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Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-054161
Article Type:	Original research
Date Submitted by the Author:	07-Jun-2021
Complete List of Authors:	Rehm, Jürgen; Centre for Addiction and Mental Health, Social and Epidemiological Research O'Donnell, Amy; Newcastle University Kaner, Eileen; Newcastle University Jane Llopis, Eva; Maastricht University; Ramon Lull University Manthey, Jakob; Technische Universität Dresden, Institute of Clinical Psychology and Psychotherapy Anderson, Peter; Newcastle University; Maastricht University
Keywords:	PUBLIC HEALTH, SOCIAL MEDICINE, Substance misuse < PSYCHIATRY

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

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Abstract

Objective To assess if the impact of minimum unit price introduced in Scotland on May 1 2018 on alcohol consumption differs between women and men.

Design Controlled interrupted time series analysis, with consumption in England used as a control.

Setting Kantar WorldPanel Alcovision online survey.

Participants 53,347 women and 53,143 men.

Intervention Introduction of minimum unit price for sale of alcohol in Scotland on May 1 2018.

Main outcome measure Consumption of grams of alcohol during previous week.

Results The introduction of MUP was associated with an overall drop in reported consumption of 6.2% (95% CI=2.3% to 8.4%), with a drop in off-trade consumption of 5.2% that was almost significant (95%CI=-0.02 to 10.4%), and a non-significant drop in on-trade consumption of 8.3% (95%CI=-4.64% to 21.3%). Associated drops in overall consumption in all analyses were restricted to women and largely unaffected by age, when adjusting for levels of deprivation. Although drops in consumption varied by level of residential deprivation, and differently for men and women, there was no clear finding that larger drops in consumption occurred in respondents who lived in more as opposed to less deprived areas.

Conclusions The evidence base supporting the overall positive impact of MUP reported in this paper is strengthened by comparable results from previous analyses of household alcohol-purchase data. That these changes largely occur amongst women, rather than men, who, on average drink more, and that there are no consistent greater changes with greater deprivation potentially acts as a constraint on the overall impact of MUP policy.

Key words: alcohol; control policies; minimum unit pricing; Scotland; interrupted time-series analysis; health inequalities; sex

Strengths and limitations of this study

- The study uses a large commercial data set of 106,490 respondents from Great Britain.
- The data provided respondents' sex, age and truncated postcode to assess level of residential deprivation as potential explanatory variables of the results.
- The study uses interrupted time-series analyses with a control design using survey data from England as a control for data from Scotland.
- The study uses subjective reports of drinking which tend to underestimate consumption, with, however, no reason to believe that underreporting varied by country or before or after the introduction of minimum unit price in Scotland.
- The study uses timeline follow-back survey method over one week, which, whilst a short period is a strength for population average data, as biases due to memory loss are small.

INTRODUCTION

Alcohol use is a major risk factor for burden of disease and mortality.^{1,2} Policies can reduce alcohol-related harm, with the World Health Organization recommending three “best buys” as the most effective, cost-effective, and easy-to-implement policies: (1) policies to increase the price via taxation increases or floor pricing; (2) restrictions on availability; and (3) bans on marketing.³ Despite the effectiveness of such policies,⁴ other policies such as drink-driving or educational campaigns seem preferred by governments.⁵ However, following the lead of Scotland and some Eastern European countries, policies where alcoholic beverages cannot be sold under a threshold price are currently gaining support.^{6,7} Therefore, an evaluation of such policies is crucial to inform governments in other countries.⁸⁻¹⁰

This paper aims to evaluate the impact of the introduction in Scotland of a minimum unit price (MUP) of 50 GB pence per unit (8 grams) of pure alcohol sold (6.25 pence per gram) on 1st May 2018.⁶ The rationale for introducing MUP in Scotland was to specifically target 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 suggested that a MUP is likely to produce greater reductions in mortality inequalities by alcohol use than either taxation on a volumetric basis (based on product strength/ethanol content) or an ad valorem basis (proportionate to product value).¹¹ 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 found decreases in alcohol purchases, use and heavy drinking,^{8-10, 13} many of the evaluations are based on alcohol sales, household expenditures, or mortality data, which could not differentiate by sex. 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.¹⁴ Kantar WorldPanel’s Alcovision survey, a continuous retrospective online timeline follow-back (TLFB) diary survey, allows us to specifically investigate gender-based impact of MUP in Scotland using England as a control group.

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 in off-premise locations.
3. The reduction in consumption would be more pronounced for heavy drinkers with scarce resources; in Scotland this would be men from lower socio-economic strata.

METHODS

Study design

We undertook location-controlled, interrupted time-series regression and before-and-after analyses of the short-term associated impact of the introduction of MUP on 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}

Data sources

Our data source is the Kantar WorldPanel (KWP) Alcovision survey,¹⁵ an ongoing cross-sectional online timeline follow-back (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 seven days, and whether drinks are consumed off- or on-trade for each day. Participants complete the survey only once, without repeated surveys. Quota samples based on age, sex, social class, and geographic region are drawn from Kantar's managed access panel.¹⁵ 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 class, and geographical region are constructed using UK census data to ensure representativeness of British adults. Residents from Scotland and 18-34-year-olds are oversampled, (see Appendix Figures 1-2, page 1). In the data set we analysed, 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).

We grouped respondents into four age groups, 18-24, 25-44, 45-64 and 65+ years. We received truncated postal code data, which we used to identify respondents as being residents of Scotland or England. We used the English¹⁶ and the Scottish¹⁷ Indices of Multiple Deprivation to group respondents into levels of residential deprivation. [For details, see Appendix, pages 2-5, Figures 3-6].

The number of drinks consumed were recorded separately for off- and on-trade, with information given on serving sizes in millilitres (ml). Drinks were categorized within 19 categories, which we collapsed, grouped, and coded as beers, ciders, wines, spirits, fortified wines, and ready-to-drink products. In the data set we analyzed, detailed product description was provided for beers, including alcohol-free beers, but not for the other beverages. For non-beer products, the alcohol by volume (ABV) averages of the categories obtained from household purchase data over the same four years (2015-2018) were used.¹⁸ For beer-products, the brand-specific ABVs from the household purchase data were used.¹⁸ Volume was combined with ABV to calculate grams of alcohol (1 ml alcohol = 0.79 grams pure alcohol). We summed individual seven-day consumption into grams of alcohol by drink group per week for each individual.

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, on-trade consumption, and off-trade consumption. We plotted the seasonally adjusted total consumption over time (study week) by England and Scotland (Appendix Figure 7, 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.

Statistical analyses

Interrupted time series analyses

Interrupted time series analyses¹⁹ were done with the weekly consumption data averaged across all respondents, 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. We created three new dependent variables of Scotland minus England for each of the weeks for: (i) the average consumption of all grams of all alcohol per week, separately for men and women; (ii) the average consumption of all grams of all alcohol per week consumed off-trade, separately for men and women; and, (iii) the average consumption of all grams of all alcohol per week consumed on-trade, 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 averages for each of the 208 weeks, to be normally distributed. We adjusted the dependent variables for any seasonality. Based on Durbin-Watson tests, there was no

evidence of autocorrelation, and based on Augmented Dickey-Fuller tests, 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 general 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. The independent variables were the dummy-variable event, and time (each week from 1 to 208). The regression equation is:

Difference in consumption = 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.

We repeated the models separately for each of the four age groups, and for each of the five deprivation groups (thus, comparing same age and deprivation 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 standard deviations, rather than original units. This allowed us to compare the relative importance of the regression coefficients, and thus changes, across the characteristics of both the age and deprivation groups.

Before and after analyses

The before-and-after analyses were done with individual-respondent seven-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 ranking. 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 Appendix Figures 8-9, page 7). Thus, in our general linear models, which we ran separately for men and women, we used a negative binomial probability distribution for our dependent variables, self-reported consumption of alcohol in grams per week (for total consumption, on-trade consumption and off-trade consumption), with a Logit link function $[f(x)=\ln(x / (1-x))]$.²⁰ The independent variables were as follows: the event variable (introduction of MUP) was coded as a dummy variable as above for the interrupted time-series analysis; country as a factor (England or Scotland); age as a covariate; deprivation score as a covariate; and, week as a covariate. For each of the dependent variables, we ran two separate models, with the following regression equations:

Model 1: link function(consumption) = intercept + time + event + country + age + country*event + country*event*age

Model 2: link function(consumption) = intercept + time + event + country + deprivation score + country*event + country*event*deprivation score

where

- time is in weeks (Week 1 to Week 208)
- event is the dummy-coded variable for the introduction of MUP
- country is either England or Scotland
- Age is given in years
- Deprivation score is the ranking of deprivation, ranging from 0 to 100.

We plotted, for men and women separately, the means (and 95% confidence intervals) of the predicted values of the dependent variables per week, derived from the regression models for each age and for each integer deprivation ranking by age and deprivation ranking, respectively.

Analyses were performed with SPSSv26 (IBM Corp 2019).²⁸

Patient and public involvement

This research was done without patient involvement. Patients were not consulted to develop the research question, nor were they involved in identifying the study design or outcomes. We did not invite any patients to participate in the interpretation of results, nor in the writing or editing of this document. There are no plans to directly involve patients in the dissemination of these research findings.

RESULTS

Overall, 106,490 respondents (53,347 women and 53,143 men) contributed to the data set (for details, see Appendix Table 1 and Appendix Figures 10-11, pages 8-9). For respondents, the mean consumption per week was 125.8 grams for men (66.4% consumed off-trade) and 71.3 grams for women (71.3% consumed off-trade); for details, see Appendix Table 2, page 10). Consumption decreased with age, similarly for both sexes, from an intercept of 89.8 grams per week (95% CI=87.2 to 92.5) by 5.1 grams per every 10 years of increasing age (95% confidence interval, CI=4.4 to 5.7). Consumption decreased by only a small amount with decreasing deprivation, similarly for both sexes, from an intercept of 76.9 grams (95% CI=74.1 to 79.8) by 1.1 grams per every 10 points (within a scale, 1-100) of decreasing deprivation (95% confidence interval, CI=4.4% to 5.6%).

Interrupted time-series analyses

Table 1 gives the results of the associated impact of MUP on alcohol consumption changes. Overall, the introduction of MUP was associated with a drop in consumption of 5.9 grams (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%), with an almost significant drop of 3.3 grams (95% CI=-0.01 to 6.6) in off-trade consumption (a 5.2% drop, 95%CI=-0.02 to 10.4%), and a non-significant drop of 2.7 grams (95% CI=-1.5 to 6.8) in on-trade consumption (an 8.3% drop, 95%CI=-4.6% to 21.3%). Associated significant decreases in consumption were restricted to women (an 8.6 drop in grams, 95% CI=2.9 to 14.3), with a significant drop in off-trade consumption (5.2 grams, 95% CI=1.7 to 8.7) and a non-significant drop in on-trade consumption (3.4 grams, 95% CI=-3.8 to 10.5). Overall, 72.2 of the associated drop in consumption was due to women (95% CI=58.3 to 86.1), and 55.1% due to off-trade consumption (95%CI=48.3 to 61.9).

Table 1. Unstandardized coefficients from interrupted time series analyses (95% confidence intervals) for all respondents, and separated for men and women, by total consumption, off-trade consumption, and on-trade consumption, with Durbin-Watson statistic and Augmented Dickey Fuller test of models added. The level change is the estimated reduction in consumption of alcohol in Scotland (grams per week) associated with the introduction of MUP, controlling for any changes in England, with statistically significant changes highlighted in bold.

		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)
	Week	0.003 (-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)	-2.97 (-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)
	Week	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)	0.417 (-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)
	Week	-0.001 (-0.027 to 0.025)	0.011 (-0.015 to 0.036)	-0.012 (-0.057 to 0.032)

Figure 1 displays the associated changes in the difference in consumption following the introduction of MUP by age group, plotting standardized coefficients, allowing for relative, rather than absolute comparisons across the age groups. In relative terms, there were greater and significant associated drops in all consumption and in off-trade consumption for both men and women aged 65+ years. For younger men, there was an increase in off-trade consumption, which was offset by decreases in on-trade consumption in the same group. Figure 2 displays similar data by deprivation group, with, for men, relative increases in off-trade consumption and decreases in on-trade consumption for the middle-deprived group. Otherwise, there was no obvious pattern by deprivation group, and no evidence that those living in the most deprived areas (groups 1 and 2) reduced their consumption more than those living in the least deprived areas (groups 4 and 5).

Figure 1 here

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Figure 2 here

Before-and-after analyses

Figure 3 plots the associated changes in alcohol consumption (in absolute terms, using unstandardized coefficients) following introduction of MUP for all consumption, off-trade consumption, and on-trade consumption by gender and age. For men, reductions in consumption following the introduction of MUP became greater with increasing age, more so for off-trade consumption than for on-trade consumption. For younger men (those aged less than 35 years), the introduction of MUP was associated with increased consumption, more so for younger ages. For women, the associated decreases in consumption associated with MUP remained fairly stable with increasing age, a balance between off-trade consumption (where the decreases became greater with age), and on-trade consumption (where the decreases became smaller with age).

Figure 4 plots the associated changes in alcohol consumption (in absolute terms, using unstandardized coefficients) following the introduction of MUP for all consumption, off-trade consumption, and on-trade consumption by gender and deprivation ranking. For men, reductions in consumption following the introduction of MUP became greater with less deprivation, more so for on-trade consumption than for off-trade consumption, with those living in the most deprived areas showing increases in consumption. For women, the associated decreases in consumption associated with MUP were larger with increasing deprivation. This change was driven by changes in on-trade consumption, whereas the changes in off-trade consumption remained relatively stable across deprivation scores.

Figure 3 here

Figure 4 here

The plots in Figures 3 (age) and 4 (deprivation) had similarities, perhaps explained by a strong J-shaped relationship between deprivation ranking and age, with, after the age of 30 years, less deprivation with increasing age (see Appendix, Figure 12, page 11). Thus, when analysing the associations of changes in consumption by age within deprivation quintile, the relationship of changes in consumption by age largely disappeared, Figure 5, which plots z-scores, allowing for relative, rather than absolute comparison by age within deprivation quintile. For the total sample of men and women, respondents with mid-deprivation ranking (i.e., quintile 3) had an associated relative increase in consumption following the introduction of MUP across all age groups. Whereas those with the least or most deprivation ranking had a relative reduction in consumption, the least deprived (quintiles 4 and 5) had the greatest relative reduction. When looking at men and women separately, most of the changes by age group also disappeared, but there was no clear pattern by deprivation quintile, with the most deprived (quintiles 1 and 2) not demonstrating a consistent greater relative reduction than the least deprived (quintiles 4 and 5) (see Appendix Figures 13-14, page 12).

Figure 5 here

DISCUSSION

Compared to respondents from England, Scottish respondents reported reduced average consumption after MUP was implemented, with the 6% drop in reported consumption per week similar to the effect size predicted by modelling. However, contrary to the predictions, women reduced their consumption more than men, in total, and for off-trade consumption. Whilst reductions in consumption associated with MUP tended to be greater amongst older respondents, age-related differences largely disappeared when controlling for deprivation, since, beyond the age of 30 years, older respondents lived in less deprived areas. For the sample as a whole, those who lived in less deprived areas showed the greatest reduction in consumption.

Before we discuss these results further, it is important to mention potential strengths and limitations. First, all results are based on subjective reports of drinking. While such reports tend to underestimate consumption,²¹ there is no reason to believe that underreporting would differ by sex, by country, or before or after the introduction of the MUP. The timeline follow-back survey method has been criticized 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, however, is a strength when it comes to the characterization of population averages, where the shorter the time period, the smaller the biases due to memory, and the more accurate the population average.²² Second, as with all survey-based research on alcohol, this research cannot claim representativeness,²³ which would need to be based on probabilistic sampling design combined with high response rates.²⁴ Instead, post-stratification based on sex, age, social class, and geographical region was used to allow for generalizations to be made for the general population.^{23,25,26} However, externally validated indicators,^{23,27} corroborate our findings that the introduction of MUP is associated with decreases in sales²⁸ and purchases^{9, 10} of alcohol. Finally, it cannot be excluded that the actual reductions may have been due in part to the media reports²⁹ surrounding the introduction of the MUP rather than to the floor pricing itself. However, it seems highly unlikely that media reports would produce exactly the abrupt and lasting pattern of changes found.

Despite these potential limitations, most research corroborates the results of our study that MUP results in reduced sales and purchases of alcohol.^{9, 10, 28} Our results are based on a control group design, where the intervention was only introduced in one group, thus strengthening our confidence in a real effect.³⁰ However, 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.⁶ Our results indicate that this goal may not be fully realized. First, we found that women, who are less heavy drinkers than men,³¹ were responsible for most of the reported reduction in alcohol consumption. Second, we could not find a consistent effect for reported reduction in consumption by respondents' area of residential deprivation. These results are surprising, as modelling studies would have suggested otherwise.^{11,14}

CONCLUSIONS

Whilst MUP was associated with an overall reduction in consumption, the processes postulated to lead to this result did not play out as expected. If mainly women, who are typically less heavy drinkers than men, are affected, and those living in most deprived areas are not more affected, we would not expect the same impact on alcohol-attributable hospitalisations and mortality, which are associated with heavy drinking in men and in those of lower socioeconomic status.³²⁻³⁵ If our findings are corroborated in other studies, this might imply that additional pricing mechanisms may need to be implemented to reduce alcohol-attributable hospitalizations and mortality, such as tax increases.³⁶

1
2
3 **Acknowledgements:** We thank Kantar WorldPanel for providing the raw data and reviewing the
4 method description as it describes the consumption data. Kantar WorldPanel had no role in the study
5 design, data analysis, data interpretation, or writing of the manuscript. Professor Kaner is a National
6 Institute for Health Research (NIHR) Senior Investigator, and Director of the NIHR Applied Research
7 Collaboration, North East and North Cumbria. Dr. O'Donnell is a National Institute for Health Research
8 (NIHR) Advanced Fellow. The views expressed in this article are those of the authors and not
9 necessarily those of NIHR, or the Department for Health and Social Care.
10
11

12 **Contributors:** JR conceptualised the paper and prepared the draft of the introduction and discussion.
13 PA undertook the analyses and prepared the draft of the methods and results and submitted the
14 paper. All the authors refined the various versions of the full paper and approved the final manuscript
15 for submission. The corresponding author attests that all listed authors meet authorship criteria and
16 that no others meeting the criteria have been omitted. All authors had access to the data used for
17 analyses, and PA, AO'D and EJ-L verified the raw data sets received from Kantar WorldPanel, and are
18 the guarantors for the data used for the analyses.
19
20

21 **Competing interests:** All authors have completed the ICMJE uniform disclosure form at
22 www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted
23 work; within the previous five years, PA declares receipt of funds from AB InBev Foundation outside
24 the submitted work; the remaining authors declare no financial relationships with any organisations
25 in the previous five years that might have an interest in the submitted work; all authors declare no
26 other relationships or activities that could appear to have influenced the submitted work.
27
28

29 **Ethical approval:** Not required.
30

31 **Data sharing:** No additional data available. Kantar WorldPanel data cannot be shared due to licensing
32 restrictions.
33

34 **Affirmation:** PA and AO'D affirm that the manuscript is an honest, accurate, and transparent account
35 of the study being reported; that no important aspects of the study have been omitted; and that any
36 discrepancies from the study as initially planned have been explained.
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39 **Funding**

40 The authors have not declared a specific grant for this research from any funding agency in the
41 public, commercial or not-for-profit sectors.
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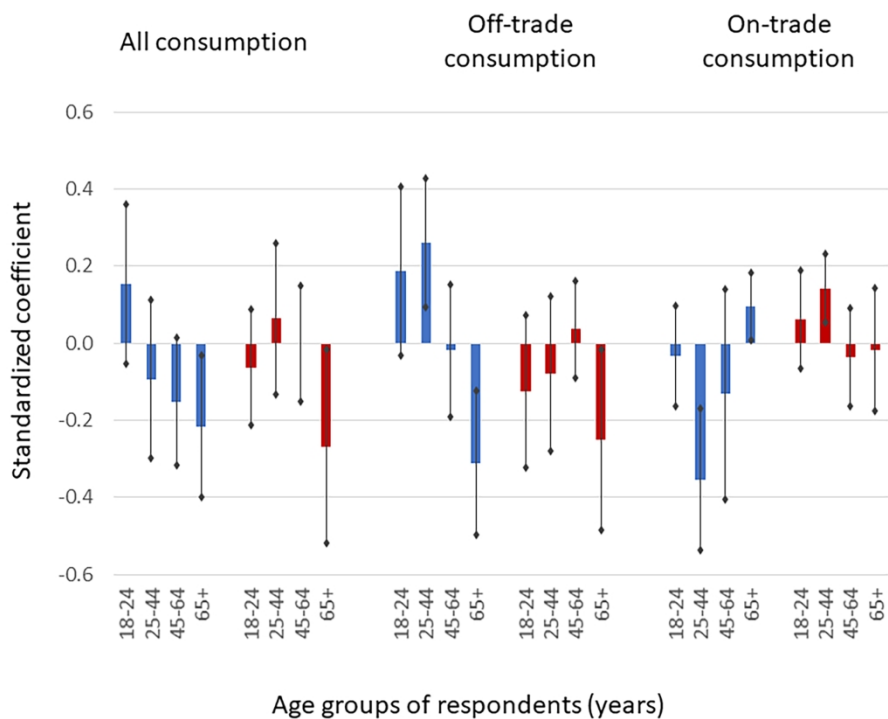
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3 **Figure 1** Associated changes in consumption following introduction of MUP for all consumption, off-trade
4 consumption, and on-trade consumption by age group for men (blue) and women (red). Consumption changes
5 are standardized coefficients from interrupted time series analyses with 95% confidence intervals.
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8 **Figure 2** Associated changes in consumption following introduction of MUP for all consumption, off-trade
9 consumption, and on-trade consumption by deprivation group (1, most deprived; 5, least deprived) for men
10 (blue) and women (red). Consumption changes (standardized coefficients) from interrupted time series analyses
11 are presented with 95% confidence intervals.
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13 **Figure 3** Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol
14 consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in
15 England) derived from the regression models of the before and after analyses for each age group in years. Plots
16 of men and women, with different vertical axes scales for total consumption, off-trade consumption, and on-
17 trade consumption. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at
18 zero (i.e., no change).
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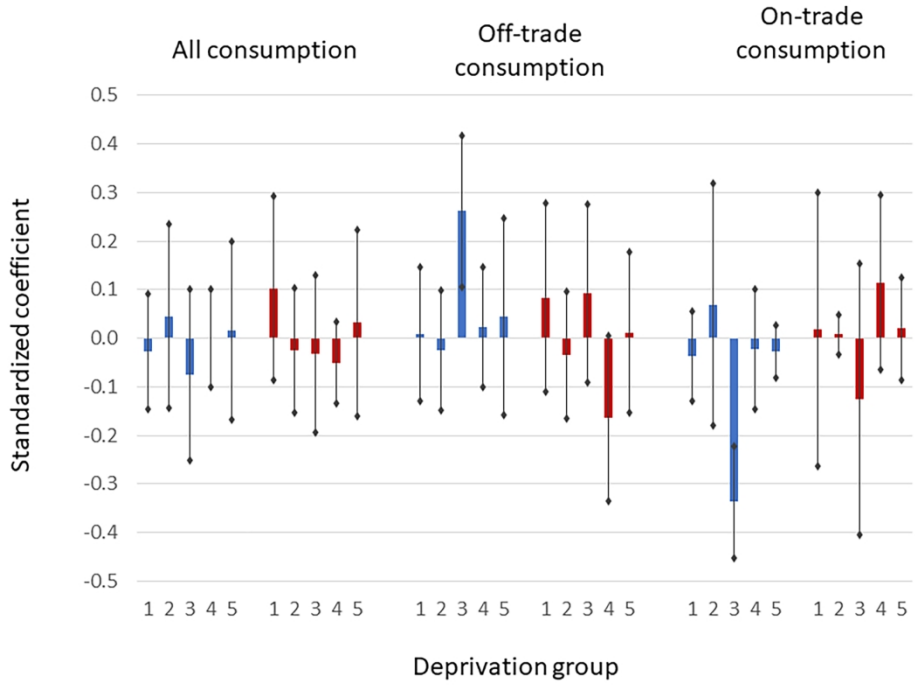
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21 **Figure 4** Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol
22 consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in
23 England) derived from the regression models of the before and after analyses for each deprivation score on a
24 scale from 1 (most deprived) to 100 (least deprived). Plots of men and women, with different vertical axes scales
25 for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner lines:
26 95% confidence intervals. Horizontal black line set at zero (i.e., no change).
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29 **Figure 5** Plots of the means of the predicted values of the dependent variables (changes in all alcohol
30 consumption, men and women combined, per week in grams, expressed as z-scores, associated with the
31 introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the
32 before and after analyses for each age in years, by deprivation quintile (1=most deprived; 5=least deprived).
33 Gaps: missing data. Horizontal black line set at zero (i.e., no change).
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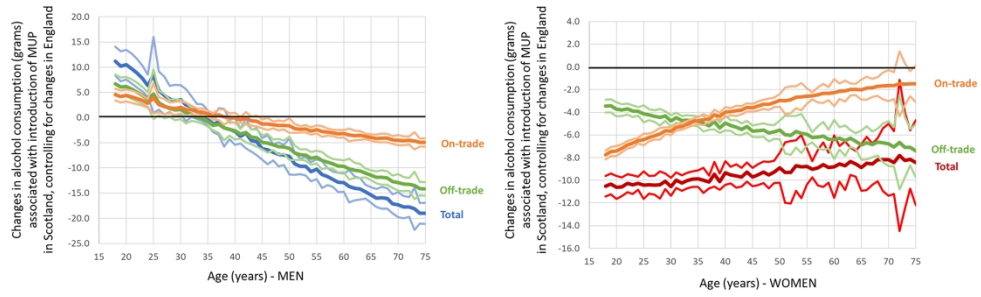
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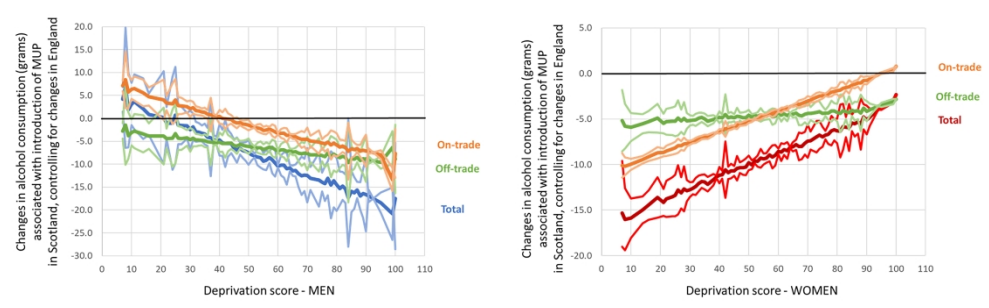
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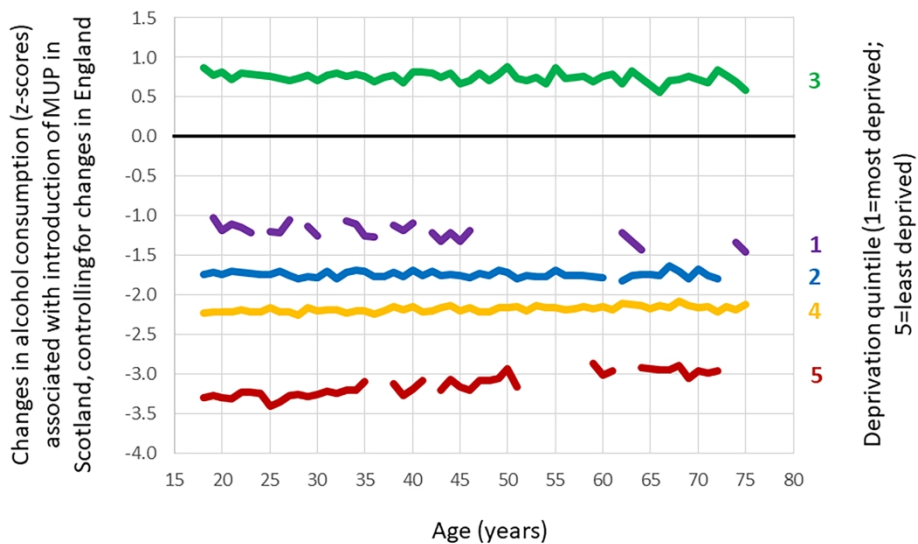


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APPENDIX



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>.

