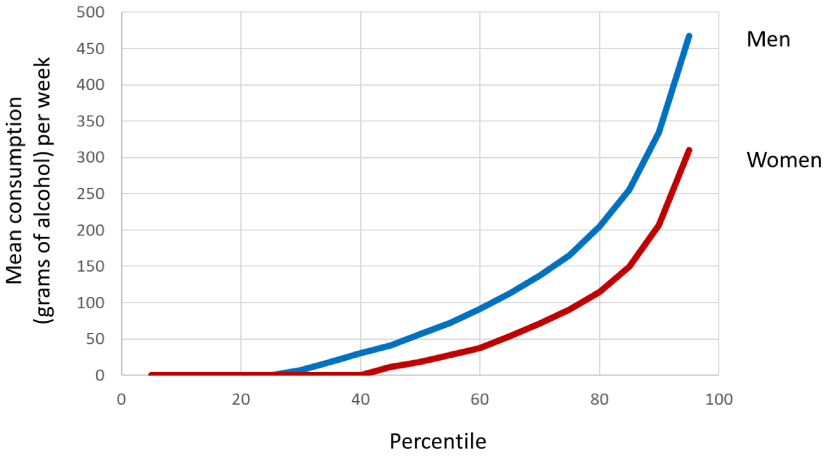

Figure 16. Mean consumption, grams of alcohol per week, by percentile distribution of consumption for men and women.

Supplement Table 9 Associated changes (and 95% confidence intervals) in the net difference in alcohol consumption (Scotland minus England) following the introduction of MUP by drinking percentile distribution of total alcohol consumption

	Men			**Women**		
Consumption percentile	Coefficient	Lower 95% confidence interval	Upper 95% confidence interval	Coefficient	Lower 95% confidence interval	Upper 95% confidence interval
5	0.042	-0.082	0.167	0	0	0
10	0.048	-0.079	0.176	0	0	0
15	-0.362	-0.821	0.097	-0.001	-0.021	0.019
20	0.062	-0.829	0.953	-0.006	-0.168	0.156
25	-0.456	-1.581	0.669	0.01	-0.327	0.346
30	0.157	-1.812	2.125	0	0	0
35	-2.448	-6.852	1.955	0	0	0
40	-0.464	-5.058	4.13	-0.133	-1.671	1.405
45	0.307	-5.088	5.703	1.495	-0.451	3.441
50	0.067	-6.297	6.431	-3.767	-6.947	-0.588
55	-2.559	-8.078	2.96	-9.296	-12.183	-6.409
60	-5.055	-11.564	1.454	-11.2	-11.2	-11.2
65	-2.508	-11.198	6.182	-12.795	-16.807	-8.782
70	-5.167	-15.185	4.852	-15.775	-21.859	-9.691
75	-5.131	-17.915	7.653	-15.365	-21.286	-9.445
80	0.96	-4.646	6.566	-18.71	-27.335	-10.086
85	0	-4	4	-26.605	-32.6	-20.6
90	2.08	-3.5	7.93	-7.57	-21.374	6.234
95	13.75	5.75	21.5	4.75	-4	13.74

There were 633 Scottish residents and 4046 English residents in each percentile prior to MUP, and 121 Scottish residents and 805 English residents in each percentile after the introduction of MUP split roughly equally between men and women.

Table 10 Figure 3 of main paper: Data by age group: B, Coefficient; upper 95% confidence interval; lower 95% confidence interval.

Consumption	Sex of respondent	Age	B	Upper	Lower
Total consumption	**Men**	18-24	0.154	0.361	-0.054
		25-44	-0.094	0.113	-0.300
		45-64	-0.151	0.015	-0.317
		65+	-0.216	-0.032	-0.399
	Women	18-24	-0.063	0.087	-0.213
		25-44	0.064	0.259	-0.131
		45-64	0.000	0.150	-0.150
		65+	-0.267	-0.018	-0.517
Off-trade consumption	**Men**	18-24	0.186	0.405	-0.033
		25-44	0.261	0.428	0.094
		45-64	-0.019	0.153	-0.192
		65+	-0.311	-0.125	-0.497
	Women	18-24	-0.125	0.073	-0.322
		25-44	-0.078	0.122	-0.279
		45-64	0.036	0.163	-0.091
		65+	-0.251	-0.015	-0.486
On-trade consumption	**Men**	18-24	-0.033	0.097	-0.162
		25-44	-0.354	-0.170	-0.538
		45-64	-0.132	0.141	-0.404
		65+	0.096	0.183	0.008
	Women	18-24	0.062	0.189	-0.065
		25-44	0.142	0.232	0.052
		45-64	-0.036	0.091	-0.163
		65+	-0.017	0.142	-0.176

Table 11 Figure 3 of main paper: Data by social grade group: B, Coefficient; upper 95% confidence interval; lower 95% confidence interval.

Consumption	Sex of respondent	Social grade group	B	Upper	Lower
Total consumption	**Men**	DE	0.053	0.245	-0.138
		C2	-0.165	-0.009	-0.321
		C1	-0.177	-0.017	-0.338
		AB	0.230	0.472	-0.011
	Women	DE	0.111	0.302	-0.080
		C2	-0.030	0.083	-0.142
		C1	-0.220	-0.105	-0.336
		AB	-0.090	0.115	-0.295
Off-trade consumption	**Men**	DE	0.023	0.198	-0.151
		C2	-0.147	0.088	-0.381
		C1	-0.261	-0.072	-0.450
		AB	0.515	0.694	0.336
	Women	DE	-0.018	0.106	-0.143
		C2	-0.009	0.085	-0.103
		C1	-0.207	-0.083	-0.330
		AB	-0.046	0.131	-0.223
On-trade consumption	**Men**	DE	0.030	0.111	-0.052
		C2	-0.018	0.172	-0.208
		C1	0.084	0.172	-0.004
		AB	-0.285	0.012	-0.582
	Women	DE	0.129	0.374	-0.116
		C2	-0.021	0.038	-0.080
		C1	-0.014	0.029	-0.056
		AB	-0.044	0.057	-0.145

Table 12 Figure 3 of main paper: Data by deprivation grade group: B, Coefficient; upper 95% confidence interval; lower 95% confidence interval.

Consumption	Sex of respondent	Deprivation group (1-most deprived)	B	Upper	Lower
Total consumption	**Men**	1	-0.027	0.091	-0.146
		2	0.045	0.234	-0.143
		3	-0.075	0.101	-0.252
		4	0.000	0.100	-0.100
		5	0.016	0.200	-0.168
	Women	1	0.103	0.291	-0.086
		2	-0.026	0.102	-0.154
		3	-0.032	0.130	-0.195
		4	-0.050	0.034	-0.135
		5	0.031	0.222	-0.160
Off-trade consumption	**Men**	1	0.009	0.145	-0.128
		2	-0.024	0.099	-0.147
		3	0.262	0.417	0.106
		4	0.023	0.146	-0.101
		5	0.044	0.246	-0.157
	Women	1	0.084	0.278	-0.110
		2	-0.034	0.097	-0.164
		3	0.093	0.276	-0.090
		4	-0.165	0.005	-0.334
		5	0.012	0.178	-0.154
On-trade consumption	**Men**	1	-0.036	0.057	-0.128
		2	0.069	0.318	-0.179
		3	-0.337	-0.221	-0.453
		4	-0.023	0.101	-0.146
		5	-0.028	0.026	-0.082
	Women	1	0.019	0.301	-0.263
		2	0.008	0.049	-0.033
		3	-0.125	0.154	-0.404
		4	0.114	0.294	-0.065
		5	0.019	0.125	-0.086