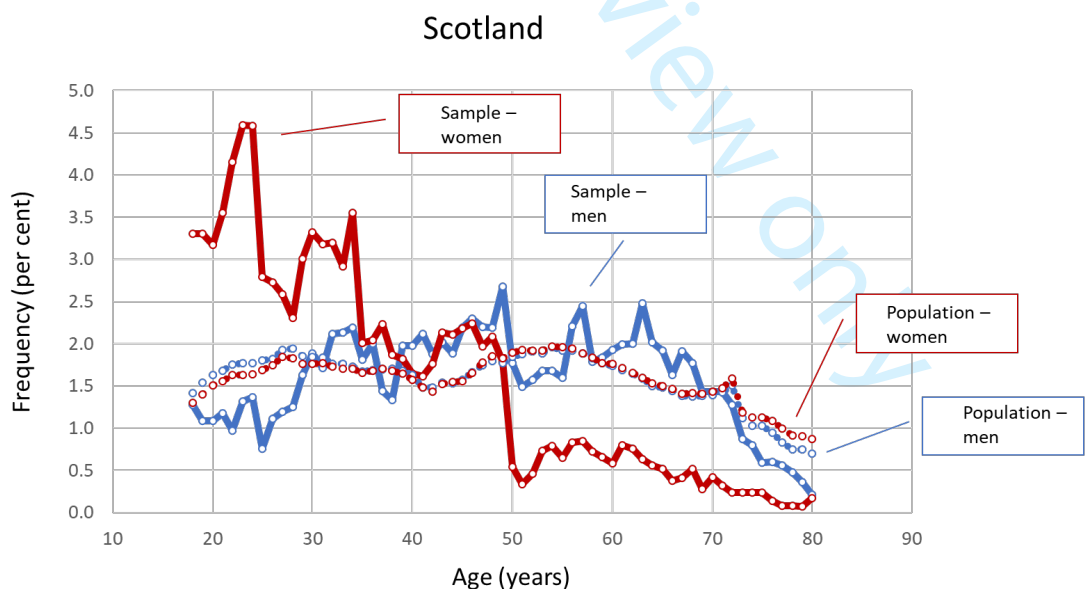


Figure 2 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for age range 18-80 years), Scotland. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and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

Indices of Multiple Deprivation

The indices are calculated differently for England and Scotland. In England, the index is estimated at Lower-Layer Super Output Areas, data zones 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 (least deprived) to highest (most deprived). Data for each data zone can be matched to a full postal code (e.g., OX3 8DT). However, to respect 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, with, 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 Appendix Figure 3, page 3. We rescaled the rankings based on the adjustment of the highest number (i.e., least deprived) in each of England and Scotland to 100. In order 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 Appendix, Figures 4 and 5, page 4. 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 least deprived levels to the mid-range and then decreasing to the highest deprived level. In relative terms, the dispersion decreased with increasing 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 class groups AB (relatively 'higher') were more likely to be in deprivation group 5, and those in social class groups DE ('lower') were more likely to be in deprivation group 1, (Appendix Figure 6, page 5).

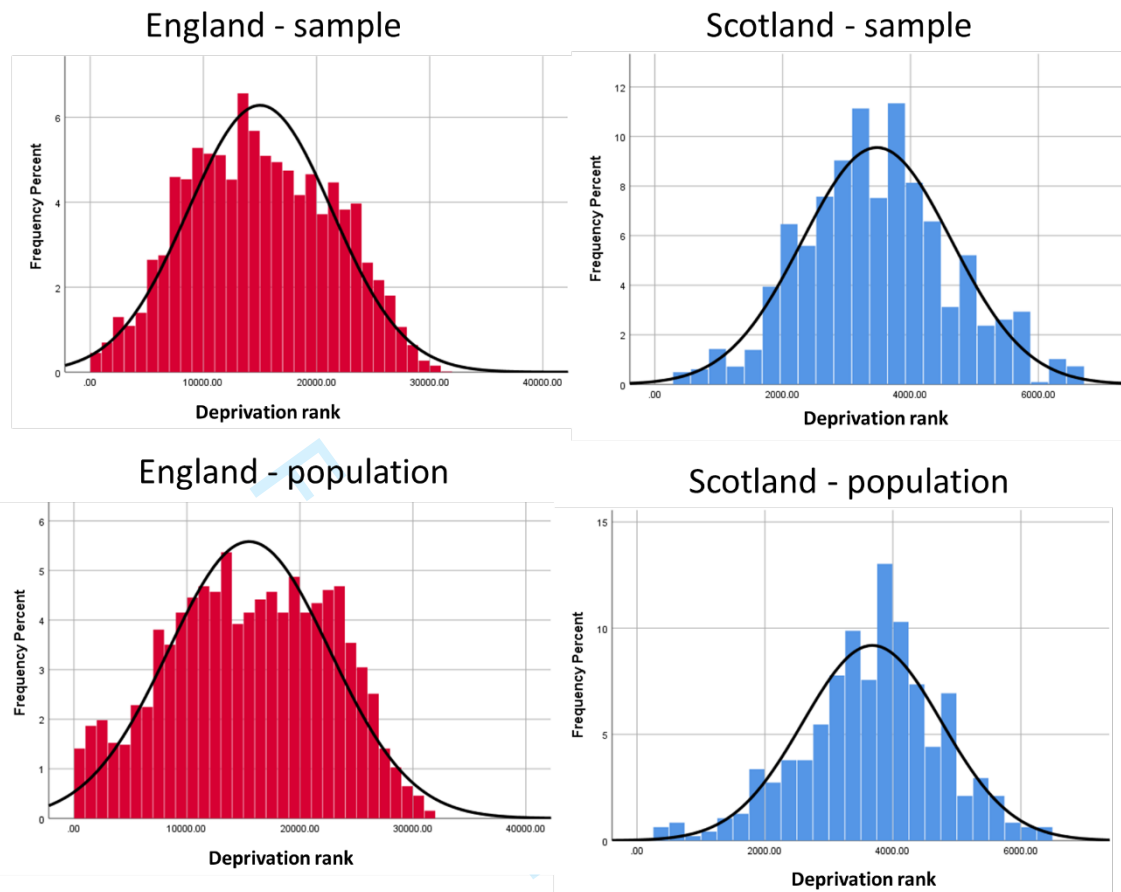


Figure 3 Per cent distribution (vertical axes) for analyzed sample and total population by deprivation rank (horizontal axes), England and Scotland. Data for total population from GOV.UK. National Statistics: English indices of deprivation 2019. <https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019>;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

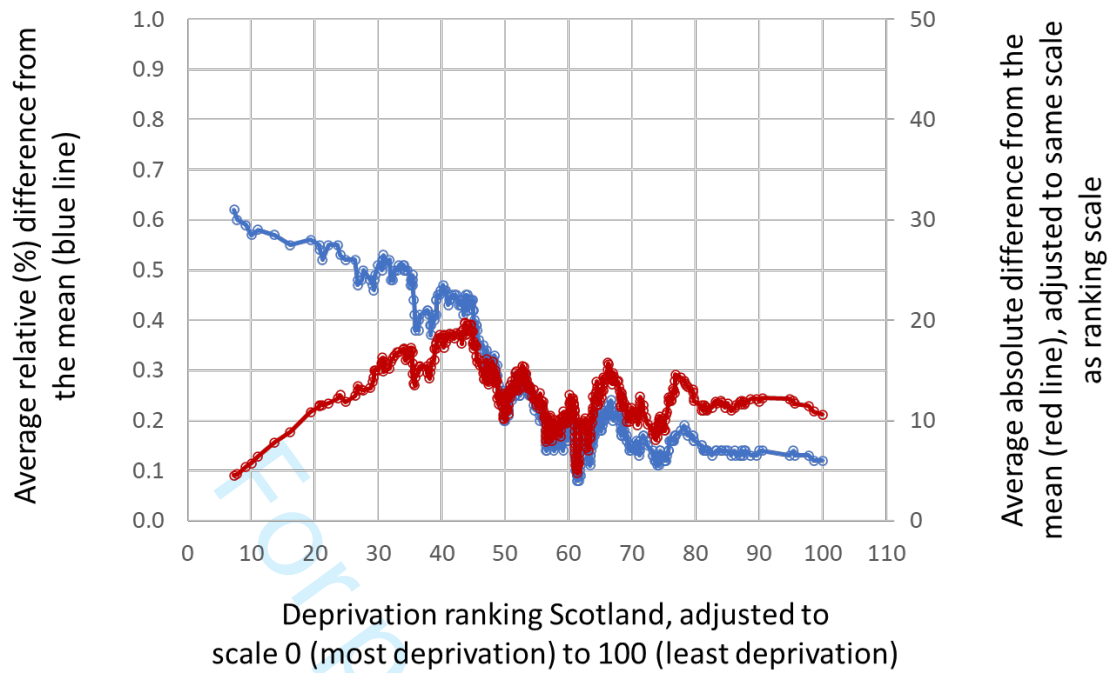


Figure 4 Dispersion of aggregated deprivation ranking, Scotland. The horizontal axis is the ranking from 0 (most deprived) to 100 (least deprived). The red line (right vertical axis) is the average absolute difference of the original ranking at local data zone level from the mean calculated at the truncated 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).

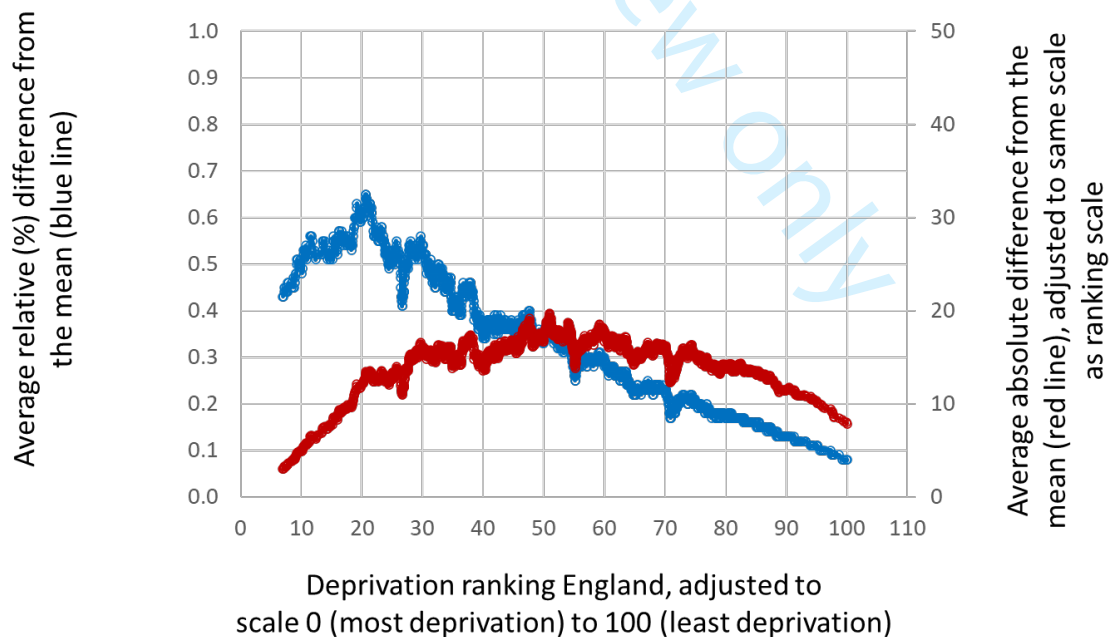


Figure 5 Dispersion of aggregated deprivation ranking, England. For explanation, see legend to Figure 4.

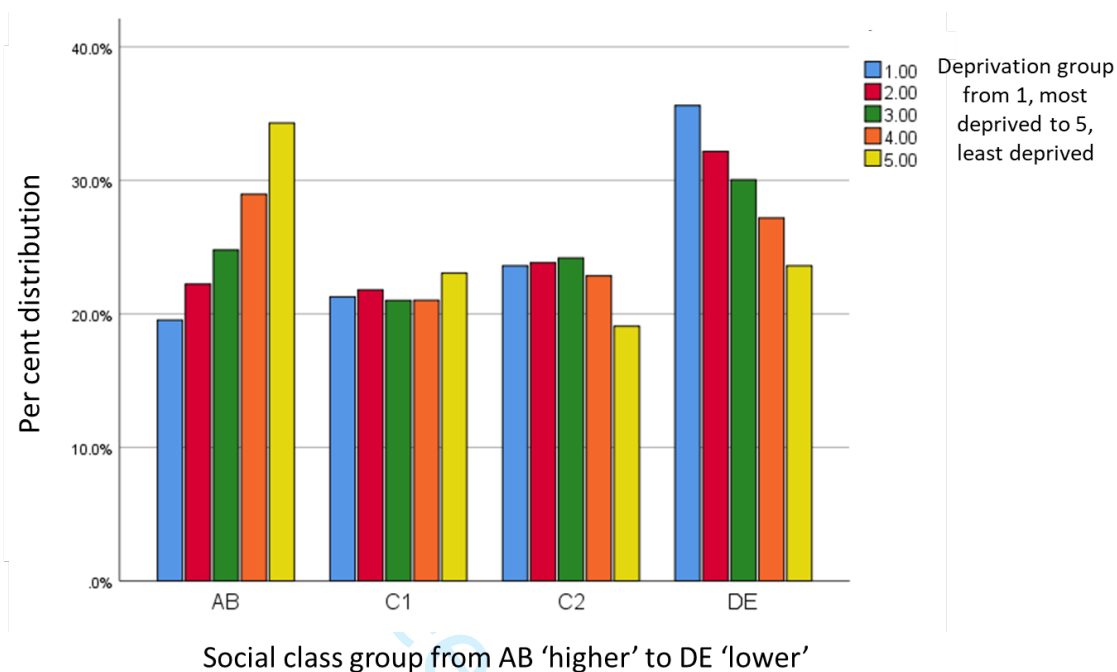


Figure 6 Distribution of deprivation group (from 1, most deprived to 5, least deprived) within social class groupings from AB, relatively higher to DE, relatively lower. Social class groups based on National Readership Survey; 2019. <http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/>.

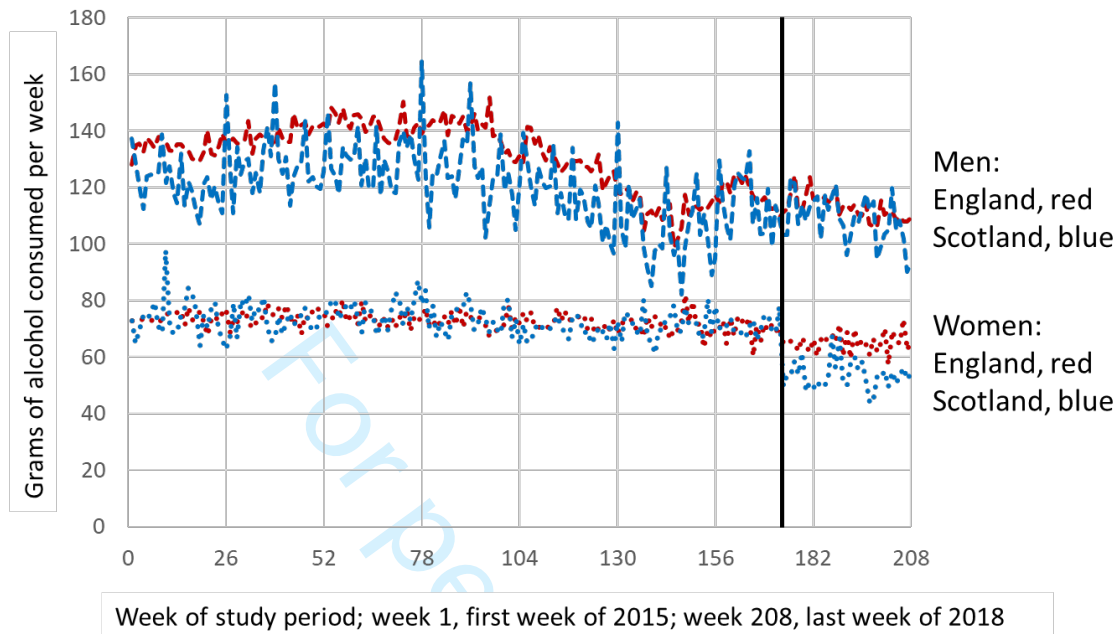


Figure 7 Plots of seasonally adjusted dependent variables (grams of alcohol consumed per week) over time (study week) by England and Scotland for men and women. Vertical black line: introduction of MUP.

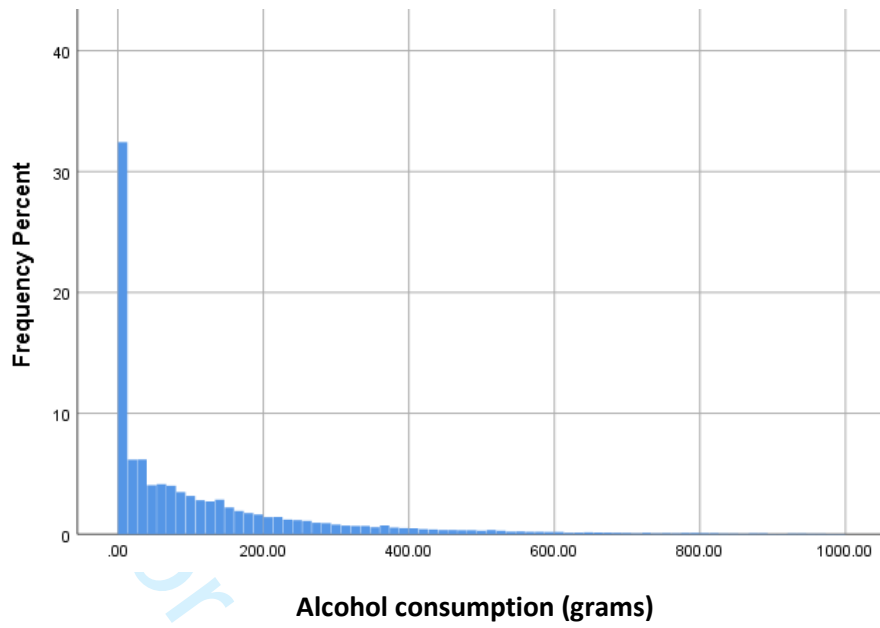


Figure 8 Distribution of weekly alcohol consumption, men.

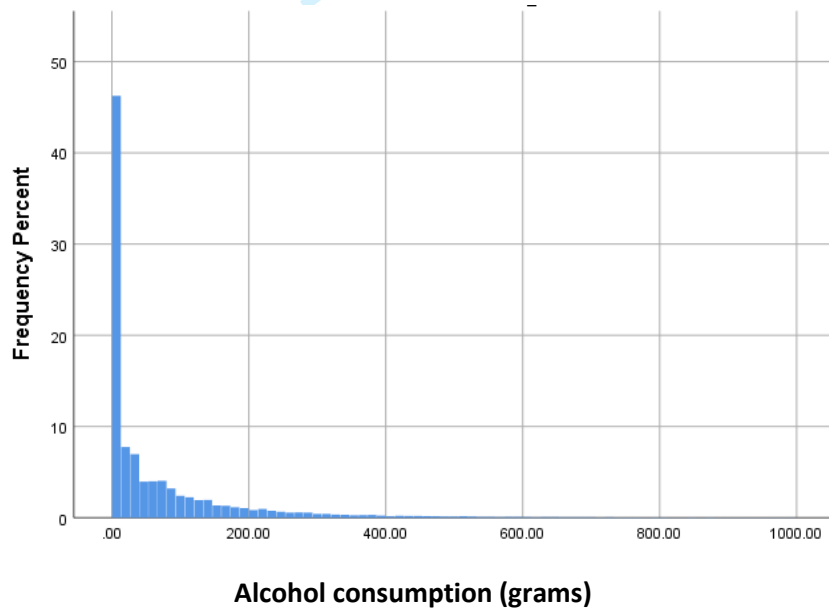


Figure 9 Distribution of weekly alcohol consumption, women.

Table 1 Number of respondents by sex, country and before and after introduction of MUP.

			Country		Total
			England	Scotland	
Prior to MUP	SEX	Male	38,448	6,080	44,528
		Female	38,423	5,943	44,366
	Total		76,871	12,023	88,894
After MUP	SEX	Male	7,482	1,133	8,615
		Female	7,810	1,171	8,981
	Total		15,292	2,304	17,596
Total	SEX	Male	45,930	7,213	53,143
		Female	46,233	7,114	53,347
	Total		92,163	14,327	106,490

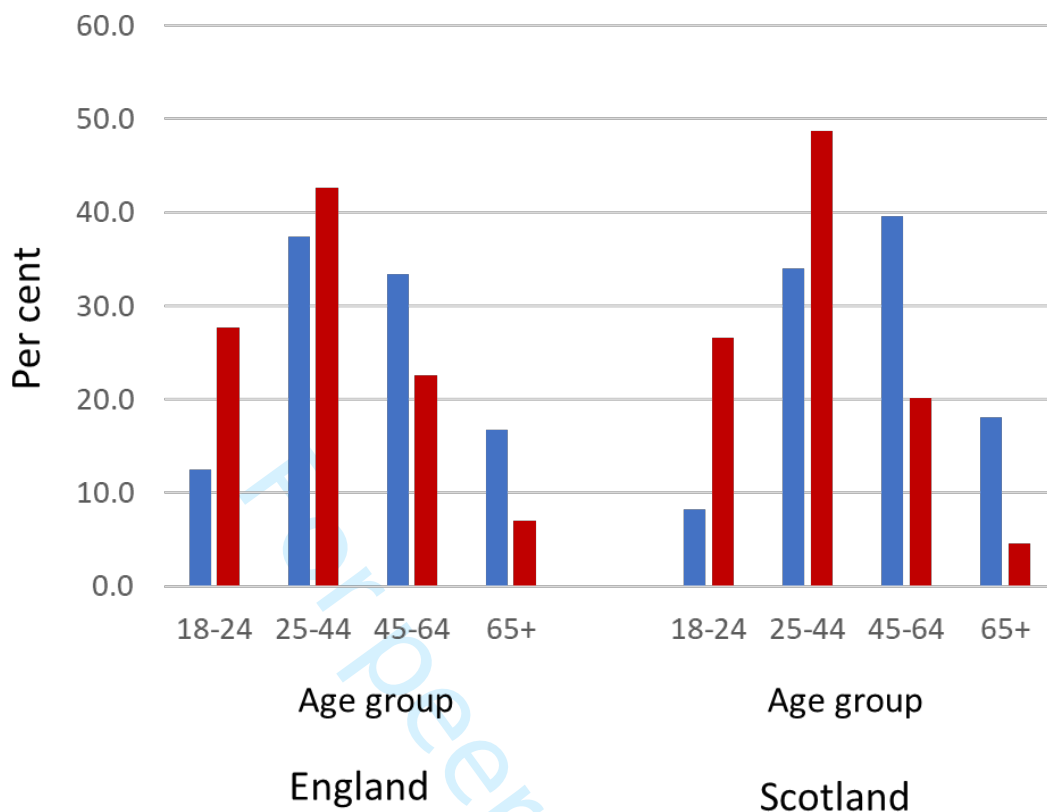


Figure 10 Distribution (per cent) of sex and age groups by country. Blue: men; red: women.

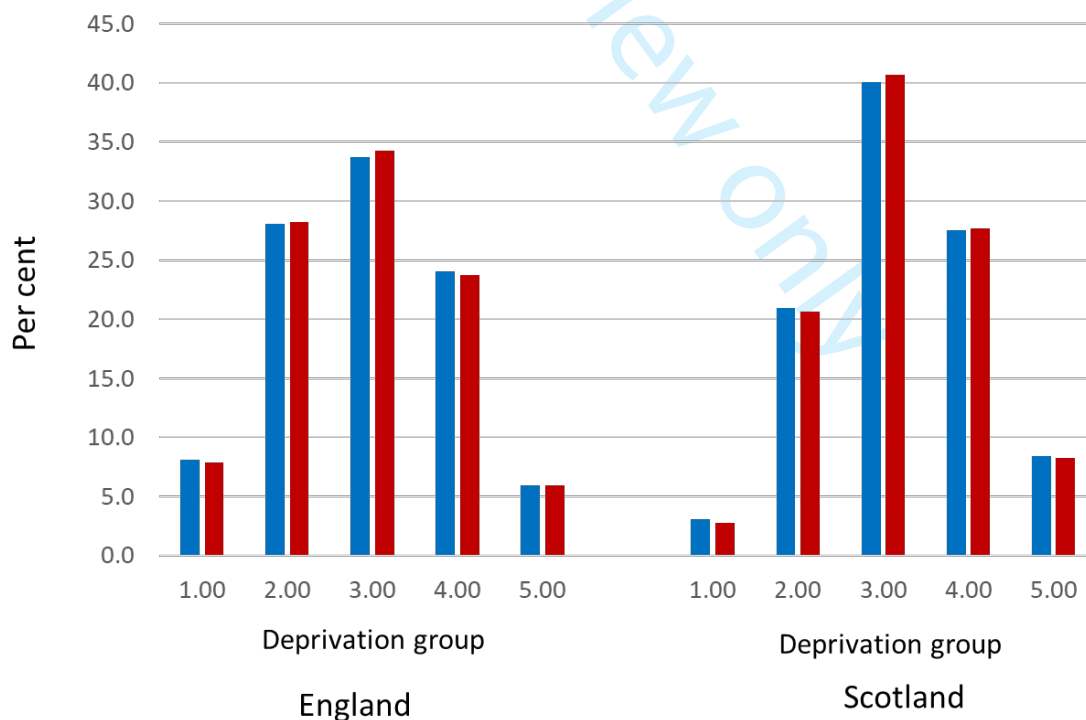


Figure 11 Distribution (per cent) of sex and deprivation groups by country. Blue: men; red: women.

Table 2 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

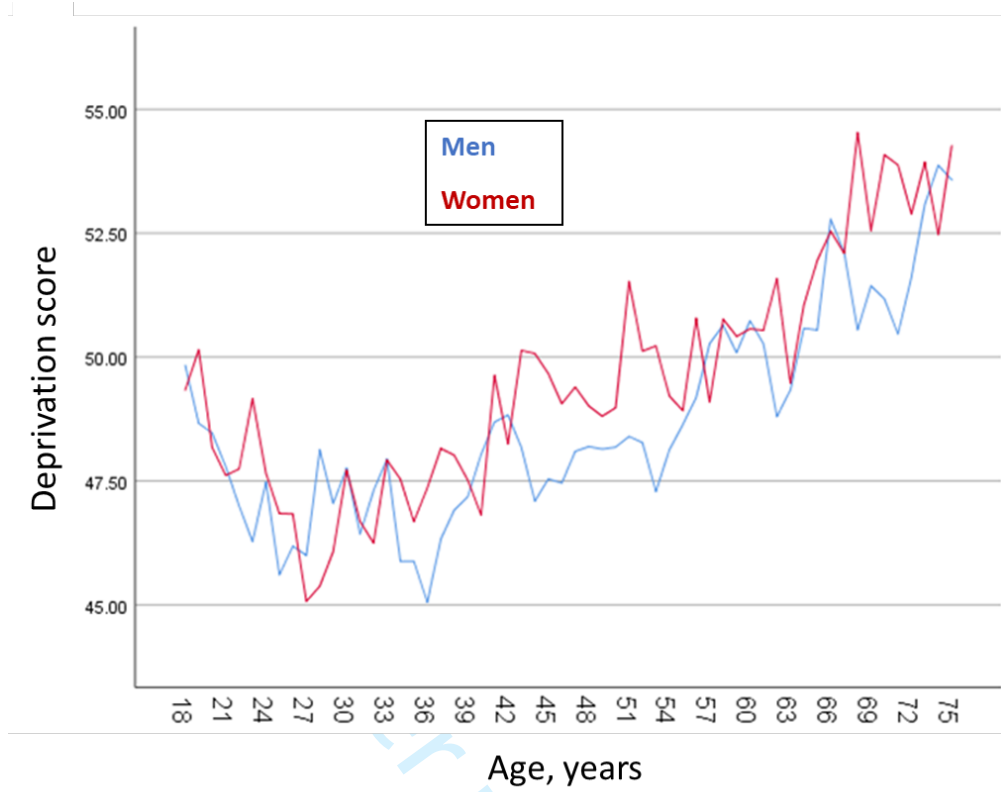


Figure 12 Mean deprivation score (higher the score, the least deprived) by age and gender.

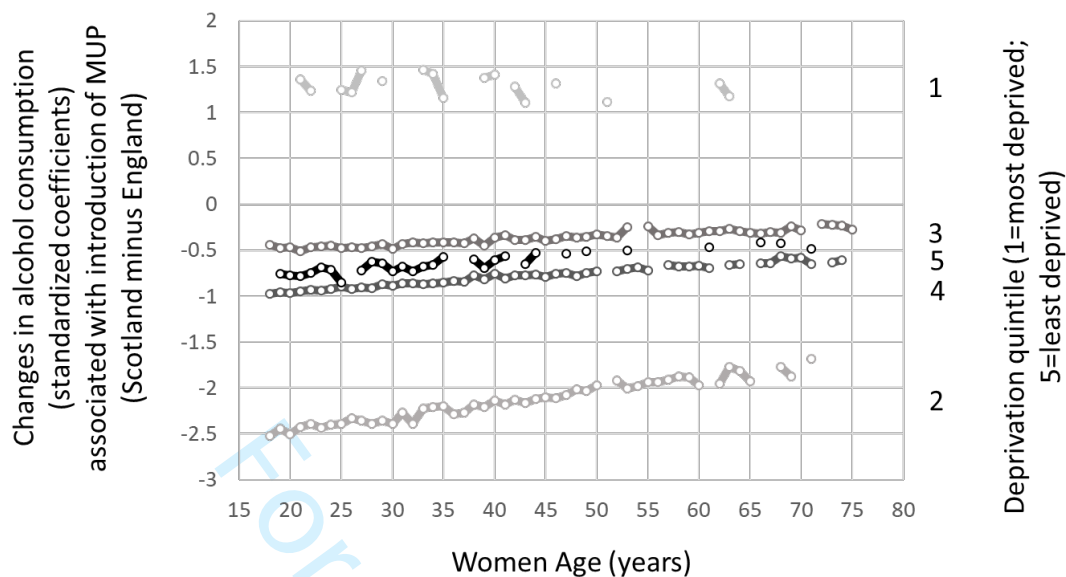


Figure 13 Associated changes in consumption (standardized coefficients) following introduction of MUP for all consumption (women) by age for each deprivation quintile (1=most deprived; 5=least deprived).

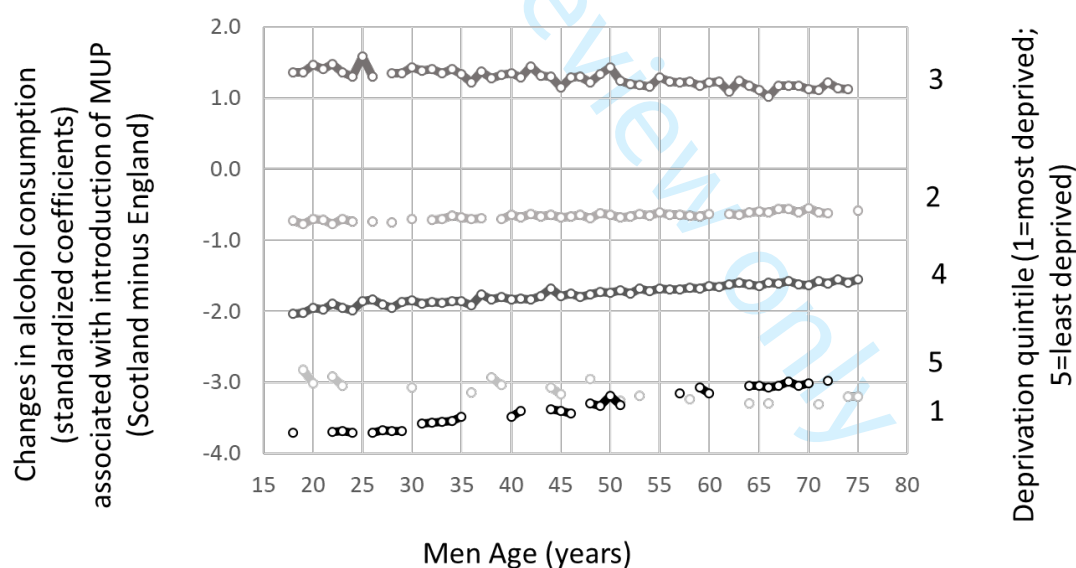


Figure 14 Associated changes in consumption (standardized coefficients) following introduction of MUP for all consumption (men) by age for each deprivation quintile (1=most deprived; 5=least deprived).

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	"controlled interrupted time series analysis" included in title and abstract, p1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract adheres to these criteria, p2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction describes the importance of the need for empirical studies of the impact of minimum unit price by sex of drinker, p3
Objectives	3	State specific objectives, including any prespecified hypotheses	Objectives included as issues to answer in last paragraph of introduction, p3
Methods			
Study design	4	Present key elements of study design early in the paper	Included in first paragraph of methods, p3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	All included in the description of the data source, p4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Fully described for interrupted time series analysis in the description of the data source, p4
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	All dependent and independent variables described in the section statistical analyses, p4-5
Data sources/	8*	For each variable of interest, give sources of	Fully described in both sections

measurement		data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	data sources and statistical analyses, p4-5
Bias	9	Describe any efforts to address potential sources of bias	Dependent variables are data from timeline follow-back surveys, p4
Study size	10	Explain how the study size was arrived at	Number of observations prior to and post introduction of minimum unit price meet all criteria required for interrupted time series analyses and are based on weekly data for the four years 2015-18.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why.	Fully described in the statistical analyses section, p4-5
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Detailed descriptions of the interrupted time series analyses are described in the statistical analysis section, p4-5.
		(b) Describe any methods used to examine subgroups and interactions	How the data were split into groups of respondent characteristics is described in the methods, p5.
		(c) Explain how missing data were addressed	No missing data, p4
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(e) Describe any sensitivity analyses	We did not undertake sensitivity analysis as it did not seem required.

Continued on next page

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Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	All respondents and all weeks included in analyses, p4-6
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Distribution of demographic characteristics of households described in methods. No confounders added to model, p4
		(b) Indicate number of participants with missing data for each variable of interest	No missing data.
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Not applicable
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	Not applicable
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Not applicable
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Estimates given with 95% confidence intervals. No confounders included in models (see above), p6-8
		(b) Report category boundaries when continuous variables were categorized	Category groupings for respondent characteristics described, p4.
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not relevant
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Additional analyses for respondent groupings described, p5.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Included in first paragraph of discussion, p9.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Main limitations (e.g., use of survey data) fully described in discussion, p9.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity	Included in Conclusion paragraph, p9

of analyses, results from similar studies, and
other relevant evidence

Generalisability	21	Discuss the generalisability (external validity) of the study results	Included conclusion paragraph, p9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	No funding was received in support of the study, p10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-054161.R1
Article Type:	Original research
Date Submitted by the Author:	18-Nov-2021
Complete List of Authors:	Rehm, Jürgen; CAMH, Social and Epidemiological Research O'Donnell, Amy; Newcastle University Kaner, Eileen; Newcastle University Jane Llopis, Eva; Maastricht University; Ramon Llull University Manthey, Jakob; Technische Universität Dresden, Institute of Clinical Psychology and Psychotherapy Anderson, Peter; Newcastle University; Maastricht University
Primary Subject Heading:	Public health
Secondary Subject Heading:	Addiction
Keywords:	PUBLIC HEALTH, SOCIAL MEDICINE, Substance misuse < PSYCHIATRY

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

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Words: 6500

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 Controlled interrupted time series analysis, supplemented with before and after analysis, of the impact of introducing MUP in Scotland, using the alcohol consumption data for England as control.

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

Participants 53,347 women and 53,143 men.

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

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

Results The introduction of MUP was associated with a drop in reported consumption of 5.94 grams per week (95% CI=1.29-10.60 grams), with a drop in off-trade consumption of 3.27 grams per week (95%CI=-0.01-6.56 grams), and a drop in on-trade consumption of 2.67 grams per week (95%CI=-1.48-6.82 grams). Associated reductions were larger for women than for men and were greater amongst heavier as opposed to lighter drinkers, except for the 5% of heaviest drinking men, who seemed to increase their consumption. Reductions in women's consumption were greater amongst younger women and those living in more deprived areas; reductions in men's consumption were greater amongst older men and those living in less deprived areas. Younger men and men living in more deprived areas seemed to increase their consumption.

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.

Funding: No funding was received in support of this study.

Strengths and limitations of this study

- The study uses a large commercial data set 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 the sex, level of alcohol consumption, age, social grade, and level of residential deprivation of respondents.
- The sample of respondents is not a random sample, rather a quota sample and cannot claim 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.

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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 World Health Organization 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 (that is, 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 (e.g.,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 grams) of pure alcohol (ethanol) sold (6.25 pence per gram) beginning on May 1, 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 studies¹¹ 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 £0.50 GB 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 Alcovision survey,¹⁴ a continuous retrospective online timeline follow-back (TLFB) diary survey, allows us to specifically investigate gender-based impact of MUP in Scotland using England as a control group. In addition to allowing us to disaggregate consumption by socio-demographic 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 socio-economic strata who would be most affected by MUP.

METHODS

Study design

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. We undertook before and after analyses, as a validity check, investigating 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 Kantar WorldPanel (KWP) Alcovision survey,¹⁴ an ongoing cross-sectional online timeline follow-back (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 seven days, including details on brands and volumes drunk, and whether these are consumed off-trade (for example, at home) or on-trade (for example 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 geographic 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 to ensure representativeness of British adults. Based on client requests, Kantar oversamples residents from Scotland and 18-34-year-olds from both England and Scotland, (see Supplement Figures 1-2, page 1). In the data set we analysed, 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).

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 English¹⁷ and the Scottish¹⁸ Indices of Multiple Deprivation to group respondents into levels of residential deprivation. The indices are calculated differently for England and Scotland. In England, the index is estimated at Lower-Layer Super Output Areas, data zones 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 2). 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 3). 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), (Supplement Figure 6, page 4). 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 4).

The number of drinks consumed were recorded separately for on- and off-trade, with information given on serving sizes in millilitres (ml). In the data set that we analyzed, we had records of all drinks consumed during the seven-day time-period, but not specified by day of week. Drinks were categorized within 19 categories, which we collapsed, grouped, and coded as beers, ciders, wines, spirits, fortified wines, and ready-to-drink products. In the data set we analyzed, detailed product description was provided for beers, including alcohol-free beers, but not for the other beverages. For non-beer products, the alcohol by volume (ABV) averages of the categories obtained from household purchase data over the same four 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 grams 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: (i) four age groups (18-24; 25-44; 45-64; and 65+ years); and (ii) 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, on-trade consumption, and off-trade consumption. We plotted the seasonally adjusted total consumption over time (study week) by England and Scotland (Supplement Figure 8, page 5). 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 Supplement Table 1, page 5).

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

Interrupted time series analyses

Interrupted time series analyses²¹ were done 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 for each of the weeks for: (i) the average consumption of all grams of all alcohol per week, separately for men and women; (ii) the average

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3 consumption of all grams of all alcohol per week consumed off-trade (e.g., at home), separately for
4 men and women; and, (iii) the average consumption of all grams of all alcohol per week consumed
5 on-trade (e.g., in pubs, bars or restaurants), separately for men and women.
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8 For each of the three dependent variables, we examined the distribution visually and with Q-Q plots
9 and found all variables, being the differences Scotland minus England for the means of consumption
10 by respondent for each of the 208 weeks, to be normally distributed (see Supplement Figures 8 and
11 9, page 6). We adjusted the dependent variables for any seasonality, using the ratio-to-moving-
12 average method.²² Based on Durbin-Watson tests (range 1.53 to 2.18), there was no evidence of
13 autocorrelation, and based on Augmented Dickey-Fuller tests, the series were found to be stationary
14 (see Table 1 in Results section). We examined the immediate and permanent level changes due to the
15 event, the introduction of MUP in Scotland, at Week 174. The event variable was entered as a dummy
16 variable, coded with 0 for each week before the event and with 1 for each week from the event
17 forwards. Thus, in our generalized linear regression models, which we ran separately for men and for
18 women, the dependent variables were the difference in reported consumption of grams of alcohol
19 between Scotland and England. The independent variables were the dummy-variable event, and time
20 (each week from 1 to 208). The regression equation is:
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23 Regression equation 1

24 Difference in consumption = intercept + time + event + error

25 where time is weeks 1 through week 208, and the event is the dummy-coded variable for the
26 introduction of MUP. (For SPSS syntax, see Supplement Box 1, page 7).
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29 We repeated the models separately for each of the: four age groups; four social grade groups; and
30 five deprivation groups (thus, comparing same groups in England and Scotland). For these analyses,
31 we transformed the continuous variables into their z-scores and used the z-scores as the dependent
32 variables, so that the results could be compared between groups in terms of standard deviations,
33 rather than original units. This allowed us to compare the relative importance of the regression
34 coefficients, and thus changes, across the socio-demographic characteristics of the respondents.
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37 For the analyses by the separate consumption percentiles, for each separate percentile, we also
38 created a difference in consumption by subtracting the mean consumption, Scotland minus England.
39 We repeated regression equation 1 separately for each of the 19 percentiles (from 5% to 95%) and
40 plotted the coefficient and 95% confidence intervals associated with the event (introduction of MUP)
41 by the percentile, separately for men and women.
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44 **Sensitivity analysis**

45 We repeated the main interrupted time series analyses using men and women resident in Northern
46 England as control for Scotland, rather than all of England.
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49 **Before and after analyses as validity check**

50 The before-and-after analyses were done with individual-respondent seven-day consumption data
51 summed across each week, separately for men and women as a validity check to better understand
52 variation in the associated impact of MUP by age and deprivation, for each individual age and each
53 individual deprivation score, rounded to an integer, rather than by the four age groups and the five
54 deprivation groups used in the interrupted time series analyses. For these analyses, we did not
55 compute a new dependent variable (Scotland minus England), but rather used the original data by
56 country. We examined the distribution of the dependent variables and found them to be highly
57 dispersed (see Supplement Figures 10-11, page 8). We treated the dependent variables as count
58 variables (rounded to integers) and used a negative binomial probability distribution for the
59
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dependent variables, self-reported consumption of alcohol in grams per week (for total consumption, on-trade consumption and off-trade consumption), with a Logit link function $[f(x)=\ln(x / (1-x))]$.²³

The independent variables were as follows: the event variable (introduction of MUP) was 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, with the following regression equation:

Regression equation 2

Consumption (log link function) = intercept + time + event + country + age/or/deprivation score as dummy-coded variables for each individual age and for each individual deprivation score + country*event + country*event*age/or/deprivation score (each age or deprivation score as a dummy coded variable) + error (For SPSS syntax, see Supplement Box 2, page 7).

where

- time is weeks from 1 to 208
- event is the dummy coded variable for the introduction of MUP
- country is England or Scotland
- 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.

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% confidence interval 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 each individual deprivation score. We plotted the differences of the marginal means as above (with their 95% confidence intervals) for men and women separately, by each age and each integer deprivation ranking, respectively.

Given the relationship between age and deprivation score (Supplement Figure 7, page 4), 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 a regression model as follows:

Regression equation 3

Differences in consumption, Scotland minus England (as derived above from regression equation 2) = intercept + age + deprivationgroup + age*deprivationgroup + error. (For SPSS syntax, see Supplement Box 3, page 7).

Sensitivity analysis

We repeated the before and after analyses excluding all respondents with zero consumption during the week. This time, we took the natural log of the consumption data, resulting in a normal distribution of the natural logged data (see Supplement Figures 12-13, page 9). We repeated regression equation (2), with the dependent variables the natural logs of reported consumption and an identity link function. We took the exponential of the resultant coefficients and plotted the by age and deprivation score separately for men and women.

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

Analyses were performed with SPSSv26 (IBM Corp 2019).²⁵ For our regression models, we used generalized 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 data set (for details of numbers of respondents by country, before and after the introduction of MUP and by socio-demographic characteristics, see Supplement Table 2, page 10). 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 11-13). Whereas Scottish women 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 12).

For all respondents (English and Scottish), the mean reported consumption per week was 125.8 grams for men (66.4% consumed off-trade) and 71.3 grams for women (71.3% consumed off-trade; for details, see Supplement Table 6, page 14). Consumption decreased with age, 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) (see Supplement Figure 14, page 15). Consumption decreased by only a small amount with decreasing deprivation, 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), (see Supplement Figure 15, page 15).

Interrupted time-series analyses – main findings

Figure 1 plots the differences in consumption of alcohol (grams) Scotland minus England for each of the 208 weeks, 2015-2018. Table 1 gives 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 drop in consumption of 5.9 grams per week (95% CI=1.3 to 10.6 grams) (a 6.2% drop from the mean pre-MUP level in Scotland, 95% CI=2.3% to 8.4%). The reductions in consumption seem largely driven by women (a reduction of 8.6 grams per week, 95%CI=2.9 to 14.3 grams) rather than by men (a reduction of 3.3 grams per week, 95%CI=-3.6 to 10.4). Supplement Table 7, page 16, gives the results of the models with the interaction terms (sex of 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 -8.801 grams per week (-15.672 to -1.930 grams).

Figure 1 here

Table 1. Unstandardized coefficients from interrupted time series analyses (95% confidence intervals) for all respondents, and separated for men and women, 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. The level change is the estimated reduction in consumption of alcohol in Scotland (grams per week) associated with the introduction of MUP, controlling for any changes in England.

		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	0.003 (-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)	-.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)	0.417 (-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)

Interrupted time-series analyses – sensitivity analyses

Table 2 gives 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 drop in consumption of 5.9 grams per week (95% CI=2.6 to 9.2 grams), 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 6.022 grams per week (95% CI=1.035 to 11.009 grams), a slightly lower level to that when using all of England as a control (see Supplement Table 8, page 16).

Table 2 Sensitivity analysis, using Northern England as a control for Scotland. Unstandardized coefficients from interrupted time series analyses (95% confidence intervals) for all respondents, and separated for men and women, by total consumption, off-trade consumption, and on-trade consumption. The level change is the estimated reduction in consumption of alcohol in Scotland (grams per week) associated with the introduction of MUP, controlling for any changes in Northern England.

		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 .167)	-7.487 (-12.269 to -2.704)
	Time in weeks	.009 (-.012 to .030)	.022 (-.005 to .050)	-.005 (-.035 to .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 -.591)	.658 (-2.328 to 3.643)	-6.715 (-10.062 to -3.367)
	Time in weeks	.022 (.007 to .037)	.025 (.006 to .043)	.019 (-.002 to .040)
On-trade consumption	Intercept	2.565 (-.034 to 5.165)	2.846 (-.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 .672)	-.772 (-6.841 to 5.297)
	Time in weeks	-.013 (-.039 to .013)	-.002 (-.037 to .033)	-.024 (-.062 to .014)

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 17). 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 seeming greater for women than for men. For the 95th percentile for men, the introduction of MUP seemed to be associated with an increase in consumption. For the 95th percentile for women, the confidence intervals crossed zero.

Figure 2 here

Figure 3 displays 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 standardized coefficients, allowing for relative, rather than absolute comparisons across the groups (for numerical data, see Supplement Tables 9-11, pages 18-20).