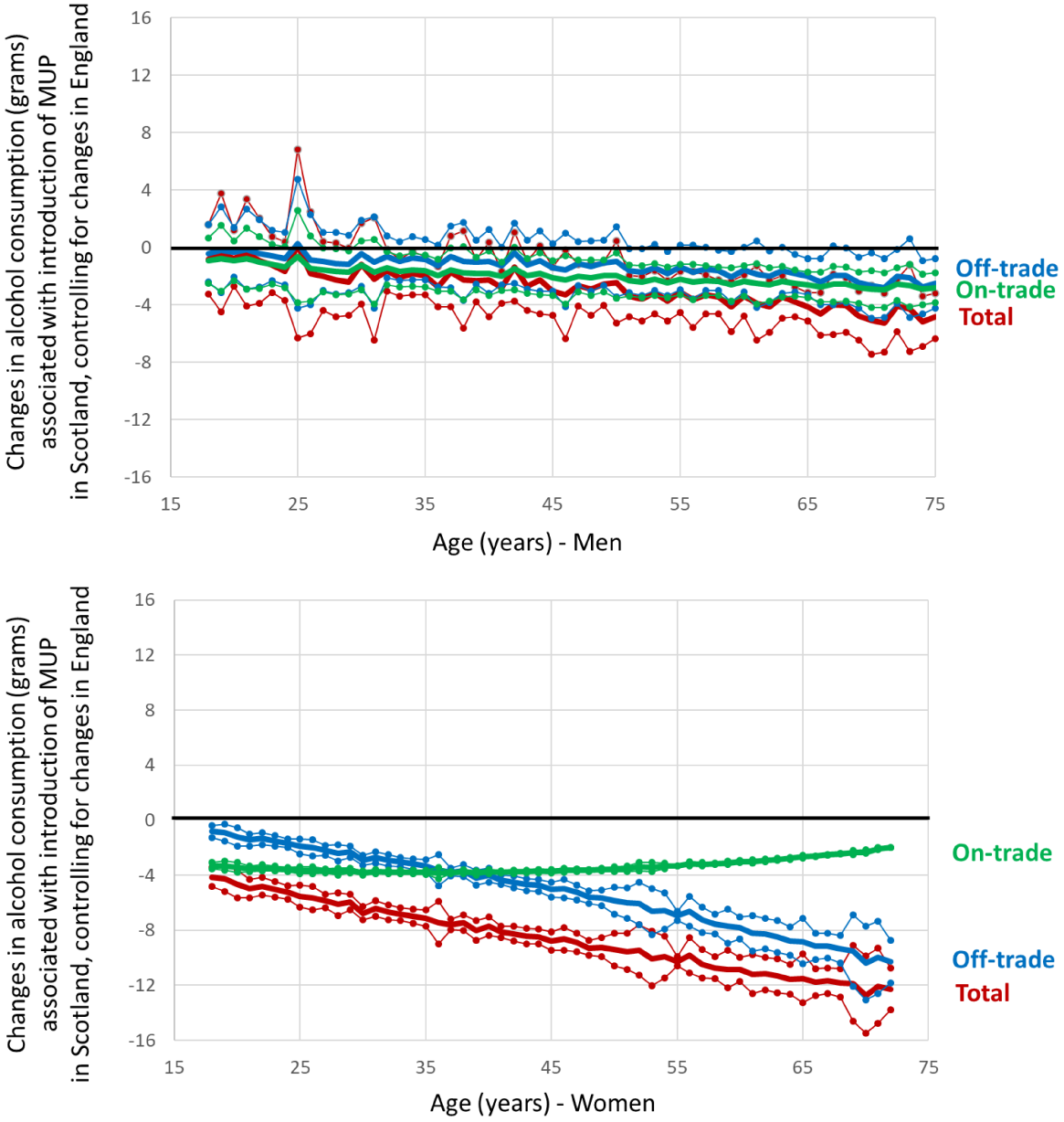

Figure 17 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each age group in years. Plots of men and women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change). Analyses based on sample of respondents who consumed alcohol during previous week; square roots of consumption taken prior to regression models, with squares of resultant coefficients taken prior to plots.