Figure 3 here

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3 By age group (top graph), in general, it seemed that there were greater associated drops in all
4 consumption and in off-trade consumption for both men and women with increasing age. For younger
5 men, there was an increase in off-trade consumption, which was offset by decreases in on-trade
6 consumption in the same group. There appeared no clear or consistent discernible pattern by social
7 grade (middle graph), or by deprivation group (bottom graph).
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10 11 12 **Before and after analyses as validity check**

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14 We undertook the before-and-after analyses as validity checks to better understand variation in the
15 associated impact of MUP by each individual age and each individual deprivation score, rather than as
16 grouped variables as were used for the interrupted time series analyses (as in Figure 3 above). Figure
17 4 plots the associated changes in alcohol consumption (in grams of alcohol) following introduction of
18 MUP for all consumption, off-trade consumption, and on-trade consumption by gender and age. We
19 extracted the mean values of the changes (y-axes) from the plots and performed a linear regression
20 of these values by age. For men, reductions in consumption following the introduction of MUP became
21 greater with increasing age, more so for total consumption (linear regression coefficient across age
22 (RC) =-0.533 (95%CI=-0.548 to -0.518) and off-trade consumption (RC =-0.368 (95%CI=-0.376 to -
23 0.360) than for on-trade consumption (RC =-0.167 (95%CI=-0.174 to -0.160). For younger men (those
24 aged less than 35 years), the introduction of MUP was associated with increased consumption, more
25 so the younger the age. For women, there was a different pattern with less pronounced changes with
26 age; reductions in off-trade consumption became slightly greater with increasing age (RC =-0.062
27 (95%CI=-0.065 to -0.060) and reductions in on-trade consumption slightly smaller with increasing age
28 (RC =0.108 (95%CI=0.102 to 0.114); and reductions in total consumption became very slightly smaller
29 with increasing age (RC =0.046 (95%CI=0.043 to 0.049). The coefficient for the interaction term,
30 sex=men by age, was -0.579 (95%CI=-0.594 to -0.564) confirming the difference in the slopes by age
31 between men and women.
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42 **Figure 4 here**

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44 Figure 5 plots the associated changes in alcohol consumption (in grams of alcohol) following the
45 introduction of MUP for all consumption, off-trade consumption, and on-trade consumption by
46 gender and deprivation ranking. We extracted the mean values of the changes (y-axes) from the plots
47 and performed a linear regression of these values by deprivation score. For men, reductions in
48 consumption following the introduction of MUP became greater with less deprivation, more so for on-
49 trade consumption (RC =-0.164 (95%CI=-0.169 to -0.158) and total consumption (RC =-0.246 (95%CI=-
50 0.254 to -0.239) than for off-trade consumption (RC =-0.075 (95%CI=-0.078 to -0.072), with those living
51 in the most deprived areas showing some increases in consumption. For women the opposite pattern
52 was apparent; reductions in consumption following the introduction of MUP became smaller with less
53 deprivation, more so for on-trade consumption (RC =0.108 (95%CI=0.107 to 0.110) and total
54 consumption (RC =0.123 (95%CI=0.120 to 0.126) than for off-trade consumption (RC =0.017
55 (95%CI=0.016 to 0.019). The coefficient for the interaction term, sex=men by deprivation score, was -
56 0.369 (95%CI=-0.377 to -0.362) confirming the difference in slopes by age between men and women.
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Figure 5 here

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3 The age-related patterns of Figure 4 were independent of deprivation. Regression equation (3) found
4 no interaction between age in years and deprivation group in the changes in total alcohol consumption
5 in Scotland associated with the introduction of MUP: for men, the coefficient for the interaction was
6 5.7^{-7} , 95%CI -6.0^{-5} to 6.1^{-5} ; for women, the coefficient was 1.9^{-7} , 95%CI -2.2^{-5} to 6.0^{-5} . In other words,
7 the slopes between changes in alcohol consumption by age for men and women plotted in Figure 3
8 were almost identical across the five deprivation groups.
9

10 **Before and after analyses – sensitivity analyses**

11 We repeated the before and after analyses excluding all respondents who reported zero alcohol
12 consumption during the previous week and using logged grams of alcohol consumption as the
13 dependent variable, with similar patterns of findings to Figures 3 and 4 (see Supplement Figures 17
14 and 18, Page 22).
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20 **DISCUSSION**

21 We found that MUP was associated with a change in overall reported alcohol consumption in line with
22 the predicted direction. Compared to respondents from England, Scottish respondents reported a
23 6.2% drop in alcohol consumption (95% CI=2.3% to 8.4%) associated with MUP. Sensitivity analyses
24 using respondents from Northern England, with more similar drinking levels to Scotland than England
25 as a whole,²⁶ found an almost identical associated drop in alcohol consumption. The drop in
26 consumption was larger for heavier as opposed to lighter drinkers, with the exception of the top 5%
27 of heaviest drinking men who seemed to have an increase in consumption associated with the
28 introduction of MUP.
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31 Against expectations, we found that associated drops in consumption were greater for women than
32 for men, both in the main (using all of England as a control) and in the sensitivity (using Northern
33 England as a control) analyses. Men and women also responded differently by age. Based on both the
34 interrupted time series analysis and the before and after analysis, for men, the size of the associated
35 drop in consumption seemed to get smaller with decreasing age, with younger men showing an
36 associated increase in consumption. For women, the associated drop in consumption seemed to vary
37 less by age. Whilst the interrupted times series analysis seemed to suggest that the oldest group of
38 women (aged 65+ years) had a larger associated drop in consumption than younger women (Figure 3,
39 this pattern was not present in the before and after analysis (Figure 4).
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43 We included two potential measures of socio-economic disadvantage: social grade and an index of
44 residential deprivation based on multiple measures of income, employment, education, health, crime,
45 access to housing, and environmental quality,^{17,18} noting that the risk of alcohol-related harm
46 increases both the more socio-economically disadvantaged the individual is, and, over and above that,
47 the more socially disadvantaged the residential area in which the individual resides.²⁷ It should be
48 noted that estimates of the indices of residential deprivation differ between Scotland and England,
49 and thus, in absolute terms, they may not be the same. However, in our analyses we compare relative
50 deprivation; for example, comparing the bottom fifth of deprivation of Scotland with the bottom fifth
51 of deprivation of England, noting that relative deprivation, itself, is a key determinant of ill-health.²⁸
52 Based on the interrupted time series analyses, for both men and women, there was no discernible
53 pattern by social grade or deprivation group. However, based on the before and after analysis, the
54 size of the associated drop in consumption for men seemed to get smaller with increasing deprivation,
55 with men living in the most deprived areas seeming to have an associated increase in consumption.
56 For women, the associated drop in consumption seemed to decrease slightly with decreasing
57 deprivation score.
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3 The drop in consumption of 6.2% is a little lower than the 7.6% drop we found in our previous analysis
4 of household purchase data in both the short⁹ and medium term.¹⁰ As with the present study based
5 on survey data, our previous analyses of household purchase data also found that drops in
6 consumption were greater amongst households with higher rather than lower usual purchases of
7 alcohol.^{9,10} However, with our previous analyses of household purchase data, we could not test the
8 impact of MUP on purchases by age or gender, as the purchase data were for the household as a whole
9 and not attributable to individual household family members. Nor did those analyses report the
10 impact of MUP by the social grade of the household or the level of deprivation in which the household
11 was located. The findings presented in this paper thus provide a more nuanced understanding of the
12 differential impact of MUP on different population sub-groups. Specifically, what we identified in the
13 present analysis is the top 5% of heavy drinking men did not reduce their consumption in association
14 with MUP; rather, our results suggest an increase in associated consumption amongst this group.
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18 We do not know why, for both younger men (those aged less than 35 years), and for those living in
19 residential areas in the bottom fifth of deprivation, there seemed to be an increase in consumption
20 associated with MUP, compared to older men and those living in less deprived areas who seemed to
21 decrease their consumption. It has been suggested that some very heavy drinkers (as we found for
22 the top 5% of heavy drinking men) would be less prone to the potential impact of MUP,²⁹ with a
23 response to MUP varying by individual and psychosocial factors, including socio-economic
24 disadvantage, which may interact with the situational availability of alcohol.³⁰ This is clearly an area
25 for further study.
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27
28 Before we discuss the implications of the results, it is important to mention potential strengths and
29 limitations of our study. We based our analysis on a large sample of 53,347 women and 53,143 men
30 from England and Scotland, that, apart from the oversampling of 18–34-year-olds, was representative
31 of the sex and age structure of the population (Supplement Figures 1-2). The sample was neither more
32 nor less deprived than the population of England or Scotland as a whole (Supplement Figure 3). A
33 strength of the interrupted time series analyses is the large number of data points (weekly
34 consumption) before (n=173) and from the introduction of MUP onwards (n=25), considered more
35 than sufficient for interrupted time series analyses.²² A second strength overall and for the before and
36 after analyses is the large sample size, 88,894 respondents prior to the introduction of MUP and
37 17,596 respondents thereafter. A third strength is the use of a location control, both all of England,
38 and Northern England in sensitivity analysis. Location controls allow for other extraneous factors
39 beyond the intervention to be controlled for, for example, an unusual heat wave during the months
40 of June, July and August that affected all of Great Britain.³¹
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44 For limitations, first, all results are based on subjective reports of drinking. While such subjective
45 reports tend to underestimate consumption as measured by sales or other recorded data in general
46 in all European countries (e.g.,³²), there is no reason to believe that underreporting should differ by
47 country or region, or before or after the introduction of the MUP. The timeline follow-back survey
48 method has been criticized for the limited time-period of drinking it covers, thus missing heavy
49 episodic drinking occasions among participants with a low frequency of such occasions. This limitation
50 for classifying individuals is actually a strength when it comes to the characterization of population
51 averages, however, where the shorter the time period, the smaller the biases due to memory, and the
52 more accurate the population average.³³ Second, as with all survey-based research on alcohol, this
53 research cannot claim representativeness.³⁴ Statistical theory stipulates such representativeness
54 needs to be based on probabilistic sampling design (i.e., all residents from England and Scotland need
55 to be assigned a probability > 0) combined with high response rates unaffected by systematic non-
56 response.³⁵ However, these conditions can no longer be reached in modern surveys involving alcohol,
57 no matter which methodology is used.^{34, 36, 37} Instead, post-stratification based on sex, age, social
58 grade, and geographical region was used to allow for generalizations to be made for the general
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3 population. The quota sample was derived from Kantar's managed access panel. Data were not
4 available and not attainable on the number of respondents approached to achieve the 30,000
5 respondents surveyed each year, and this information is not mentioned in existing publications based
6 on the Alcovision survey, e.g.,^{15,16}. Unlike the household purchase data which records purchases
7 wherever they are made, and thus accounts for cross-border purchases, we are unable to account for
8 any cross-border purchasing or drinking the respondents might have engaged in. If this was significant,
9 one might hypothesize that the estimated sizes of the associated impact with MUP in reducing alcohol
10 consumption would differ between using Northern England or all of England as a control, which was
11 not the case. Finally, as we only had data to end of 2018, we have been unable to examine the impact
12 of MUP beyond the immediate term.
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16 In our analysis, we used both interrupted time series analysis and before and after analyses. With the
17 interrupted time series analysis, we used England (or Northern England) as a location control, creating
18 new dependent variables, the differences between Scotland and England. Interrupted time series
19 analysis is an appropriate methodology for investigating the impact of a newly introduced natural
20 experiment (the introduction of MUP) that takes into account seasonal variation and autocorrelation
21 of the data over time.²² The before and after analysis is simply comparing the means before and after
22 the introduction of MUP. Results of before and after analyses are often presented along with
23 interrupted time series analyse, as we have done previously with household purchase data.⁹ Whilst
24 we add in an interaction term of country* event (introduction of MUP), which should take into account
25 common events outside of MUP that occurred in both Scotland and England, our analyses are unable
26 to control for seasonal variation, when comparing the longer time period before the introduction of
27 MUP and the eight month period following the introduction of MUP.
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30 Externally validated indicators,^{34, 38} using sales^{39, 40} or household purchasing data as the basis,^{9,10}
31 corroborate our results that, in comparison to England over the same and longer time periods, the
32 introduction of the MUP was associated with a decrease in alcohol consumption. Finally, the
33 reductions in alcohol consumption in Scotland were part of an overall national strategy or framework
34 for alcohol policy, where all measures had already been extensively covered in the press. It cannot be
35 excluded that the actual reductions may have been due in part to the media reports surrounding the
36 introduction of the MUP rather than to the floor pricing itself (for an example of an alcohol policy
37 measure where the media impact seems to be stronger, see⁴¹). However, it is highly unlikely that
38 media reports would produce exactly this abrupt and permanent pattern—i.e., a drop in consumption
39 starting exactly at the date of introduction of MUP and lasting for the time-period studied, in
40 comparison to a control group.
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43 Despite these potential limitations, most research corroborates the results of our study that the MUP
44 resulted in a reduction of overall alcohol consumption compared to England or Northern England.^{9, 10,}
45 ³⁹ Overall, research was based on a number of designs including purchasing data from households or
46 sales records. Our results here were based on a control group design, where the intervention was only
47 introduced in one group, thus strengthening our confidence in a real effect.⁴²
48
49

50 When the Minister for Public Health, Sport, and Wellbeing introduced the 2018 alcohol policy
51 framework,⁶ he emphasized that the implementation of the MUP was strongly motivated by an
52 interest in decreasing health inequalities through a reduction in alcohol consumption among the
53 heaviest and most vulnerable drinkers. Our results indicate that this goal may not be fully realized:
54 first, we found that women, who are less heavy drinkers in our data, and in almost all surveys
55 worldwide to date,⁴³ reduced their consumption more than men; second, the 5% of heaviest drinking
56 men seemed to have an increase in consumption associated with MUP; and, third, younger men and
57 men living in more deprived areas seemed to have an increase in consumption associated with MUP.
58 These results are surprising—as modelling studies would have suggested otherwise (e.g.;^{11, 14}). The
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3 results may also imply a diminished impact on alcohol-attributable hospitalisations and mortality,
4 which have been shown to be strongly associated with heavy drinking in men and in those of lower
5 socioeconomic status.⁴⁴⁻⁴⁷ Indeed, a large, controlled study on emergency room visits following the
6 introduction of MUP did not show any reduction in emergency room visits.⁴⁸
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8
9 Before any further conclusions can be drawn, we need to corroborate our sex-, age-, heavy drinking-
10 and socioeconomic status-related findings in different studies. This seems important as different
11 conclusions about MUPs impact may result for other countries. If indeed the findings of our study are
12 corroborated, then additional and/or different pricing mechanisms may need to be considered to
13 reduce alcohol-attributable hospitalizations and mortality. For instance, several harms from alcohol
14 use are specifically linked to on-trade drinking, such as public disorder and violence.⁴⁹ Recent
15 experiences in Lithuania have shown substantial reductions in all-cause mortality following a taxation
16 increase, that mainly affected men.⁵⁰
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20 **Acknowledgements:** We thank Kantar WorldPanel for providing the raw data and reviewing the
21 method description as it describes the consumption data. Kantar WorldPanel had no role in the study
22 design, data analysis, data interpretation, or writing of the manuscript. Professor Kaner, supported
23 by a National Institute for Health Research (NIHR) Senior Investigator award, is Director of the NIHR
24 Applied Research Collaboration, North East and North Cumbria. Dr. O'Donnell is a National Institute
25 for Health Research (NIHR) Advanced Fellow. The views expressed in this article are those of the
26 authors and not necessarily those of NIHR, or the Department for Health and Social Care.
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28

29 **Contributors:** JR conceptualised the paper and prepared the initial draft of the introduction and
30 discussion. PA undertook the analyses and prepared the draft of the methods and results and
31 submitted the paper. PA, AO'D, EJ-L, JR, JM and EK refined the various versions of the full paper and
32 approved the final manuscript for submission. The corresponding author attests that all listed authors
33 meet authorship criteria and that no others meeting the criteria have been omitted. All authors had
34 access to the data used for analyses, and PA, AO'D and EJ-L verified the raw data sets received from
35 Kantar WorldPanel and are the guarantors for the data used for the analyses.
36
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38 **Competing interests:** All authors have completed the ICMJE uniform disclosure form at
39 www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted
40 work; within the previous five years, PA declares receipt of funds from AB InBev Foundation to provide
41 evidence-based public health comment on the proposed content and evaluation of the Foundation's
42 global drinking goals, outside of the submitted work; the remaining authors declare no financial
43 relationships with any organisations in the previous five years that might have an interest in the
44 submitted work; all authors declare no other relationships or activities that could appear to have
45 influenced the submitted work.
46
47

48 **Ethical approval:** Not required.
49

50 **Data sharing:** No additional data available. Kantar WorldPanel data cannot be shared due to licensing
51 restrictions.
52

53 **Affirmation:** PA and AO'D affirm that the manuscript is an honest, accurate, and transparent account
54 of the study being reported; that no important aspects of the study have been omitted; and that any
55 discrepancies from the study as initially planned have been explained.
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20 **Figure 1** Plots of average weekly alcohol consumption (smoothed) for all respondents, Scotland minus England,
21 by week of study period for total alcohol consumption, off-trade consumption (e.g., at home) and on-trade
22 consumption (e.g., in pubs, bars and restaurants).
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24 **Figure 2** Associated changes in the difference in consumption (Scotland minus England) following the
25 introduction of MUP by drinking percentile distribution of total consumption. Blue lines: men; red lines: women.
26 Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change).
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29 **Figure 3** Associated changes in consumption following introduction of MUP for all consumption, off-trade
30 consumption, and on-trade consumption by age group, top graph; social grade, middle graph; and, deprivation
31 group, bottom graph for men (blue) and women (red). Consumption changes are standardized coefficients from
32 interrupted time series analyses with 95% confidence intervals.
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35 **Figure 4** Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated
36 with the introduction MUP in Scotland, controlling for changes in England for each age year. Plots of men and
37 women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner
38 lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change). The changes are derived from
39 the model of regression equation 2; they represent, for each age, the difference in the marginal means (and 95%
40 confidence intervals of the differences) for [Scotland*event (introduction of MUP) *age (dummy coded variable
41 for each age)] minus [England*event (introduction of MUP) *age (dummy coded variable for each age)].
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44 **Figure 5** Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated
45 with the introduction MUP in Scotland, controlling for changes in England for each deprivation score. Plots of
46 men and women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines:
47 means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change). The changes
48 are derived from the model of regression equation 2; they represent, for each deprivation score (the higher the
49 deprivation score, the less deprived), the difference in the marginal means (and 95% confidence intervals of the
50 differences) for [Scotland*event (introduction of MUP) *deprivation score (dummy coded variable for each
51 deprivation score)] minus [England*event (introduction of MUP) *deprivation score (dummy coded variable for
52 each deprivation score)].
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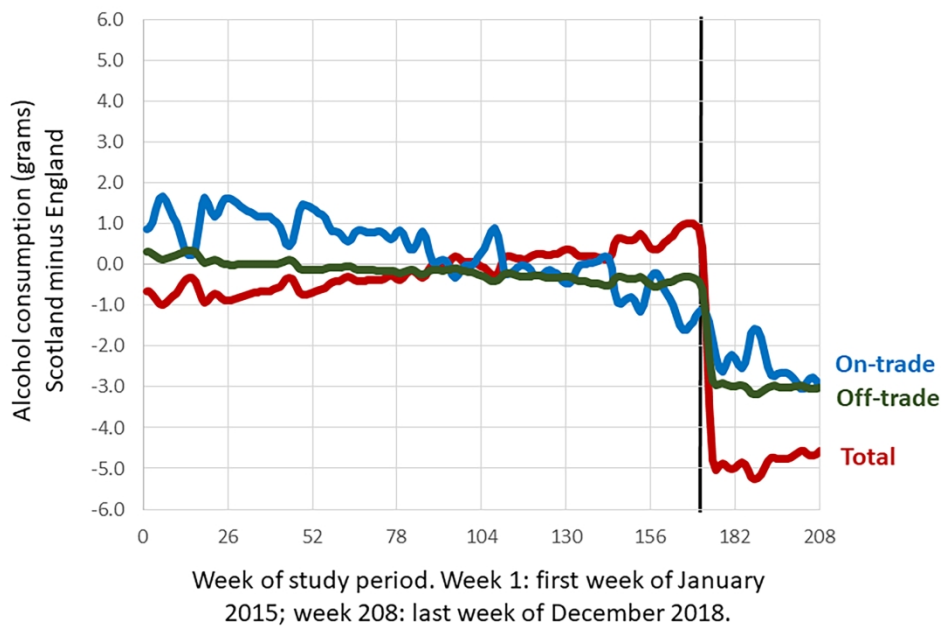


Figure 1

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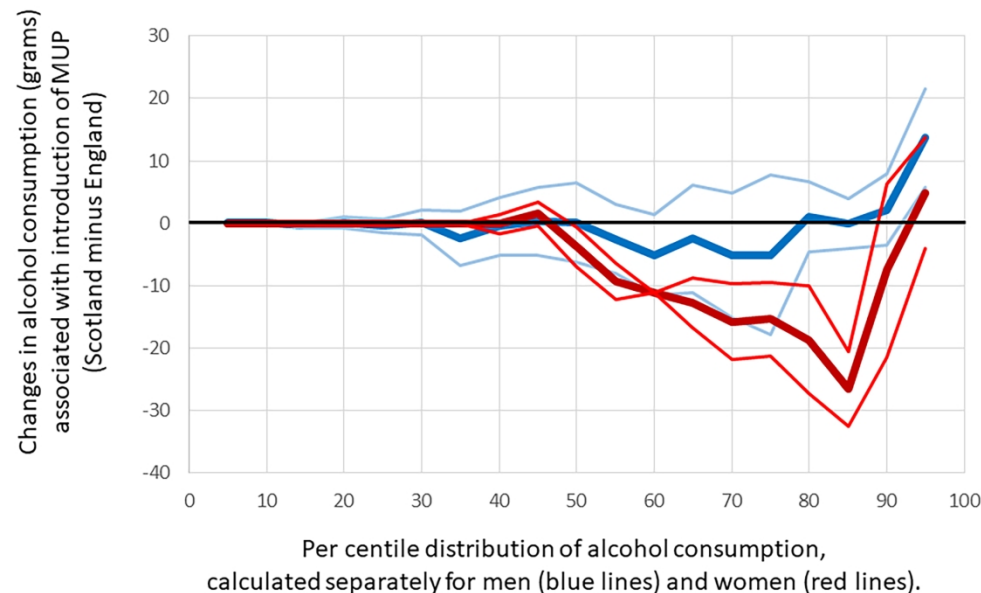


Figure 2

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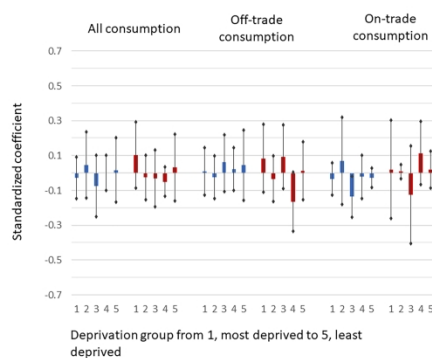
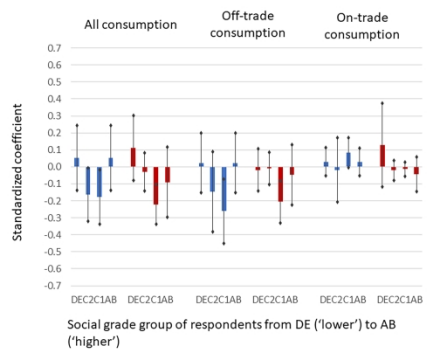
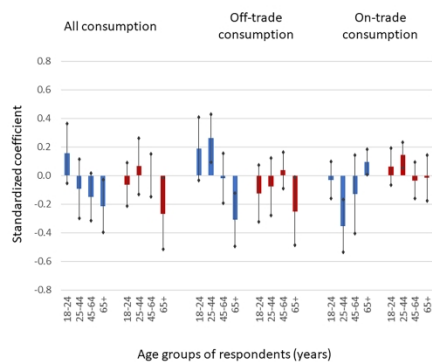


Figure 3

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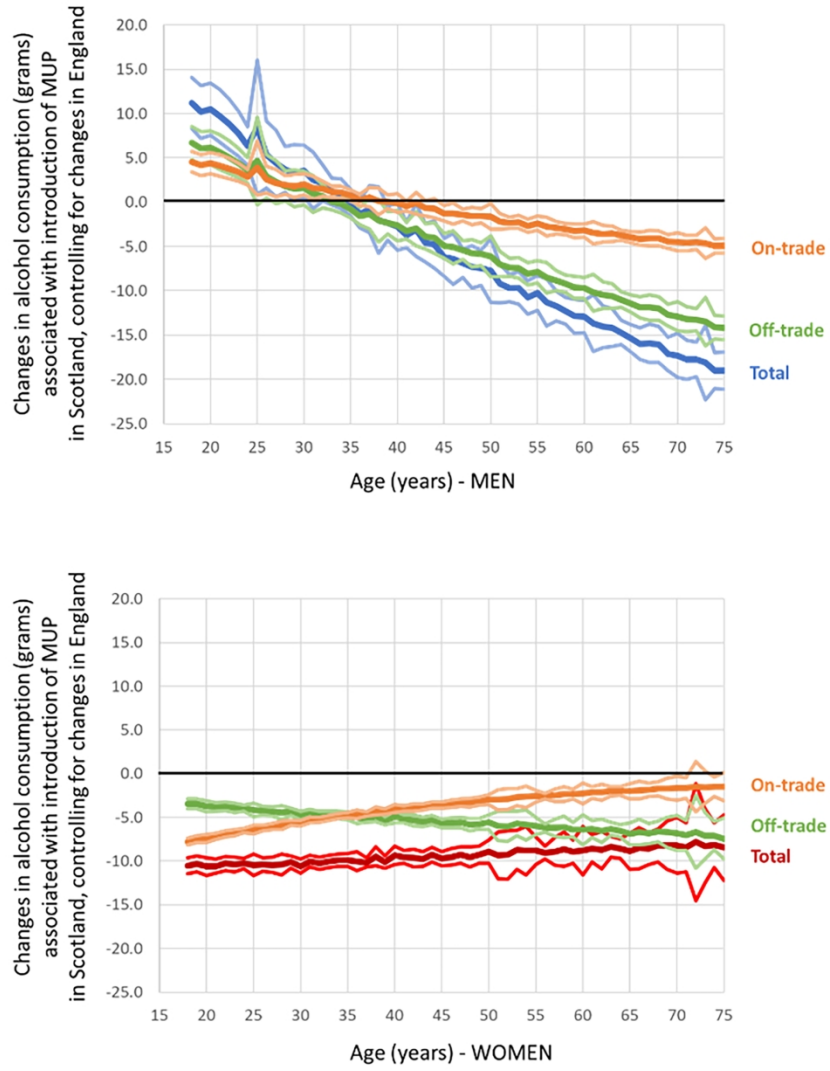


Figure 4

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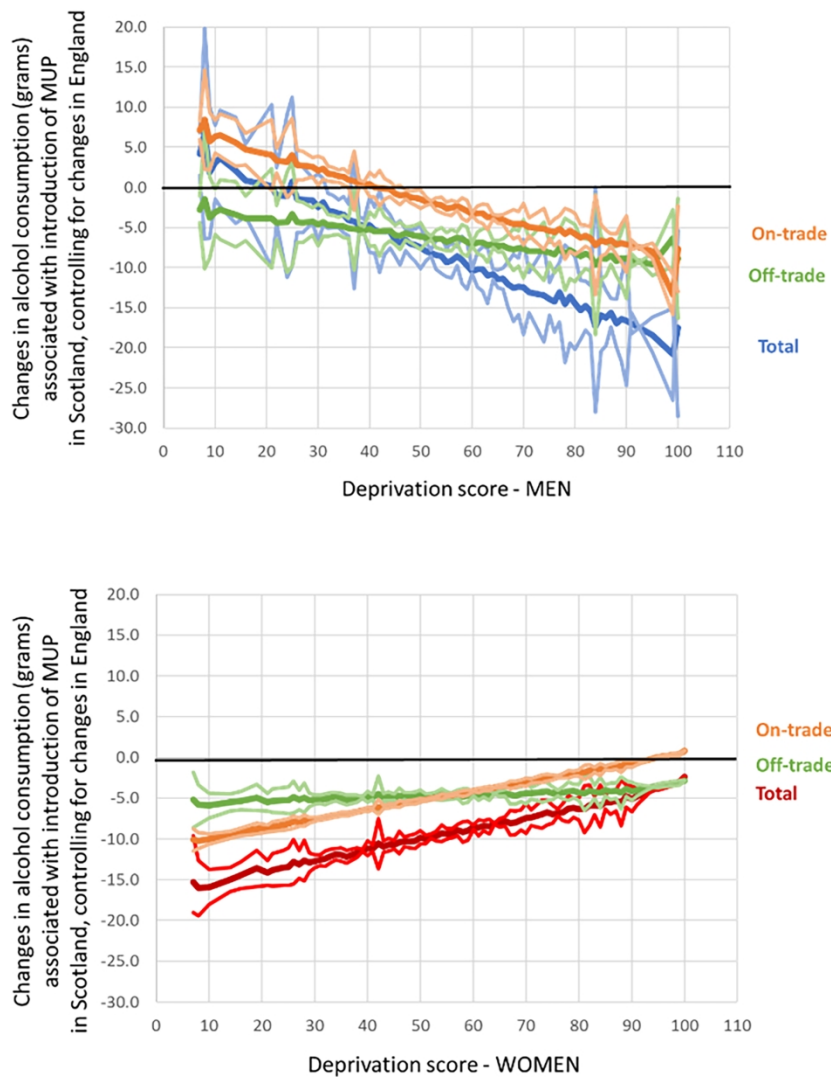


Figure 5

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SUPPLEMENT

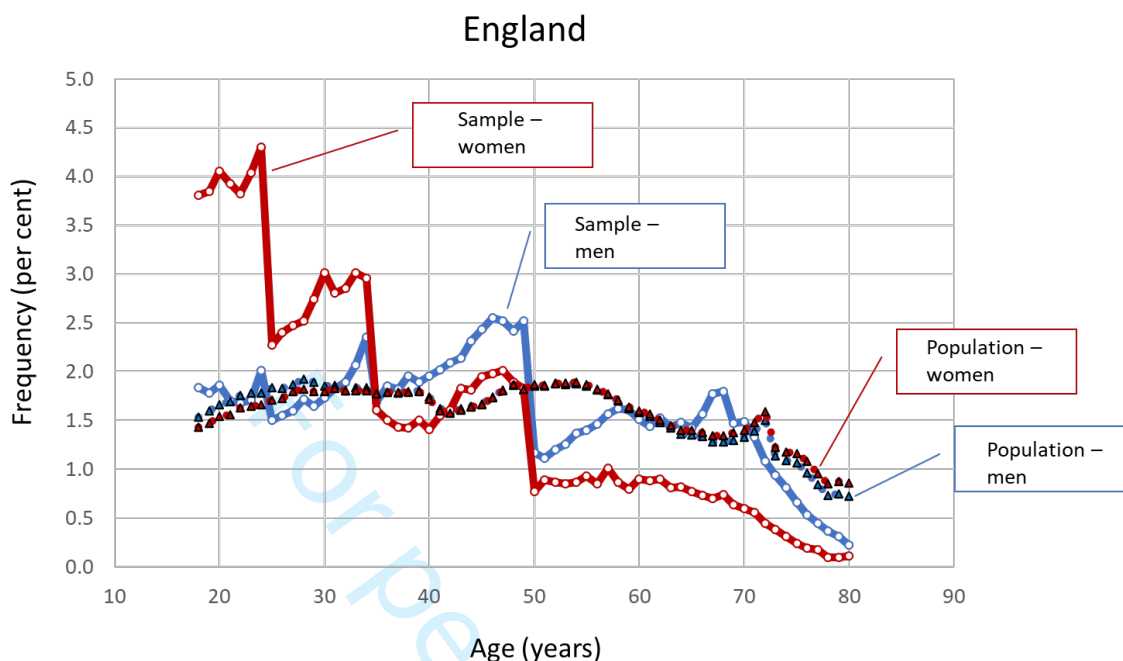


Figure 1 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for range 18-80 years), England. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and Northern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

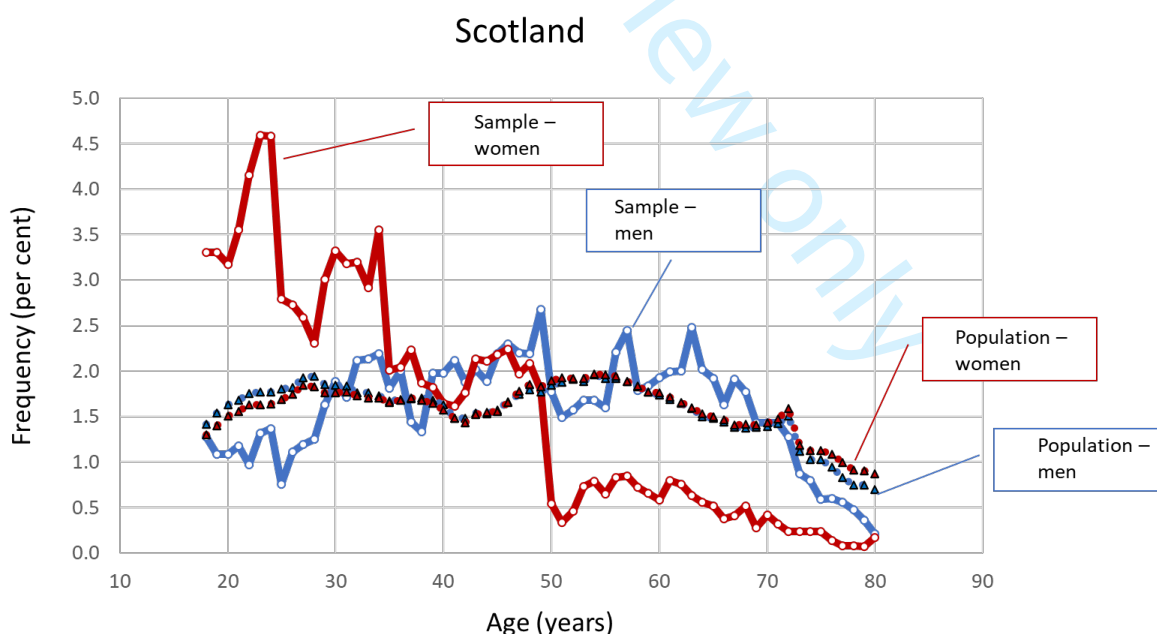


Figure 2 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for age range 18-80 years), Scotland. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and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

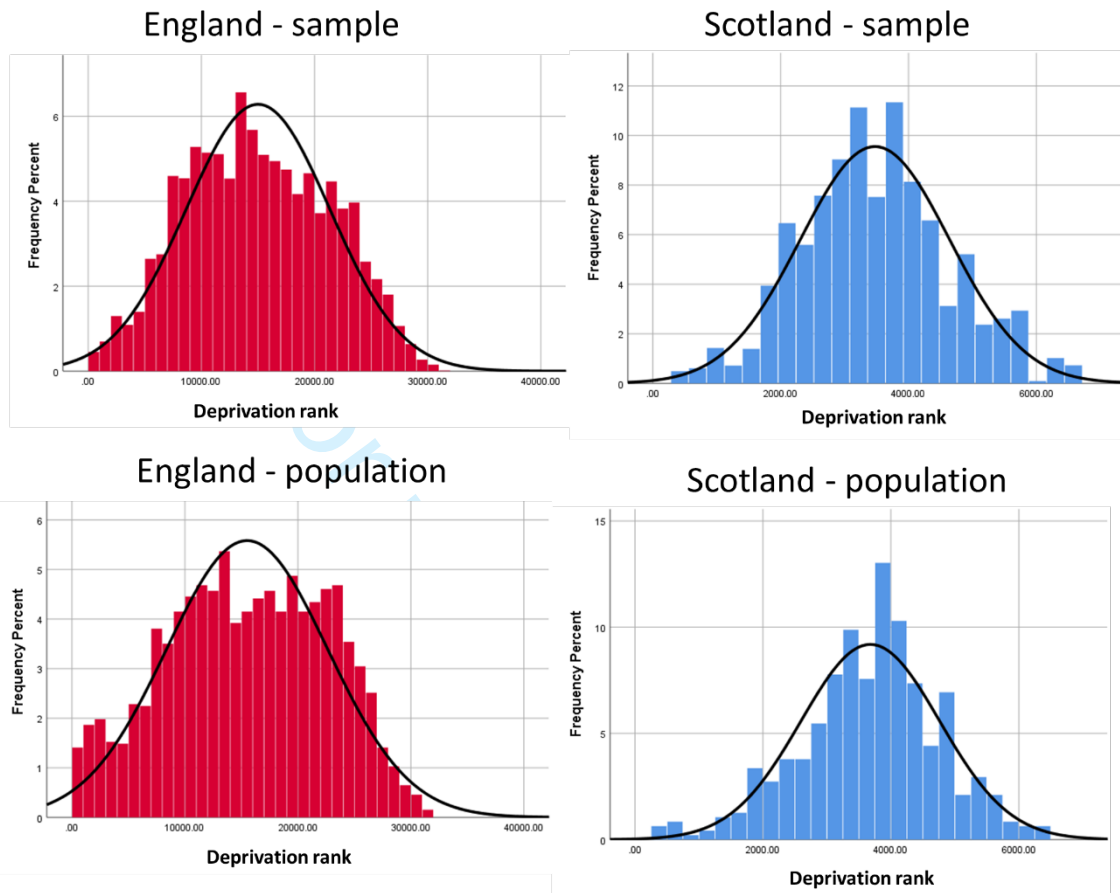


Figure 3 Per cent distribution (vertical axes) for analyzed sample and total population by deprivation rank (horizontal axes), England and Scotland. Data for total population from GOV.UK. National Statistics: English indices of deprivation 2019. <https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019>;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

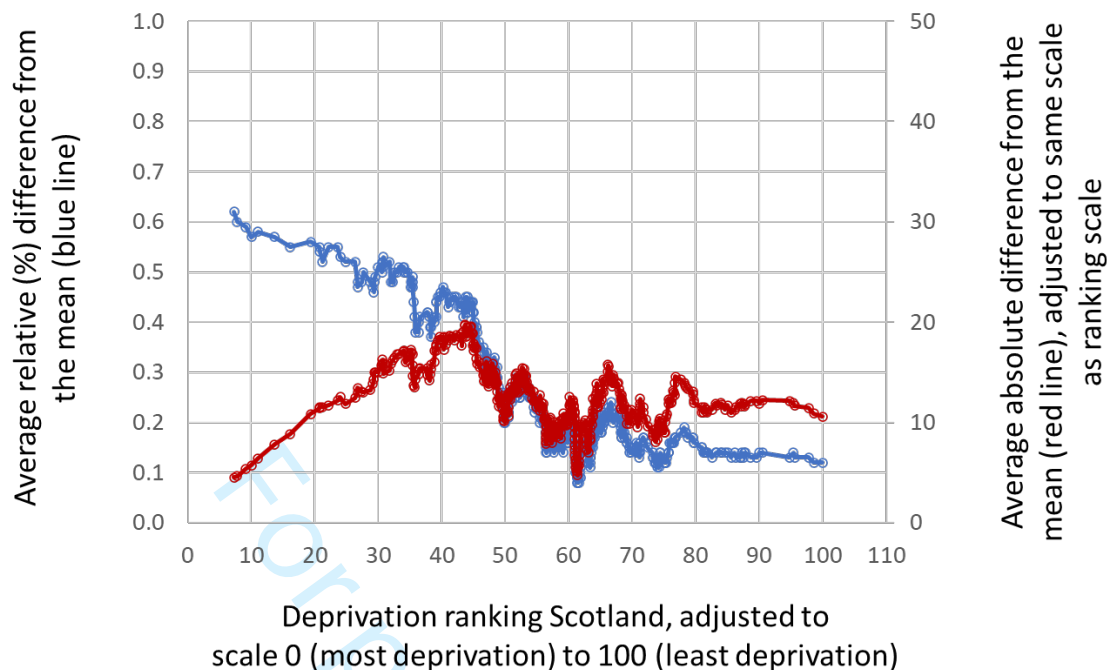


Figure 4 Dispersion of aggregated deprivation ranking, Scotland. The horizontal axis is the ranking from 0 (most deprived) to 100 (least deprived). The red line (right vertical axis) is the average absolute difference of the original ranking at local data zone level from the mean calculated at the truncated 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).

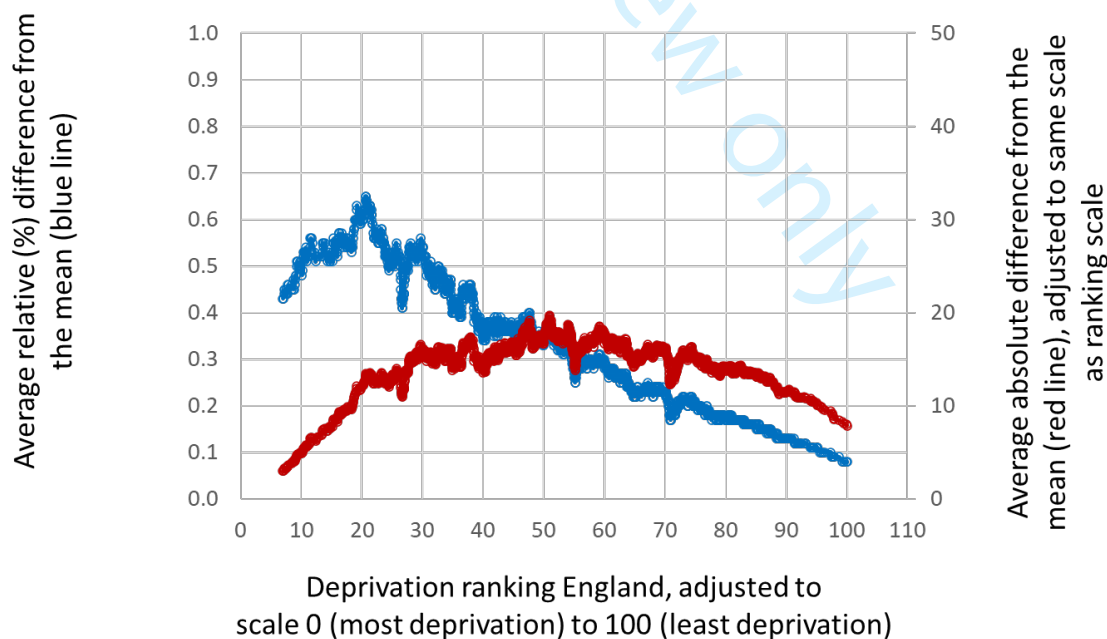


Figure 5 Dispersion of aggregated deprivation ranking, England. For explanation, see legend to Figure 4.

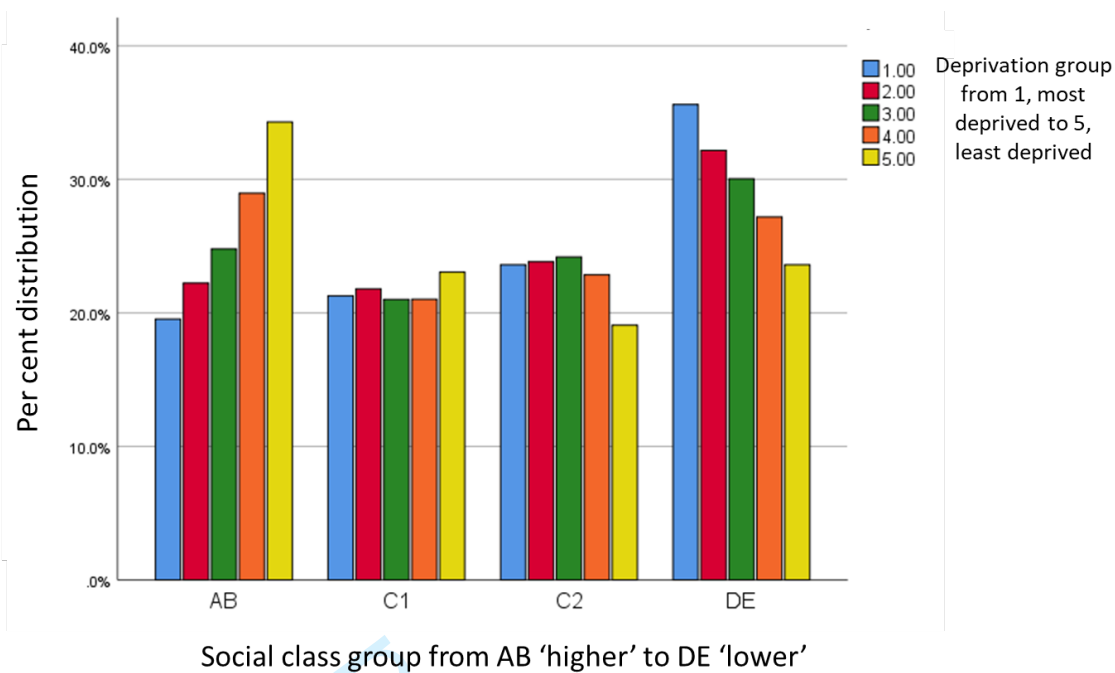


Figure 6 Distribution of deprivation group (from 1, most deprived to 5, least deprived) within social class groupings from AB, relatively higher to DE, relatively lower. Social class groups based on National Readership Survey; 2019. <http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/>.

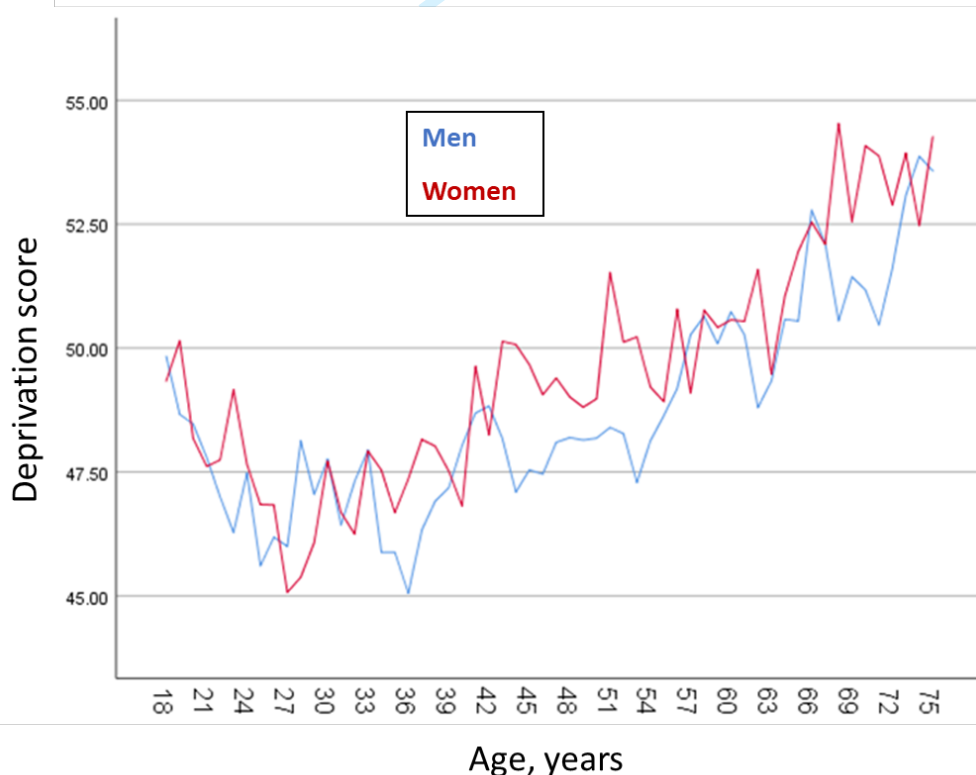


Figure 7 Plot of mean deprivation score (higher the score, the least deprived) by age and gender.

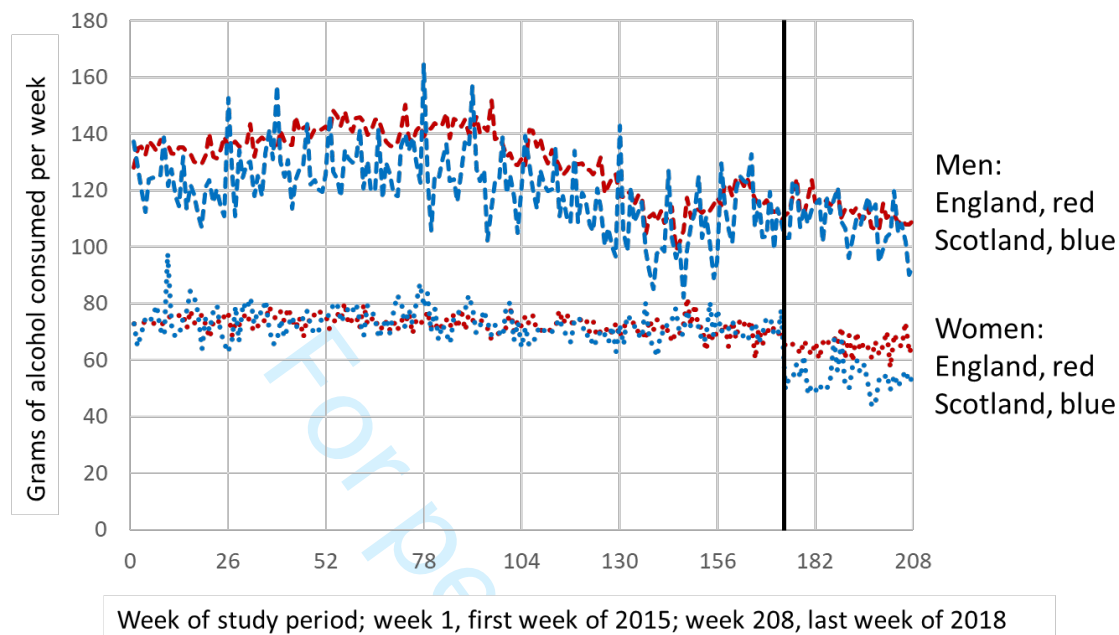


Figure 8 Plots of adjusted dependent variables (grams of alcohol consumed per week), seasonally adjusted using the ratio-to-moving-average method, over time (study week) by England and Scotland for men and women. Vertical black line: introduction of MUP.

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	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	0 ^a	.	0 ^a	.

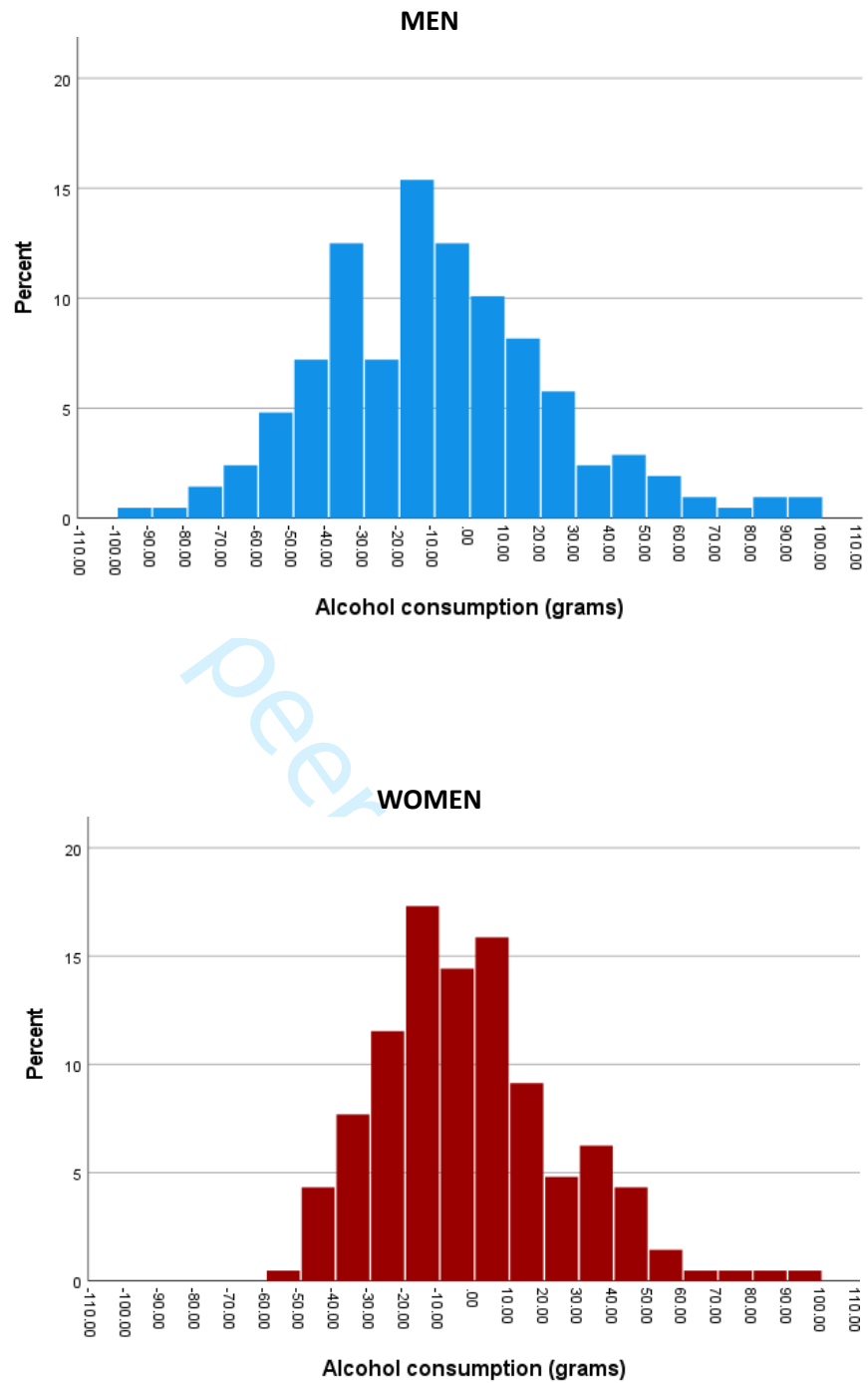


Figure 9 Plots of distributions of differences in alcohol consumption (grams), Scotland minus England for men (top) and women (bottom).