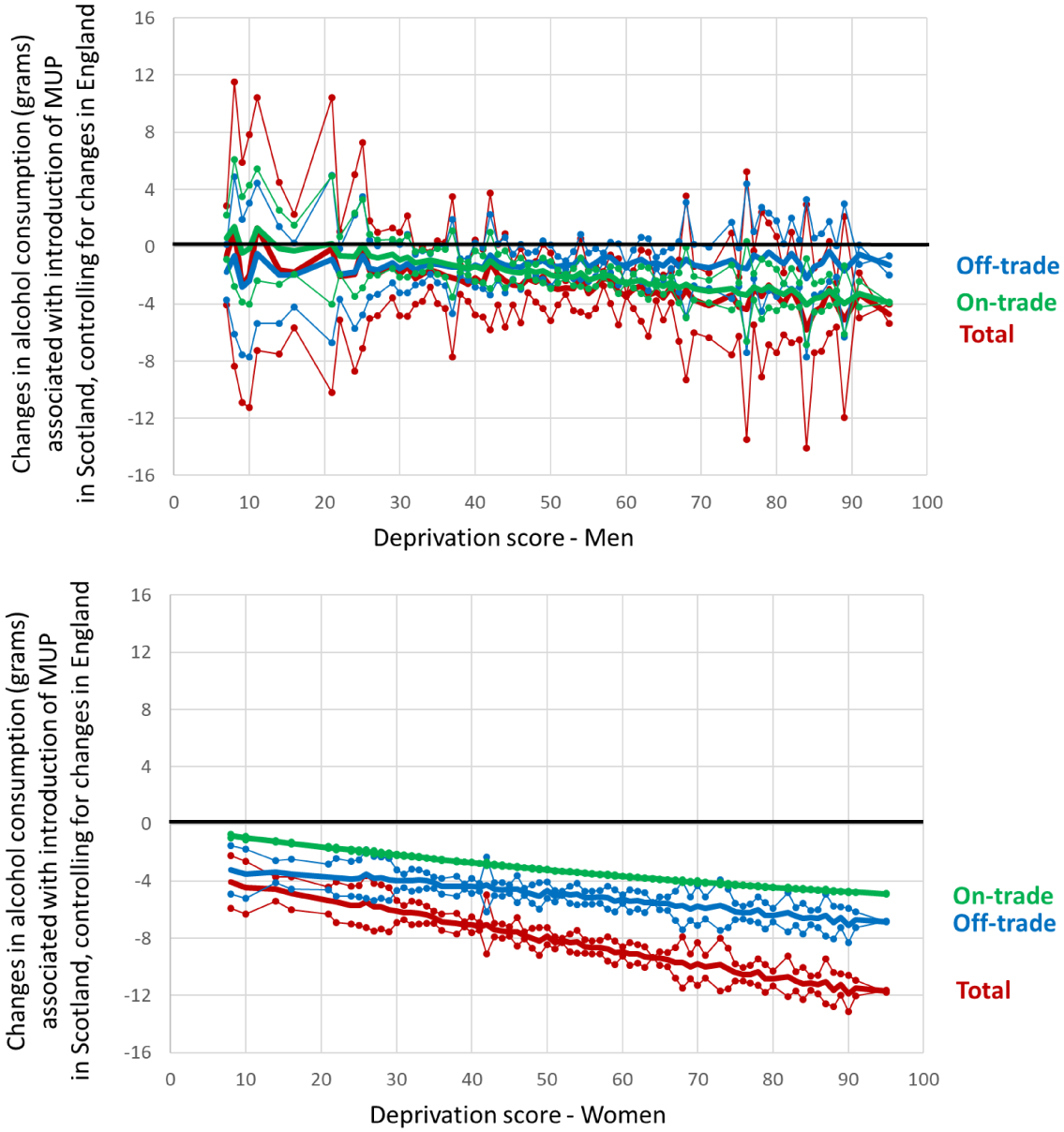

Figure 18 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each deprivation score on a scale from 1 (most deprived) to 100 (least deprived). Plots of men and women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change). Analyses based on sample of respondents who consumed alcohol during previous week; square roots of consumption taken prior to regression models, with squares of resultant coefficients taken prior to plots.