Box 1

SPSS Syntax, regression equation 1.

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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.
```

Box 2

SPSS Syntax, regression equation 2.

```
GENLIN grams BY country age/or/deprivationscore WITH event week
  /MODEL country event age/or/deprivationscore event*country
  event*country*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= event*country*age/or/deprivationscore SCALE=ORIGINAL
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
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Box 3

SPSS Syntax, regression equation 3.

```
GENLIN Scores of plotted differences from regression equation 2 BY age WITH 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.
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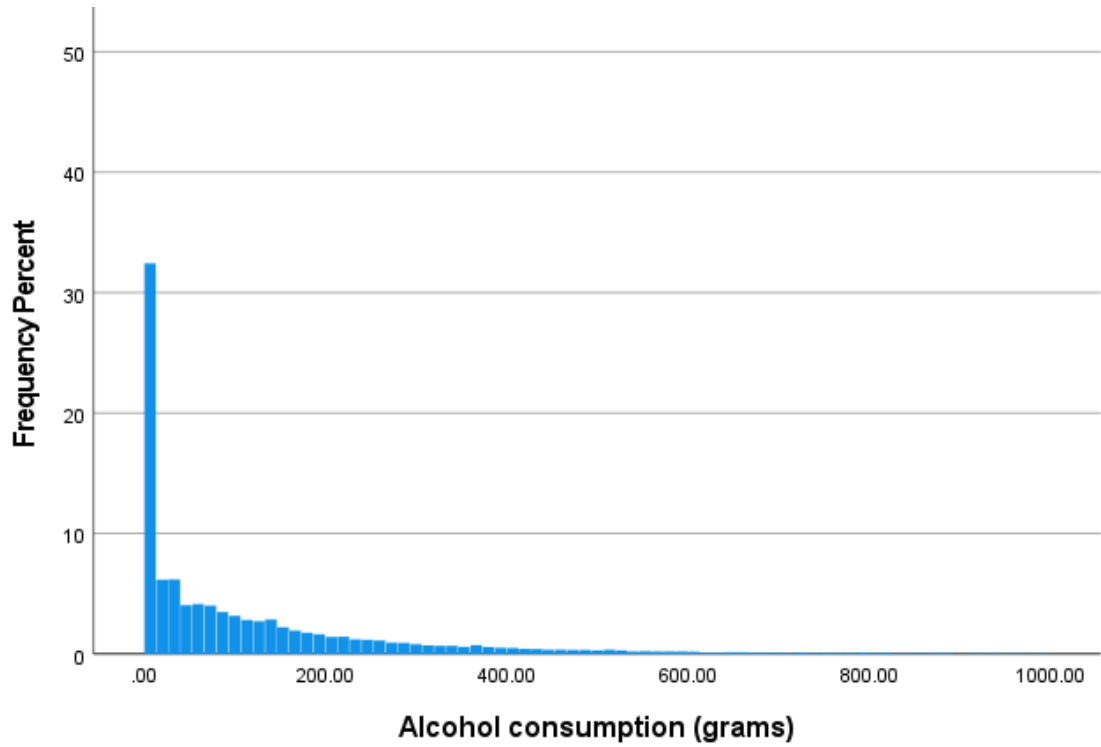


Figure 10 Distribution of weekly alcohol consumption, men.

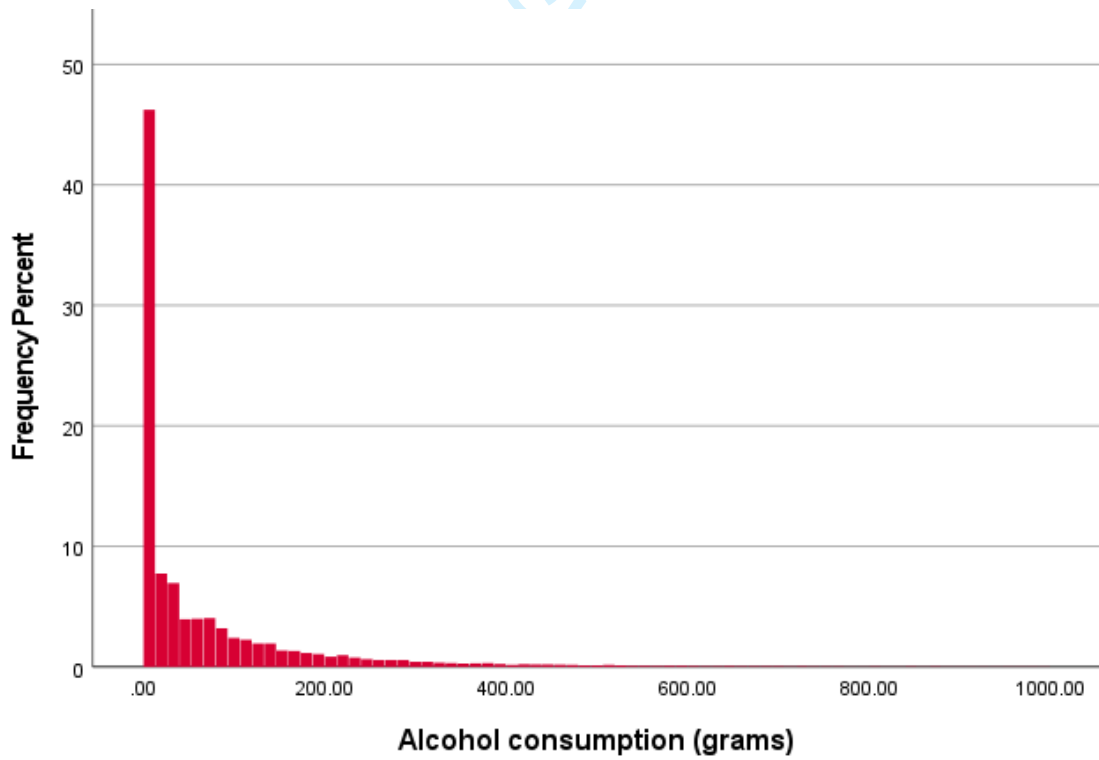


Figure 11 Distribution of weekly alcohol consumption, women.

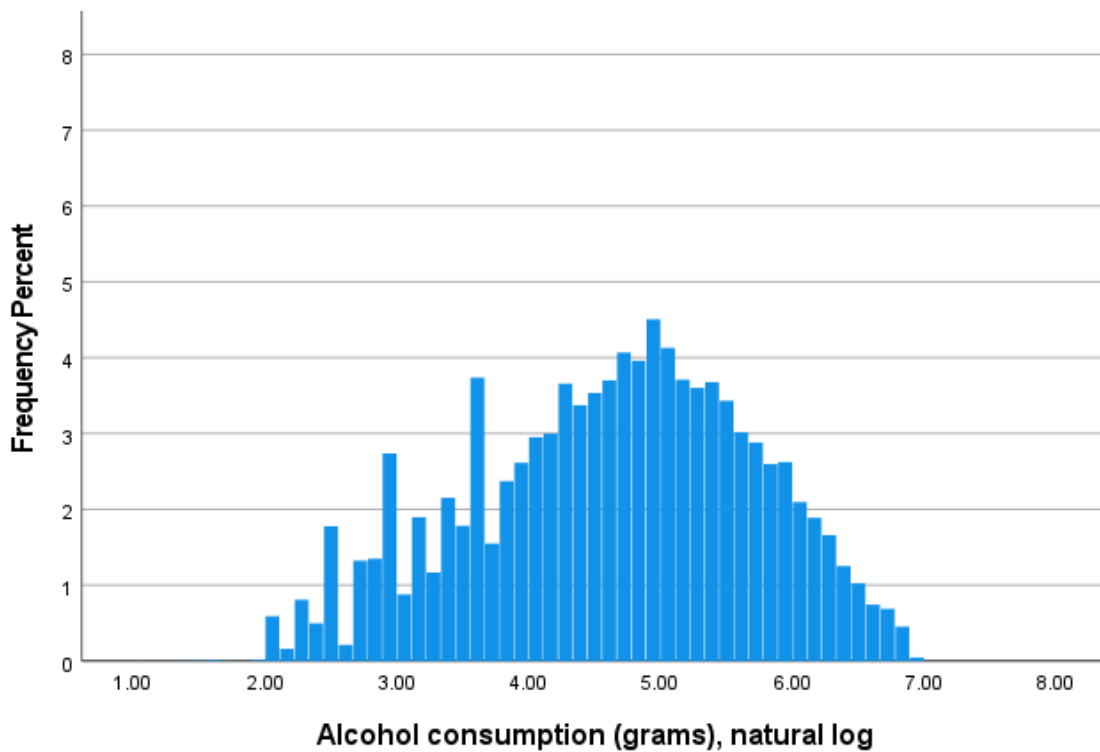


Figure 12 Distribution of weekly alcohol consumption (natural log), men who consumed alcohol during previous week.

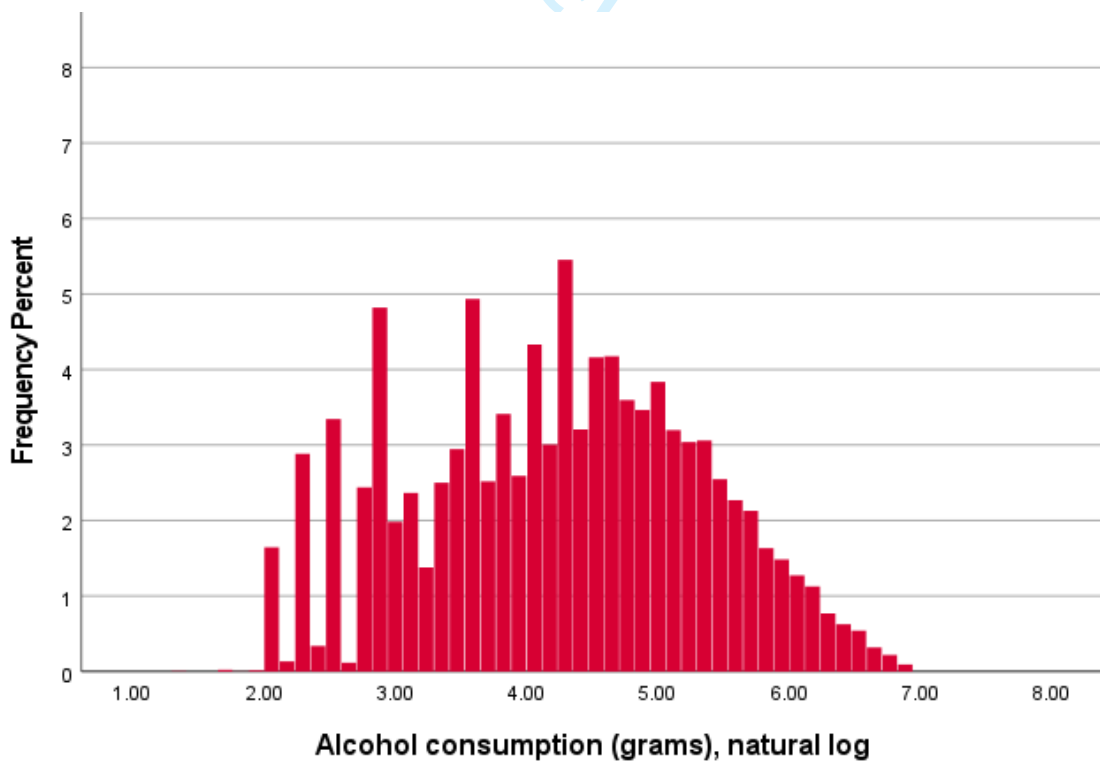


Figure 13 Distribution of weekly alcohol consumption (natural log), women who consumed alcohol during previous week.

Table 2 Numbers of respondents by country, before and after the introduction of MUP and by socio-demographic characteristics

		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=least 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

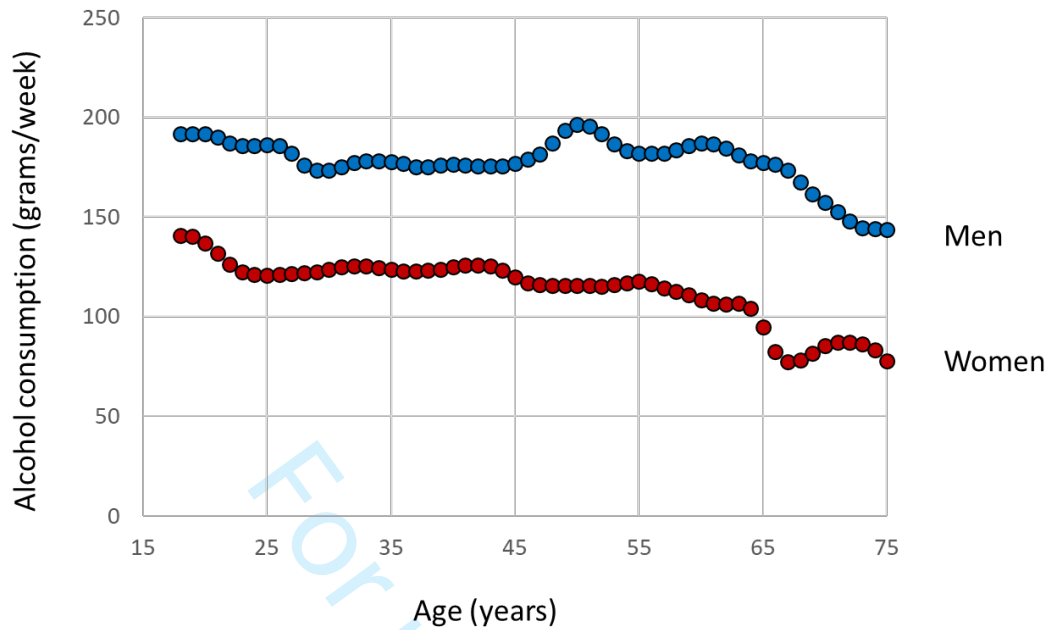


Figure 14. Mean alcohol consumption (grams per week) by age and sex, based on T4253H smoothing¹ across age.

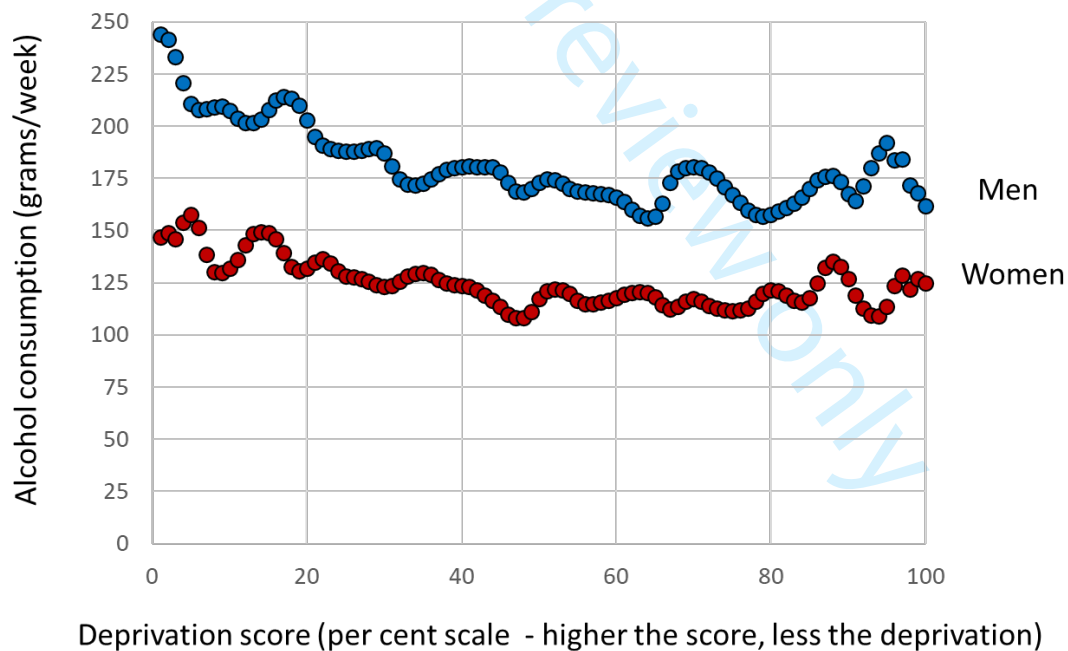


Figure 15. Mean alcohol consumption (grams per week) by deprivation score and sex, based on T4253H smoothing¹ across deprivation score.

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	.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)	.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	.000 (. to .)
Women*event (introduction of MUP)	-6.022 (-11.009 to -1.035)
Men*event (introduction of MUP)	.000 (. to .)

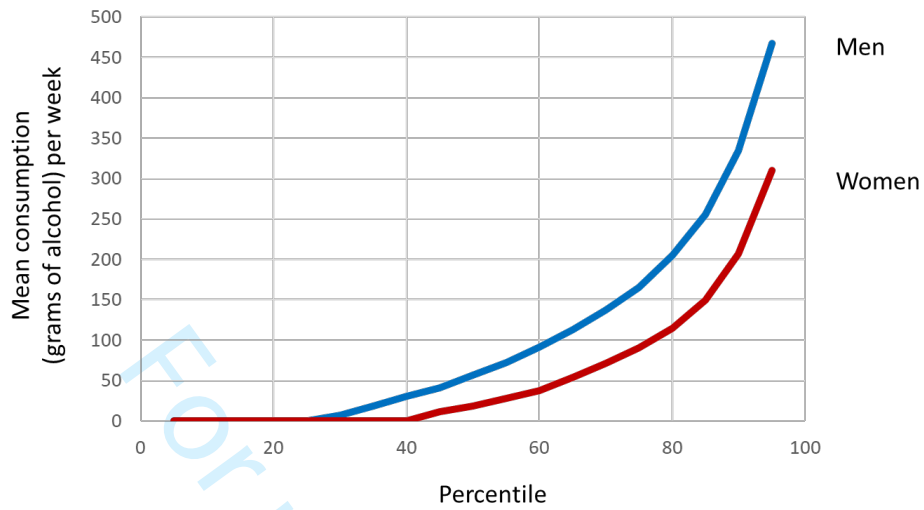


Figure 16. Mean consumption, grams of alcohol per week, by percentile distribution of consumption for men and women.

Table 9 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 10 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 11 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

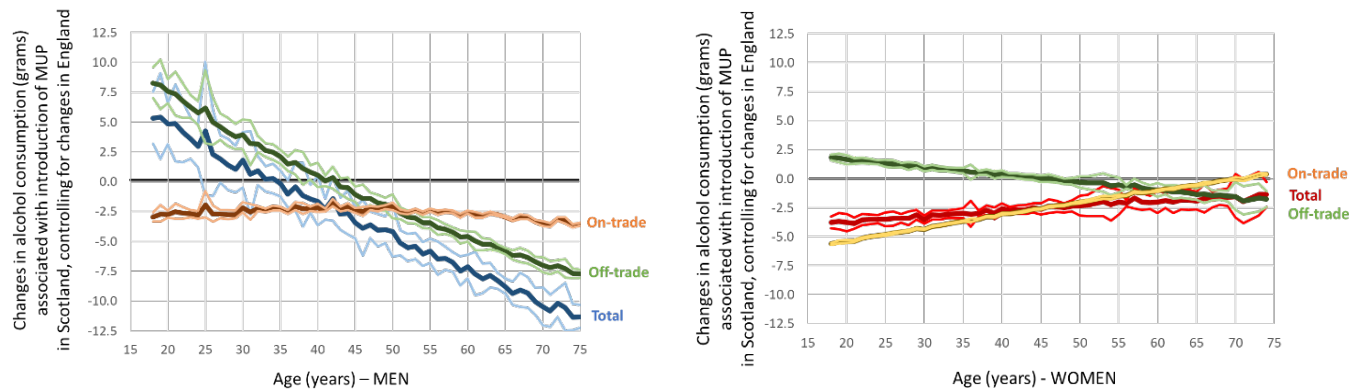


Figure 17 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each 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; consumption log normalized prior to regression models, with exponential of resultant coefficients taken prior to plots.

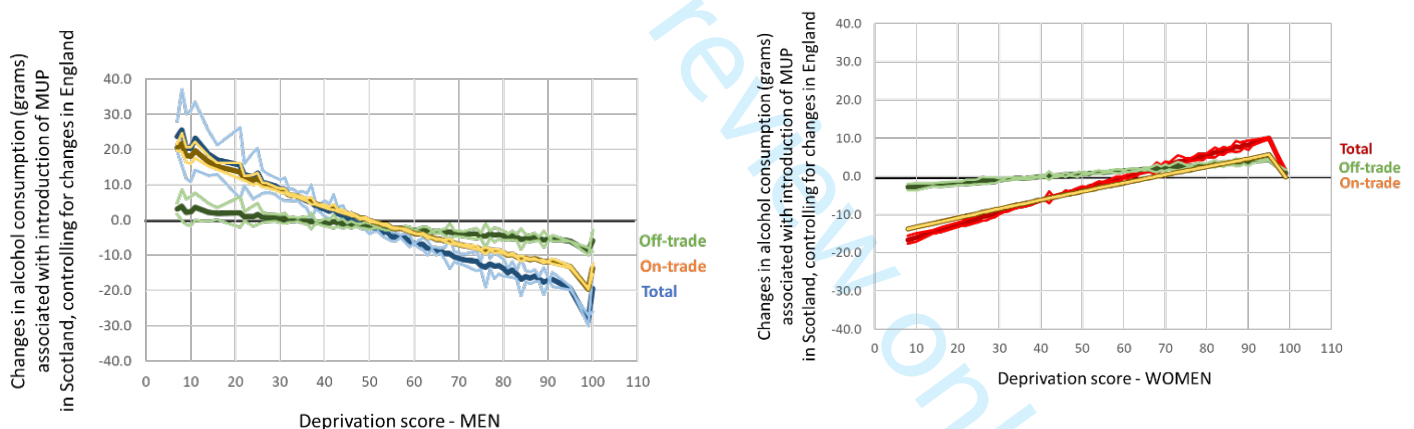


Figure 18 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each 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; consumption log normalized prior to regression models, with exponential of resultant coefficients taken prior to plots.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	"controlled interrupted time series analysis" included in title and abstract, p1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract adheres to these criteria, p2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction describes the importance of the need for empirical studies of the impact of minimum unit price by sex of drinker, p3
Objectives	3	State specific objectives, including any prespecified hypotheses	Objectives included as issues to answer in last paragraph of introduction, p3
Methods			
Study design	4	Present key elements of study design early in the paper	Included in first paragraph of methods, p3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	All included in the description of the data source, p4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Fully described for interrupted time series analysis in the description of the data source, p4
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
Variables	7	<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	All dependent and independent variables described in the section statistical analyses, p4-5
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	
Data sources/	8*	<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	Fully described in both sections
		Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	

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measurement		data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	data sources and statistical analyses, p4-5
Bias	9	Describe any efforts to address potential sources of bias	Dependent variables are data from timeline follow-back surveys, p4
Study size	10	Explain how the study size was arrived at	Number of observations prior to and post introduction of minimum unit price meet all criteria required for interrupted time series analyses and are based on weekly data for the four years 2015-18.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why.	Fully described in the statistical analyses section, p4-5
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Detailed descriptions of the interrupted time series analyses are described in the statistical analysis section, p4-5.
		(b) Describe any methods used to examine subgroups and interactions	How the data were split into groups of respondent characteristics is described in the methods, p5.
		(c) Explain how missing data were addressed	No missing data, p4
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(e) Describe any sensitivity analyses	We did not undertake sensitivity analysis as it did not seem required.

Continued on next page

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	All respondents and all weeks included in analyses, p4-6
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Distribution of demographic characteristics of households described in methods. No confounders added to model, p4
		(b) Indicate number of participants with missing data for each variable of interest	No missing data.
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Not applicable
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	Not applicable
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Not applicable
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Estimates given with 95% confidence intervals. No confounders included in models (see above), p6-8
		(b) Report category boundaries when continuous variables were categorized	Category groupings for respondent characteristics described, p4.
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not relevant
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Additional analyses for respondent groupings described, p5.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Included in first paragraph of discussion, p9.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Main limitations (e.g., use of survey data) fully described in discussion, p9.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity	Included in Conclusion paragraph, p9

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of analyses, results from similar studies, and
other relevant evidence

Generalisability	21	Discuss the generalisability (external validity) of the study results	Included conclusion paragraph, p9
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Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	No funding was received in support of the study, p10
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*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-054161.R2
Article Type:	Original research
Date Submitted by the Author:	11-Feb-2022
Complete List of Authors:	Rehm, Jürgen; CAMH, Social and Epidemiological Research O'Donnell, Amy; Newcastle University Kaner, Eileen; Newcastle University Jane Llopis, Eva; Maastricht University; Ramon Llull University Manthey, Jakob; Technische Universität Dresden, Institute of Clinical Psychology and Psychotherapy Anderson, Peter; Newcastle University; Maastricht University
Primary Subject Heading:	Public health
Secondary Subject Heading:	Addiction
Keywords:	PUBLIC HEALTH, SOCIAL MEDICINE, Substance misuse < PSYCHIATRY

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

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Words: 6500

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 50p per UK unit (6.25p per gram) 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 (e.g., at home), and in on-trade (e.g., 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 grams (95% CI=1.29-10.60 grams), a drop in off-trade consumption of 3.27 grams (95%CI=-0.01-6.56 grams), and a drop in on-trade consumption of 2.67 grams (95%CI=-1.48-6.82 grams). Associated reductions were larger for women than for men and were greater amongst heavier as opposed to 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 amongst older respondents and those living in less deprived areas. The introduction of MUP was not associated with a reduction in consumption amongst 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.

Funding: No funding was received in support of this study.

Strengths and limitations of this study

- The study uses a large commercial data set 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 the sex, level of alcohol consumption, age, social grade, and level of residential deprivation of respondents.
- The sample of respondents is not a random sample, 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.

peer review only

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 World Health Organization 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 (that is, 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 (e.g.,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 grams) of pure alcohol (ethanol) sold (6.25 pence per gram) beginning on May 1, 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 studies¹¹ 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 £0.50 GB 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 Alcovision survey,¹⁴ a continuous retrospective online timeline follow-back (TLFB) diary survey, allows us to specifically investigate gender-based impact of MUP in Scotland using England as a control group. In addition to allowing us to disaggregate consumption by socio-demographic 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 socio-economic strata who would be most affected by MUP.

METHODS

Study design

As 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 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 Kantar WorldPanel (KWP) Alcovision survey,¹⁴ an ongoing cross-sectional online timeline follow-back (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 seven days, including details on brands and volumes drunk, and whether these are consumed off-trade (for example, at home) or on-trade (for example 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 geographic 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 18-34-year-olds from both England and Scotland, (see Supplement Figures 1-2, page 1). In the data set we analysed, 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).

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 English¹⁷ and the Scottish¹⁸ Indices of Multiple Deprivation to group respondents into levels of residential deprivation (for details, see Supplement, pages 2-5, and Supplement 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 data set that we analyzed, we had records of all drinks consumed during the seven-day time-period, but not specified by day of week. Drinks were categorized within 19 categories, which we collapsed, grouped, and coded as beers, ciders, wines, spirits, fortified wines, and ready-to-drink products. In the data set we analyzed, detailed product description was provided for beers, including alcohol-free beers, but not for the other beverages. For non-beer products, the alcohol by volume (ABV) averages of the categories obtained from household purchase data over the same four 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 grams pure alcohol). We summed consumption into grams of alcohol by drink group per week for each individual survey respondent.

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3 In addition to the five deprivation groups, we also grouped individuals into: (i) four age groups (18-24;
4 25-44; 45-64; and 65+ years); and (ii) four occupation-based social grade groups (AB ['highest'], C1,
5 C2, DE ['lowest']), based on the National Readership Survey.²⁰
6

7
8 For the interrupted time-series analyses, we prepared weekly data by averaging consumption across
9 all respondents for each of the 208 weeks in the study period, separately for men and women, and
10 separately for total consumption, off-trade consumption, and on-trade consumption. We plotted the
11 seasonally adjusted total consumption over time (study week) by England and Scotland (Supplement
12 Figure 8, page 6). We observed parallel trends between England and Scotland prior to the introduction
13 of MUP, illustrating the appropriateness of England as a control area (tests for parallel trends, see
14 Supplement Table 1, page 6).
15

16
17 To analyse the potential impact of MUP in reducing alcohol consumption by levels of consumption,
18 we calculated, separately for men and women, and for each country (Scotland and England) and for
19 each week (from week 1 to week 208) the average consumption for separate percentiles of
20 consumption, ranging from 5% to 95% within 5% intervals.
21

22 **Statistical analyses**

23 **Primary interrupted time series analyses**

24 As primary analyses, interrupted time series regressions²¹ were undertaken with the weekly
25 consumption data averaged across all respondents, and separately for men and women, over the full
26 208 weeks, where week 1 is the first week of 2015, and week 208 is the last week of 2018. As with our
27 previous analyses,^{9,10} we created three new dependent variables of Scotland minus England (net
28 effect) for each of the weeks for: (i) the average consumption of all grams of all alcohol per week,
29 separately for men and women; (ii) the average consumption of all grams of all alcohol per week
30 consumed off-trade (e.g., at home), separately for men and women; and, (iii) the average
31 consumption of all grams of all alcohol per week consumed on-trade (e.g., in pubs, bars or
32 restaurants), separately for men and women.
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36 For each of the three dependent variables, we examined the distribution visually and with Q-Q plots
37 and found all variables, being the differences Scotland minus England (net effect) for the means of
38 consumption by respondent for each of the 208 weeks, to be normally distributed (see Supplement
39 Figure 9, page 7). We adjusted the dependent variables for any seasonality, using the ratio-to-moving-
40 average method.²² Based on Durbin-Watson tests²³ (range 1.53 to 2.18), there was no evidence of
41 autocorrelation, and based on Augmented Dickey-Fuller tests,²⁴ the series were found to be stationary
42 (see Table 1 in Results section). We examined the immediate and permanent level changes due to the
43 event, the introduction of MUP in Scotland, at Week 174. The event variable was entered as a dummy
44 variable, coded with 0 for each week before the event and with 1 for each week from the event
45 forwards. Thus, in our generalized linear regression models, which we ran separately for men and for
46 women, the dependent variables were the difference in reported consumption of grams of alcohol
47 between Scotland and England (net effect). The independent variables were the dummy-variable
48 event, and time (each week from 1 to 208). Interrupted Time Series Regression Equation 1 and SPSS
49 syntax is presented in Supplement Box 1, page 8.
50
51

52
53 To test if MUP had an associated differential impact by sex of respondent, we re-ran Interrupted Time
54 Series Regression Equation 1 for the total sample (both men and women) adding sex of respondent
55 and the interaction term sex*introduction of MUP to the model (see Supplement Box 1, page 8).
56

57
58 We repeated Interrupted Time Series Regression Equation 1 separately for each of the: four age
59 groups; four social grade groups; and five deprivation groups (thus, comparing same groups in England
60 and Scotland). For these analyses, we transformed the continuous variables into their z-scores and

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3 used the z-scores as the dependent variables, so that the results could be compared between groups
4 in terms of standard deviations, rather than original units. This allowed us to compare the relative
5 importance of the regression coefficients, and thus changes, across the socio-demographic
6 characteristics of the respondents.

7
8 For the analyses by the separate consumption percentiles, for each separate percentile, we also
9 created a difference in consumption by subtracting the mean consumption, Scotland minus England.
10 We repeated Interrupted Time Series Regression Equation 1 separately for each of the 19 percentiles
11 (from 5% to 95%) and plotted the coefficient and 95% confidence intervals associated with the event
12 (introduction of MUP) by the percentile, separately for men and women.
13

14 **Sensitivity analysis**

15 We repeated Interrupted Time Series Regression Equation 1, using men and women resident in
16 Northern England as control for Scotland, rather than residents from all of England.
17

18 **Secondary before and after analyses**

19 The secondary before-and-after analyses were done with individual-respondent seven-day
20 consumption data summed across each week, separately for men and women to better understand
21 variation in the associated impact of MUP by age and deprivation, for each individual age and each
22 individual deprivation score rather than by the four age groups and the five deprivation groups used
23 in the interrupted time series analyses. For these analyses, we did not compute a new dependent
24 variable (Scotland minus England), but rather used the original data by country. We examined the
25 distribution of the dependent variables and found them to be highly dispersed (see Supplement
26 Figures 10-11, page 11). We excluded all respondents with zero consumption during the previous
27 week, and then took the natural log of the consumption data, resulting in a normal distribution of the
28 natural logged data (see Supplement Figures 12-13, page 12). In our models, the independent
29 variables were: the event variable (introduction of MUP), coded as a dummy variable as above for the
30 interrupted time-series analysis; country as a factor (England or Scotland); age as a dummy coded
31 variable for each individual age year; deprivation as a dummy coded variable for each deprivation
32 score rounded to an integer; and, time (weeks) as a covariate. For each of the dependent variables,
33 we ran two separate models, one for age, and one for deprivation score. Before and After analysis
34 Regression Equation 2 and the SPSS syntax are presented in Supplement Box 2, pages 8-9.
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39 From the results of the regression model, and for each individual age and for each individual
40 deprivation score, we took the difference in the marginal means (and the 95% confidence interval of
41 the differences), [Scotland*MUP*age /or/ deprivation score] minus [England*MUP*age /or/
42 deprivation score], this difference representing the added associated impact of MUP in Scotland over
43 and above that in England for each individual age and for each individual deprivation score. We plotted
44 the differences of the marginal means as above (with their 95% confidence intervals) by each age and
45 each integer deprivation ranking respectively, for men and women separately. We extracted the mean
46 values of the changes (y-axes) from the plots and performed a linear regression of these values
47 respectively by age and deprivation score, separately for men and women to test how the differences
48 in the marginal means between Scotland and England (net effect) differed by age and deprivation
49 score. The Before and After Analysis Regression Equation 3 and SPSS syntax are presented in
50 Supplement Box 3, page 9. We tested the difference in slopes between men and women for total
51 consumption by repeating Regression Equation 3 for the total sample (both men and women), adding
52 the interaction term sex*age /or/ deprivation score as an additional independent variable to the
53 model. Finally, given the relationship between age and deprivation score (Supplement Figure 7, page
54 5), we also tested if any relationship between changes in alcohol consumption associated with MUP
55 and age of the respondent differed by deprivation group. We tested this by adding an interaction term
56 age*deprivation group to the regression model (See Supplement Box 4, page 10).
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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 normalize 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 normalizing the data. We tested this by adding an interaction term 'type of normalization (natural log or square root)' * age/or/deprivationscore to the regression model (See Supplement Box 5, page 10).

Power calculations are reported in the supplement, Page 13.

Analyses were performed with SPSSv26 (IBM Corp 2019).²⁵ For our regression models, we used generalized 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.

Ethical approval

Ethical approval was not required, as our analyses are based on a publicly available commercial data set.

RESULTS

Overall, 106,490 respondents (53,347 women and 53,143 men) contributed to the data set (for details of numbers of respondents by country, before and after the introduction of MUP and by socio-demographic 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).

For all respondents (English and Scottish), the mean reported consumption per week was 125.8 grams for men (66.4% consumed off-trade) and 71.3 grams 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 grams per every 10 years of increasing age (95% confidence interval, CI=4.4 to 5.7 grams) (see Supplement Figure 14, page 19). Consumption decreased by only a small amount with decreasing deprivation, 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), (see Supplement Figure 15, page 19).

Interrupted time-series analyses – main findings

Figure 1 plots the differences in consumption of alcohol (grams) Scotland minus England (net effect) for each of the 208 weeks, 2015-2018. Table 1 gives 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 grams per week (95% CI=1.3 to 10.6 grams) (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 grams per week, 95%CI=2.9 to 14.3 grams) rather than by

men (a reduction of 3.3 grams 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 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 grams per week (15.7 to 1.9 grams).

Figure 1 here

Table 1. Unstandardized coefficients from interrupted time series analyses (95% confidence intervals) for all respondents, and separated for men and women, 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. 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.

		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	0.003 (-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)	-.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)	0.417 (-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)

Interrupted time-series analyses – sensitivity analyses

Table 2 gives 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 grams per week (95% CI=2.6 to 9.2 grams) (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 grams per week (95% CI=1.0 to 11.0 grams), 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 grams 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 grams, 95%CI = 5.8 to 21.5), but not for women (of 4.8 grams, 95%CI = -4.0 to 13.7).

Table 2 Sensitivity analysis, using Northern England as a control for Scotland. Unstandardized coefficients from interrupted time series analyses (95% confidence intervals) for all respondents, and separated 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.

		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 (-.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)	.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 (-.034 to 5.165)	2.846 (-.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)

Figure 2 here

Figure 3 displays 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 standardized coefficients, allowing for relative, rather than absolute comparisons across the groups (for numerical data, see Supplement Tables 10-12, pages 23-25).

Figure 3 here

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3 By age group (top graph), there was a pattern of greater associated drops in all consumption and in
4 off-trade consumption for both men and women with increasing age. For younger men, there was an
5 increase in off-trade consumption, which was offset by decreases in on-trade consumption in the same
6 group. There appeared no clear or consistent discernible pattern by social grade (middle graph), or by
7 deprivation group (bottom graph). The secondary before and after analyses provide more detail of the
8 associated impact of MUP by individual age and deprivation ranking.
9

10 11 **Secondary before and after analyses**

12 Figure 4 plots the associated changes in alcohol consumption (in grams of alcohol) following
13 introduction of MUP for all consumption, off-trade consumption, and on-trade consumption by
14 gender and individual age. For men, reductions in consumption following the introduction of MUP
15 became greater with increasing age for both total consumption (linear regression coefficient across
16 age (RC) =-0.088 (95%CI=-0.094 to -0.083) and off-trade consumption (RC =-0.092 (95%CI=-0.097 to -
17 0.088); for on-trade consumption, reductions in consumption became very slightly smaller with
18 increasing age (RC =0.0038 (95%CI=0.0026 to 0.0050). For younger men (those aged less than 30
19 years), the introduction of MUP was not associated with a decrease in consumption, more so the
20 younger the age, as upper 95% confidence intervals were greater than zero. For women, a similar
21 pattern emerged, with reductions in consumption across all ages. Reductions in both total (RC=-0.070
22 (95%CI=-0.072 to -0.067) and off-trade consumption became slightly greater with increasing age (RC
23 =-0.087 (95%CI=-0.090 to -0.085), whereas reductions in on-trade consumption became very slightly
24 smaller with increasing age (RC =0.0179 (95%CI=0.0176 to 0.0182). The coefficient for the interaction
25 term, sex*by age (with women as reference category), was -0.019 (95%CI=-0.025 to -0.013) indicating
26 that the reduction in consumption was slightly greater with increasing age for men rather than for
27 women.
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33 **Figure 4 here**

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37 Figure 5 plots the associated changes in alcohol consumption (in grams of alcohol) following the
38 introduction of MUP for all consumption, off-trade consumption, and on-trade consumption by
39 gender and individual deprivation ranking. For men, reductions in consumption following the
40 introduction of MUP became greater with less deprivation, more so for total (RC =-0.102 (95%CI=-
41 0.108 to -0.097) and off-trade consumption (RC =-0.082 (95%CI=-0.087 to -0.078) than for on-trade
42 consumption (RC =-0.020 (95%CI=-0.022 to -0.019), with an indication that those living in the most
43 deprived areas (bottom two-fifths) showed no decrease in consumption, more so the greater the
44 deprivation (as upper 95% confidence intervals were greater than zero). For women, a similar pattern
45 emerged, with reductions in consumption across all deprivation scores. Reductions in consumption
46 following the introduction of MUP became larger with less deprivation for total consumption (RC =-
47 0.050 (95%CI=-0.051 to -0.049), off-trade consumption (RC =-0.035 (95%CI=-0.036 to -0.034), and on-
48 trade consumption (RC =-0.0151 (95%CI=-0.0155 to -0.0147). The coefficient for the interaction
49 term, sex**deprivation score (with women as reference category), was -0.053 (95%CI=-0.059 to -
50 0.046) indicating that the reduction in consumption was slightly greater with less deprivation for men
51 rather than for women.
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56 **Figure 5 here**

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3 The age-related patterns of Figure 4 were independent of deprivation. Before and After Analysis
4 Regression Equation 4 found no interaction between age in years and deprivation group in the changes
5 in total alcohol consumption (Scotland minus England, net effect) associated with the introduction of
6 MUP: for men, the coefficient for the interaction was -2.2^{-5} , 95%CI -5.5^{-3} to 5.4^{-3} ; for women, the
7 coefficient was 1.6^{-3} , 95%CI -1.1^{-3} to 4.2^{-3} . In other words, the slopes between changes in alcohol
8 consumption by age for men and women plotted in Figure 4 were almost identical across the five
9 deprivation groups.
10

11 **Before and after analyses – sensitivity analyses**

12 We repeated the before and after analyses, using the square root (as opposed to logged) grams of
13 alcohol consumption as the dependent variable, with similar patterns of findings to Figures 4 and 5
14 (see Supplement Figures 17 and 18, Pages 26-27). There were, however, differences in the slopes. For
15 total consumption, Before and After Analysis Regression Equation 5 found, with age, that the slope
16 for logged grams of alcohol was slightly steeper for men (regression coefficient of the interaction term,
17 'type of normalization*age = -0.017 (95% CI = -0.025 to -0.008), but slightly less steep for women
18 (regression coefficient of the interaction term = 0.082 (95% CI = 0.078 to 0.087) than the slope for the
19 square root of consumption. There were similar findings in the differences in slopes for dependence
20 score; the slope for logged grams of alcohol being slightly steeper for men (regression coefficient of
21 the interaction term, 'type of normalization*dependence score = -0.059 (95% CI = -0.068 to -0.050)
22 for men, and slightly less steep for women (regression coefficient of the interaction term = 0.040 (95%
23 CI = 0.038 to 0.043).
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28 **DISCUSSION**

29
30 We found that the introduction of MUP in Scotland was associated with a change in overall reported
31 alcohol consumption in line with the predicted direction. Compared to respondents from England,
32 Scottish respondents reported a 6.2% drop in alcohol consumption (95% CI=2.3% to 8.4%) associated
33 with MUP. Sensitivity analyses using respondents from Northern England, with more similar drinking
34 levels to Scotland than England as a whole,²⁶ found an almost identical associated drop in alcohol
35 consumption. The drop in consumption was larger for heavier as opposed to lighter drinkers, with the
36 exception of the top 5% of heaviest drinking men for whom there was an increase in consumption
37 associated with the introduction of MUP.
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41 Against expectations, we found that associated drops in consumption were greater for women than
42 for men, both in the main (using all of England as a control) and in the sensitivity (using Northern
43 England as a control) analyses. Men and women also responded differently by age. Based on both the
44 interrupted time series analysis and the before and after analysis, for men, the size of the associated
45 drop in consumption became smaller with decreasing age, with younger men showing no associated
46 decrease in consumption. For women, the associated drop in consumption also became smaller with
47 decreasing age, although less so than for men.
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50 We included two potential measures of socio-economic disadvantage: social grade and an index of
51 residential deprivation based on multiple measures of income, employment, education, health, crime,
52 access to housing, and environmental quality,^{17,18} noting that the risk of alcohol-related harm
53 increases both the more socio-economically disadvantaged the individual is, and, over and above that,
54 the more socially disadvantaged the residential area in which the individual resides.²⁷ It should be
55 noted that estimates of the indices of residential deprivation differ between Scotland and England,
56 and thus, in absolute terms, they may not be the same. However, in our analyses we compare relative
57 deprivation; for example, comparing the bottom fifth of deprivation of Scotland with the bottom fifth
58 of deprivation of England, noting that relative deprivation, itself, is a key determinant of ill-health.²⁸
59 Based on the interrupted time series analyses, for both men and women, there was no discernible
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3 pattern by social grade or deprivation group. However, based on the secondary before and after
4 analyses (both main and sensitivity), the size of the associated drop in consumption for men became
5 smaller with increasing deprivation, with men living in the most deprived areas having no associated
6 decrease in consumption. For women, the associated drop in consumption also decreased slightly with
7 decreasing deprivation score, although less so than for men.
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10 The drop in consumption of 6.2% is a little lower than the 7.6% drop we found in our previous analysis
11 of household purchase data in both the short⁹ and medium term.¹⁰ As with the present study based
12 on survey data, our previous analyses of household purchase data also found that drops in
13 consumption were greater amongst households with higher rather than lower usual purchases of
14 alcohol.^{9,10} However, with our previous analyses of household purchase data, we could not test the
15 impact of MUP on purchases by age or gender, as the purchase data were for the household as a whole
16 and not attributable to individual household family members. Nor did those analyses report the
17 impact of MUP by the social grade of the household or the level of deprivation in which the household
18 was located. The findings presented in this paper thus provide a more nuanced understanding of the
19 differential impact of MUP on different population sub-groups. Specifically, what we identified in the
20 present analysis is the top 5% of heavy drinking men did not reduce their consumption in association
21 with MUP; rather, our results suggest an increase in associated consumption amongst this group. For
22 women, there was an upturn in changes in alcohol consumption in the heaviest drinking percentiles
23 (Figure 2); that the lower 95% confidence interval for women did not cross zero could be due to the
24 relatively small numbers of respondents in each of the 19 consumption percentiles (Supplement Table
25 9, page 22).
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29 We do not know why, for both younger men (those aged less than 32 years), and for those living in
30 residential areas in the bottom two-fifths of deprivation, there was no decrease in consumption
31 associated with MUP, compared to older men and those living in less deprived areas. It has been