BMJ OPEN

Externally peer reviewed? Yes
Evidence type: Observational
Subjects: People

Minimum unit alcohol pricing may not be curbing drinking in those most at risk

Levels fell more in women who don't drink as heavily as men after introduction of policy
Policy not linked to reduced consumption in younger, deprived, or heaviest drinking men
Associated with an increase in consumption among 5% of heaviest drinkers

The introduction of minimum unit pricing (MUP) for alcohol may not be curbing drinking in the heaviest and most vulnerable drinkers, suggests research on the impact of the policy in Scotland, published in the open access journal ***BMJ Open.***

MUP was associated with larger reductions in consumption among heavier drinkers, overall. But consumption fell more in women who tend not to drink as heavily as men, nor was MUP associated with reduced consumption in younger, more deprived, or heaviest drinking men—those the policy was primarily designed to target—the findings show.

And consumption increased among the 5% of heaviest drinkers following its introduction.

After Scotland and several Eastern European countries adopted MUP—a threshold below which alcohol can't legally be sold—the policy is now being considered elsewhere.

The MUP in Scotland was set at £0.50 per unit (8 g) of pure alcohol (ethanol) sold from May 2018, as part of a larger national alcohol strategy, designed to curb hazardous and harmful drinking, targeting drinkers at the greatest risk of harm.

Evaluations of the policy to date have been positive, showing a general fall in alcohol purchases, use, and heavy drinking, but many of these studies have been based on alcohol sales or household expenditure.

The researchers therefore wanted to assess whether the impact of the Scottish MUP might differ by sex, existing drinking patterns, age, and level of social and economic deprivation.

They drew on data from the KWP Alcovision survey, an ongoing cross-sectional online diary survey of the previous week's alcohol consumption, which annually samples around 30,000 adults in Great Britain.

Respondents provide detailed information on their alcohol consumption over the previous 7 days, including details on brands, types, and total volume in grams drunk, as well as whether these drinks were consumed in a licensed premises or elsewhere.

The researchers compared these figures for Scottish adults with those of English adults before and after the introduction of the MUP.

They then repeated this, using adults resident in Northern England (North West, North East, and Yorkshire and Humber regions) as a comparison group, on the grounds that the drinking culture in these regions is similar to that of people living in Scotland.

The final analysis included drink diaries completed by 106,490 respondents (53,347 women and 53,143 men) from England and Scotland between 2015 and 2018. An average of 512 diaries were completed every week, a rate that remained constant over the 4-year period.

Average reported weekly consumption for all respondents was just under 126g for men and just over 71g for women.

Analysis of the survey data showed that compared with residents in England, MUP was associated with a drop in reported weekly total alcohol consumption of just under 6g a week — 2.7g in licensed premises and 3.3g elsewhere—representing a fall of just over 6%.

The reductions were larger for women (8.6g a week) than for men (3.3g a week), both when compared with England as a whole and when compared with just Northern England. And they were greater among heavier drinkers than among lighter drinkers, with the exception of the 5% of heaviest drinking men among whom consumption increased by 10%.

Further analyses showed that falls in consumption were greater among older survey respondents and those living in less deprived areas. But MUP wasn't associated with a fall in consumption among younger men (under the age of 32) and those living in the most deprived areas.

This is an observational study, and as such, can't establish cause. And the researchers acknowledge that their findings relied on subjective assessments of the quantities drunk. Nor can the research claim to fully represent all those who drink alcohol.

But they note: "When the Minister for Public Health, Sport and Wellbeing introduced the 2018 alcohol policy framework, he emphasised that the implementation of the MUP was strongly motivated by an interest in decreasing health inequalities through a reduction in alcohol consumption among the heaviest and most vulnerable drinkers.

"Our results indicate that this goal may not be fully realised: first, we found that women, who are less heavy drinkers in our data and in almost all surveys worldwide to date, reduced their consumption more than men; second, the 5% of heaviest drinking men had an increase in consumption associated with MUP; and, third, younger men and men living in more deprived areas had no decrease in consumption associated with MUP."

But they caution: "Before any further conclusions can be drawn, we need to corroborate our sex-, age-, heavy drinking- and socioeconomic status-related findings in different studies… Different conclusions about the impact of MUP may result for other countries."

They conclude: "If indeed the findings of our study are corroborated, then additional and/or different pricing mechanisms may need to be considered."