32 suggested that some very heavy drinkers (as we found for the top 5% of heavy drinking men) would
33 be less prone to the potential impact of MUP,²⁹ and in potential need of additional support to cope
34 with the impact of MUP³⁰. Responses to MUP might vary by individual and psychosocial factors,
35 including socio-economic disadvantage, which may interact with the situational availability of
36 alcohol.³¹ This is clearly an area for further study.
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39 Before we discuss the implications of the results, it is important to mention potential strengths and
40 limitations of our study. We based our analysis on a large sample of 53,347 women and 53,143 men
41 from England and Scotland, that, apart from the oversampling of 18–34-year-olds, was, in general,
42 representative of the sex and age structure of the population (Supplement Figures 1-2, page 1). The
43 sample was neither more nor less deprived than the population of England or Scotland as a whole
44 (Supplement Figure 3, page 3). A strength of the interrupted time series analyses is the large number
45 of data points (weekly consumption) before (n=173) and from the introduction of MUP onwards
46 (n=25), considered more than sufficient for interrupted time series analyses.²² A second strength
47 overall and for the before and after analyses is the large sample size, 88,894 respondents prior to the
48 introduction of MUP and 17,596 respondents thereafter. A third strength is the use of a location
49 control, both all of England, and Northern England in sensitivity analysis. Location controls allow for
50 other extraneous factors beyond the intervention to be controlled for, for example, an unusual heat
51 wave during the months of June, July and August that affected all of Great Britain.³²
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54 For limitations, first, all results are based on subjective reports of drinking. While such subjective
55 reports tend to underestimate consumption as measured by sales or other recorded data in general
56 in all European countries (e.g.,³³), there is no reason to believe that underreporting should differ by
57 country or region, or before or after the introduction of the MUP. The timeline follow-back survey
58 method has been criticized for the limited time-period of drinking it covers, thus missing heavy
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3 episodic drinking occasions among participants with a low frequency of such occasions. This limitation
4 for classifying individuals is actually a strength when it comes to the characterization of population
5 averages, however, where the shorter the time period, the smaller the biases due to memory, and the
6 more accurate the population average.³⁴ Second, as with all survey-based research on alcohol, this
7 research cannot claim full representativeness.³⁵ Statistical theory stipulates such representativeness
8 needs to be based on probabilistic sampling design (i.e., all residents from England and Scotland need
9 to be assigned a probability > 0) combined with high response rates unaffected by systematic non-
10 response.³⁶ However, these conditions can no longer be reached in modern surveys involving alcohol,
11 no matter which methodology is used.^{35, 37-39} Instead, post-stratification based on sex, age, social
12 grade, and geographical region was used to allow for generalizations to be made for the general
13 population. The quota sample was derived from Kantar's managed access panel. Data were not
14 available and not attainable on the number of respondents approached to achieve the 30,000
15 respondents surveyed each year, and this information is not mentioned in existing publications based
16 on the Alcovision survey, e.g.,^{15,16}. Unlike the household purchase data which records purchases
17 wherever they are made, and thus accounts for cross-border purchases, we are unable to account for
18 any cross-border purchasing or drinking the respondents might have engaged in. If this was significant
19 (and, a study on licensing compliance would suggest that it is not⁴⁰), one might hypothesize that the
20 estimated sizes of the associated impact with MUP in reducing alcohol consumption would differ
21 between using Northern England or all of England as a control, which was not the case. Finally, as we
22 only had data to end of 2018, we have been unable to examine the impact of MUP beyond the
23 immediate term.
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28 In our analysis, we used both interrupted time series analysis and before and after analyses. With the
29 interrupted time series analysis, we used England (or Northern England) as a location control, creating
30 new dependent variables, the differences between Scotland and England. Interrupted time series
31 analysis is an appropriate methodology for investigating the impact of a newly introduced natural
32 experiment (the introduction of MUP) that takes into account seasonal variation and autocorrelation
33 of the data over time.²² The before and after analysis is simply comparing the means before and after
34 the introduction of MUP. Results of before and after analyses are often presented along with
35 interrupted time series analysis, as we have done previously with household purchase data.⁹ Whilst
36 we add in an interaction term of country* event (introduction of MUP), which should take into account
37 common events outside of MUP that occurred in both Scotland and England, our analyses are unable
38 to control for seasonal variation, when comparing the longer time period before the introduction of
39 MUP and the eight month period following the introduction of MUP.
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42 Externally validated indicators,^{35, 39} using sales^{41, 42} or household purchasing data as the basis,^{9,10}
43 corroborate our results that, in comparison to England over the same and longer time periods, the
44 introduction of the MUP was associated with a decrease in alcohol consumption. Finally, the
45 reductions in alcohol consumption in Scotland were part of an overall national strategy or framework
46 for alcohol policy, where all measures had already been extensively covered in the press. It cannot be
47 excluded that the actual reductions may have been due in part to the media reports surrounding the
48 introduction of the MUP rather than to the floor pricing itself (for an example of an alcohol policy
49 measure where the media impact seems to be stronger, see⁴³). However, it is highly unlikely that
50 media reports would produce exactly this abrupt and permanent pattern—i.e., a drop in consumption
51 starting exactly at the date of introduction of MUP and lasting for the time-period studied, in
52 comparison to a control group.
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56 Despite these potential limitations, most research corroborates the results of our study that the MUP
57 resulted in a reduction of overall alcohol consumption compared to England or Northern England.^{9, 10,}
58 ^{41, 42} Overall, research was based on a number of designs including purchasing data from households
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3 or sales records. Our results here were based on a control group design, where the intervention was
4 only introduced in one group, thus strengthening our confidence in a real effect.⁴⁴
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7 When the Minister for Public Health, Sport, and Wellbeing introduced the 2018 alcohol policy
8 framework,⁶ he emphasized that the implementation of the MUP was strongly motivated by an
9 interest in decreasing health inequalities through a reduction in alcohol consumption among the
10 heaviest and most vulnerable drinkers. Our results indicate that this goal may not be fully realized:
11 first, we found that women, who are less heavy drinkers in our data, and in almost all surveys
12 worldwide to date,⁴⁵ reduced their consumption more than men; second, the 5% of heaviest drinking
13 men had an increase in consumption associated with MUP; and, third, younger men and men living in
14 more deprived areas had no decrease in consumption associated with MUP. These results are
15 surprising—as modelling studies would have suggested otherwise (e.g.; ^{11, 14}). The results may also
16 imply a diminished impact on alcohol-attributable hospitalisations and mortality, which have been
17 shown to be strongly associated with heavy drinking in men and in those of lower socioeconomic
18 status.⁴⁶⁻⁴⁹ Indeed, a large, controlled study on emergency department visits following the introduction
19 of MUP did not show any reduction in alcohol-related emergency department visits.⁵⁰
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22 Before any further conclusions can be drawn, we need to corroborate our sex-, age-, heavy drinking-
23 and socioeconomic status-related findings in different studies. This seems important as different
24 conclusions about MUPs impact may result for other countries. If indeed the findings of our study are
25 corroborated, then additional and/or different pricing mechanisms may need to be considered to
26 reduce alcohol-attributable hospitalizations and mortality. For instance, several harms from alcohol
27 use are specifically linked to on-trade drinking, such as public disorder and violence.⁵¹ Recent
28 experiences in Lithuania have shown substantial reductions in all-cause mortality following a taxation
29 increase, that mainly affected men.⁵²
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32 **Acknowledgements:** We thank Kantar Worldpanel for providing the raw data and reviewing the
33 method description as it describes the data collection. Kantar Worldpanel and no other entity had any
34 role in the study design, data analysis, data interpretation or writing of the manuscript. Kantar
35 Worldpanel provided the raw data free of charge to Newcastle University under a direct contract.
36 Independently, and through its own contracted work as a market research company, Kantar
37 Worldpanel received reimbursement from AB InBev to cover the costs of the data. Kantar Worldpanel
38 has similar commercial relationships with other customers who pay to have data collected on food
39 and non-food items available for sale in supermarkets and other retail outlets covered by the
40 WorldPanel. Professor Kaner, supported by a National Institute for Health Research (NIHR) Senior
41 Investigator award, is Director of the NIHR Applied Research Collaboration, North East and North
42 Cumbria. Dr. O'Donnell is a National Institute for Health Research (NIHR) Advanced Fellow. The views
43 expressed in this article are those of the authors and not necessarily those of NIHR, or the Department
44 for Health and Social Care.
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48 **Contributors:** JR conceptualised the paper and prepared the initial draft of the introduction and
49 discussion. PA undertook the analyses and prepared the draft of the methods and results and
50 submitted the paper. PA, AO'D, EJ-L, JR, JM and EK refined the various versions of the full paper and
51 approved the final manuscript for submission. The corresponding author attests that all listed authors
52 meet authorship criteria and that no others meeting the criteria have been omitted. All authors had
53 access to the data used for analyses, and PA, AO'D and EJ-L verified the raw data sets received from
54 Kantar WorldPanel and are the guarantors for the data used for the analyses.
55
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57 **Competing interests:** All authors have completed the ICMJE uniform disclosure form at
58 www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted
59 work; within the previous five years, PA declares receipt of funds from AB InBev Foundation to provide
60

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.

Data sharing: No additional data available. Kantar WorldPanel data cannot be shared due to licensing restrictions.

Affirmation: PA and AO'D affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as initially planned have been explained.

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3 **Figure 1** Plots of average weekly alcohol consumption Scotland minus England (net effect) for all respondent,
4 by week of study period for total alcohol consumption, off-trade consumption (e.g., at home) and on-trade
5 consumption (e.g., in pubs, bars and restaurants), with T4253H smoothing⁵³. Black vertical line: introduction of
6 MUP. Data used for primary Interrupted Times Series analyses.
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9 **Figure 2** Associated changes in the difference in consumption (Scotland minus England, net effect) following
10 the introduction of MUP by drinking percentile distribution of total consumption. Blue lines: men; red lines:
11 women. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no
12 change). Results from primary Interrupted Times Series analysis.
13
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15 **Figure 3** Associated changes in consumption following introduction of MUP for all consumption, off-trade
16 consumption, and on-trade consumption (Scotland minus England, net effect) by age group, top graph; social
17 grade group, middle graph; and, deprivation group, bottom graph for men (blue) and women (red). Consumption
18 changes are standardized coefficients (units of standard deviations) from primary interrupted time series
19 analyses with 95% confidence intervals.
20
21

22 **Figure 4** Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated
23 with the introduction MUP in Scotland, controlling for changes in England for each age year. Plots of men and
24 women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner
25 lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change). The changes are derived from
26 the secondary before and after analysis, regression equation 2; they represent, for each age, the difference in
27 the marginal means (and 95% confidence intervals of the differences) for [Scotland*event (introduction of MUP)
28 *age (dummy coded variable for each age)] minus [England*event (introduction of MUP) *age (dummy coded
29 variable for each age)].
30
31

32 **Figure 5** Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated
33 with the introduction MUP in Scotland, controlling for changes in England for each deprivation score (on a 100%
34 scale). Plots of men and women for total consumption, off-trade consumption, and on-trade consumption.
35 Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change).
36 The changes are derived from the secondary before and after analysis, regression equation 2; they represent,
37 for each deprivation score (the higher the deprivation score, the less deprived), the difference in the marginal
38 means (and 95% confidence intervals of the differences) for [Scotland*event (introduction of MUP) *deprivation
39 score (dummy coded variable for each deprivation score)] minus [England*event (introduction of MUP)
40 *deprivation score (dummy coded variable for each deprivation score)].
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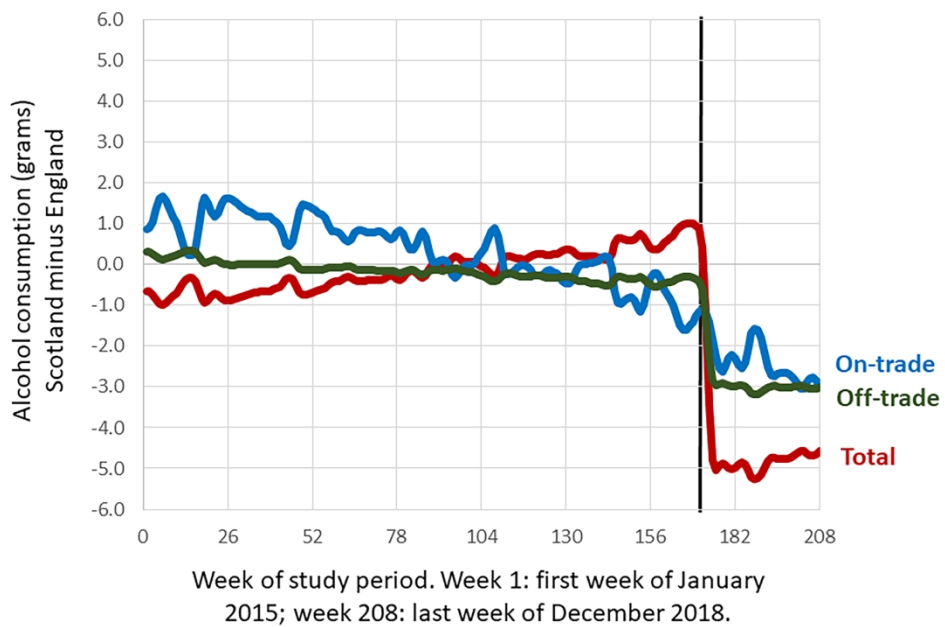


Figure 1

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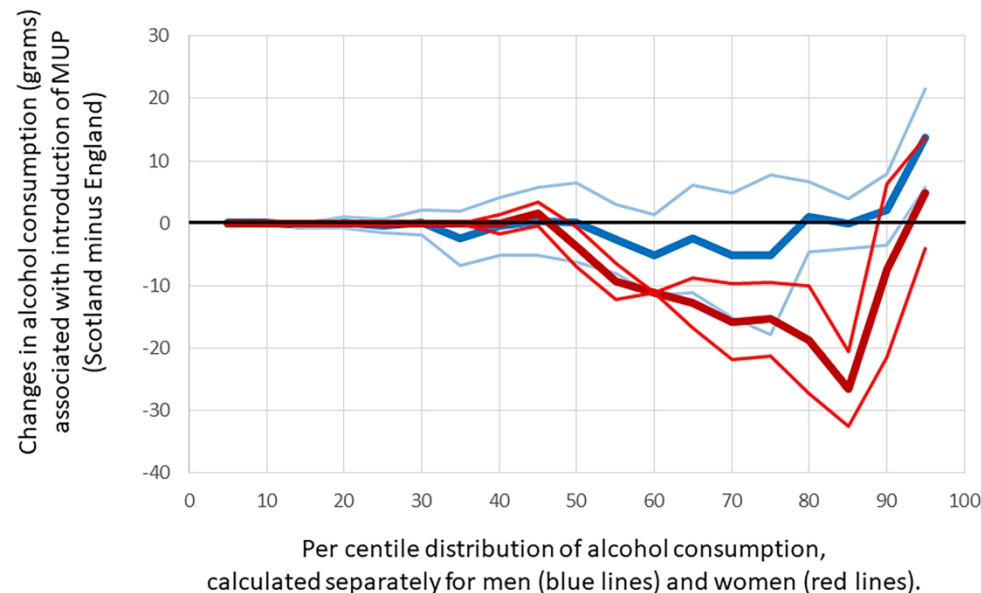


Figure 2

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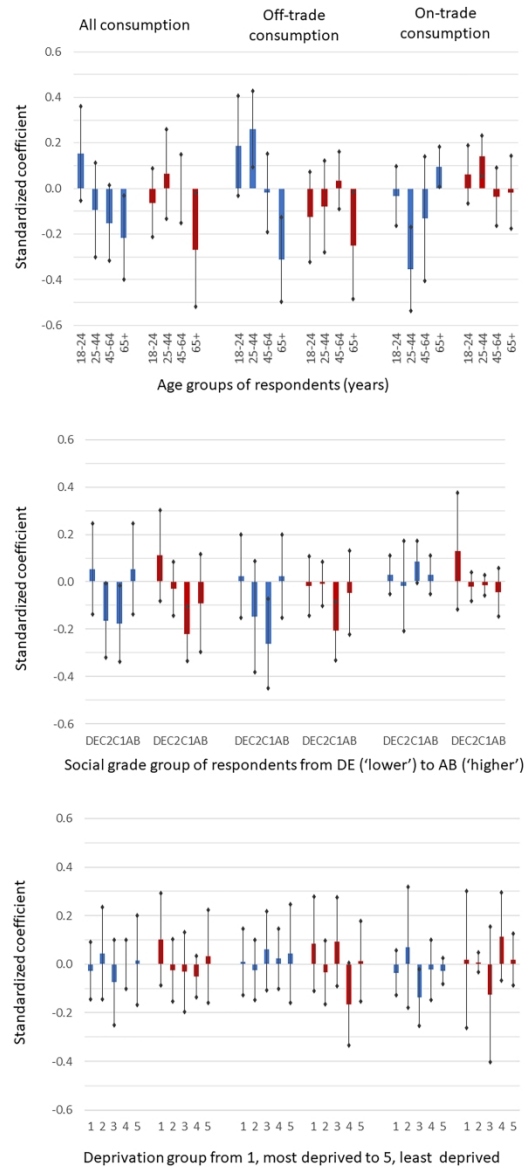


Figure 3 Associated changes in consumption following introduction of MUP for all consumption, off-trade consumption, and on-trade consumption (Scotland minus England, net effect) by age group, top graph; social grade group, middle graph; and, deprivation group, bottom graph for men (blue) and women (red).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

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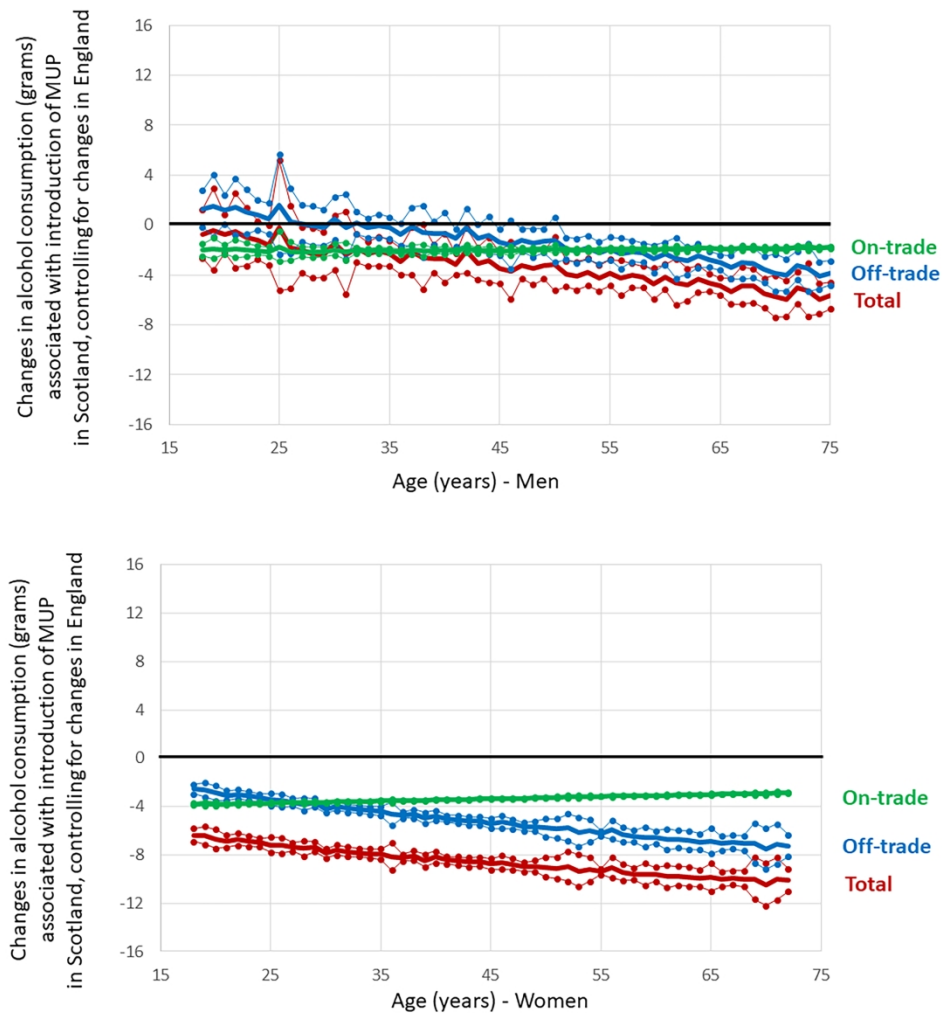


Figure 4 Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated with the introduction MUP in Scotland, controlling for changes in England for each age year. Plots of men and women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., 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% confidence intervals 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)].

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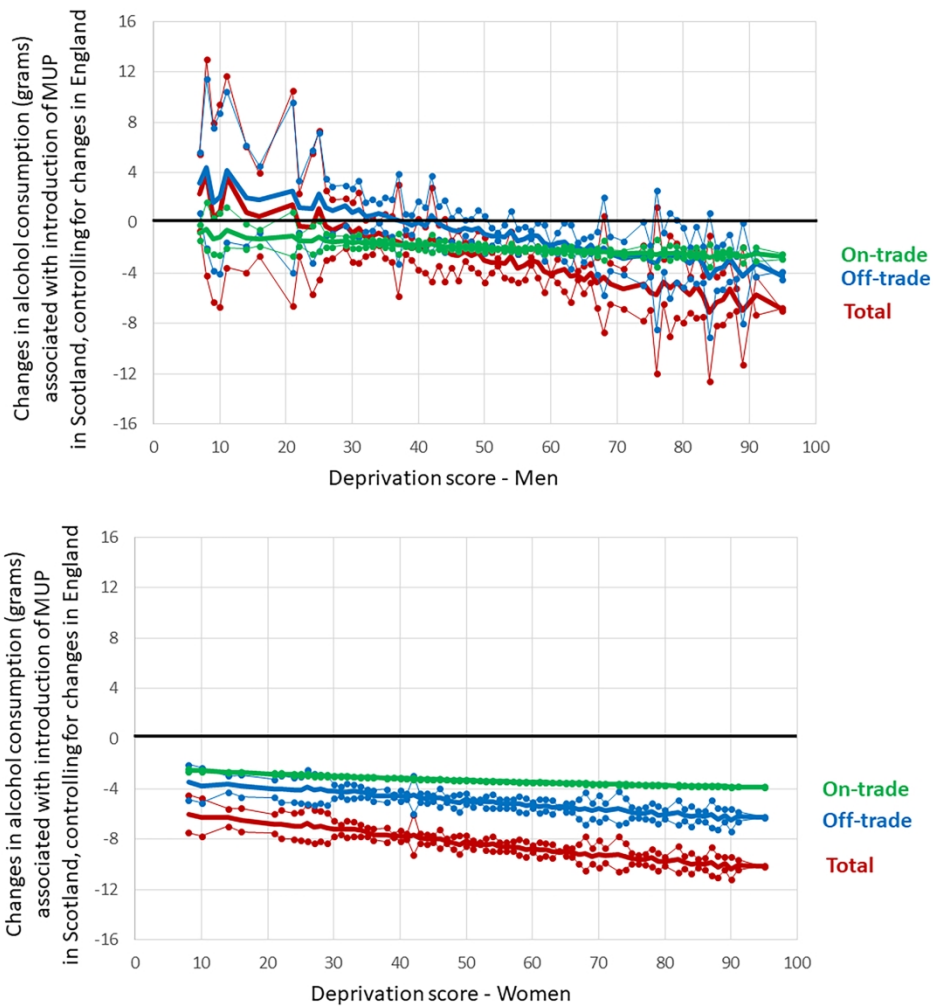


Figure 5 Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated with the introduction MUP in Scotland, controlling for changes in England for each deprivation score (on a 100% scale). Plots of men and women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., 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% confidence intervals 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)].

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SUPPLEMENT

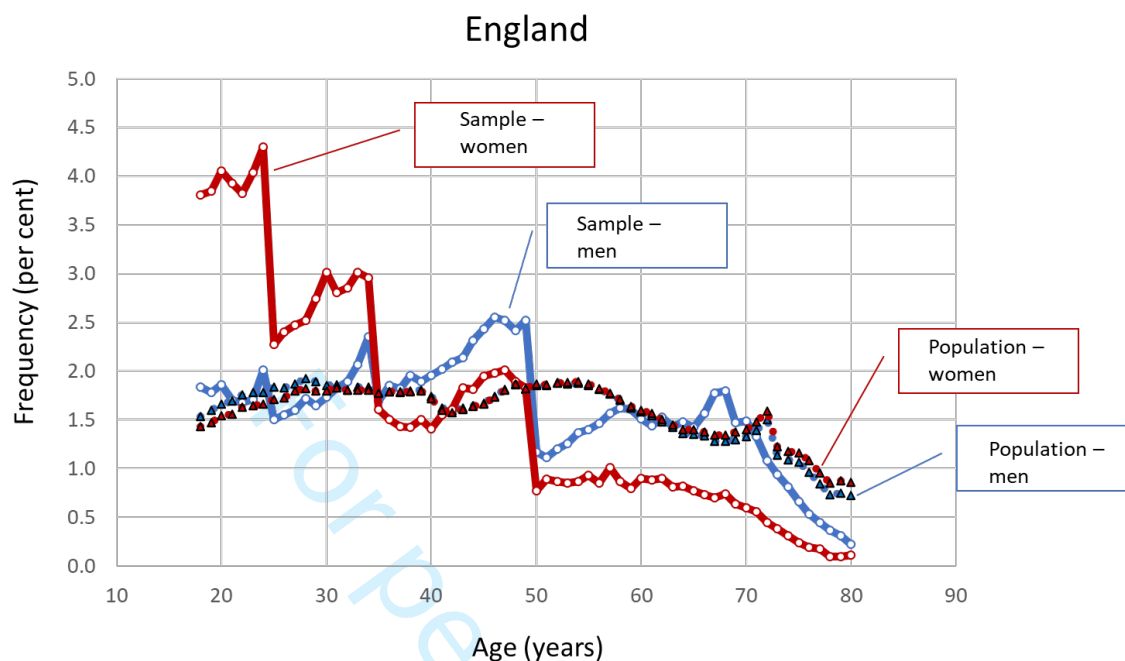


Figure 1 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for range 18-80 years), England. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and Northern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

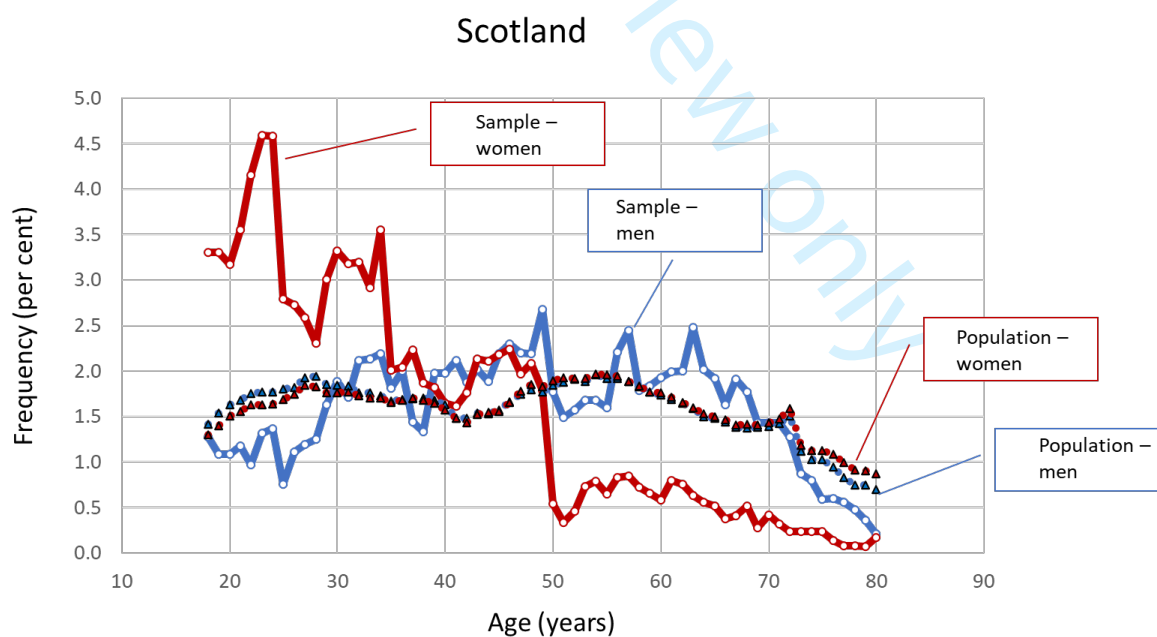


Figure 2 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for age range 18-80 years), Scotland. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and 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).

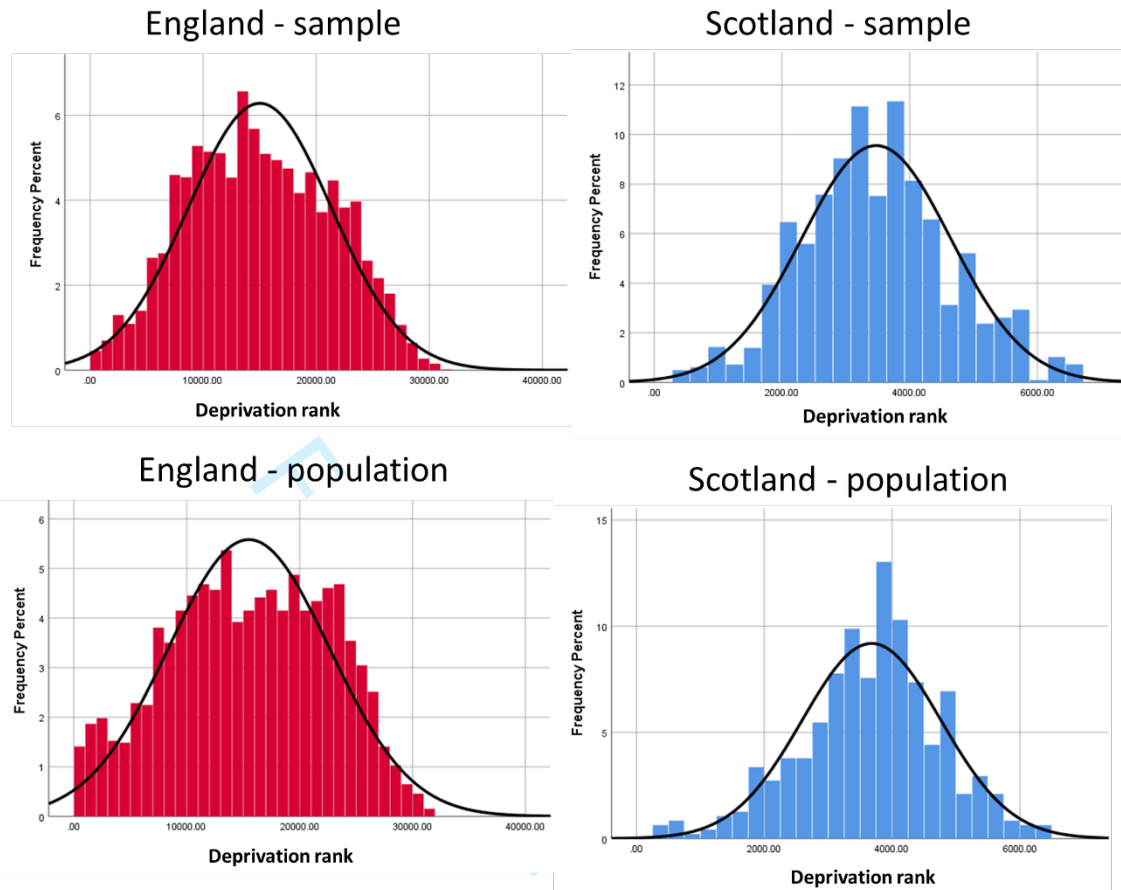


Figure 3 Per cent distribution (vertical axes) for analyzed sample and total population by deprivation rank (horizontal axes), England and Scotland. Data for total population from GOV.UK. National Statistics: English indices of deprivation 2019. <https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019>;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

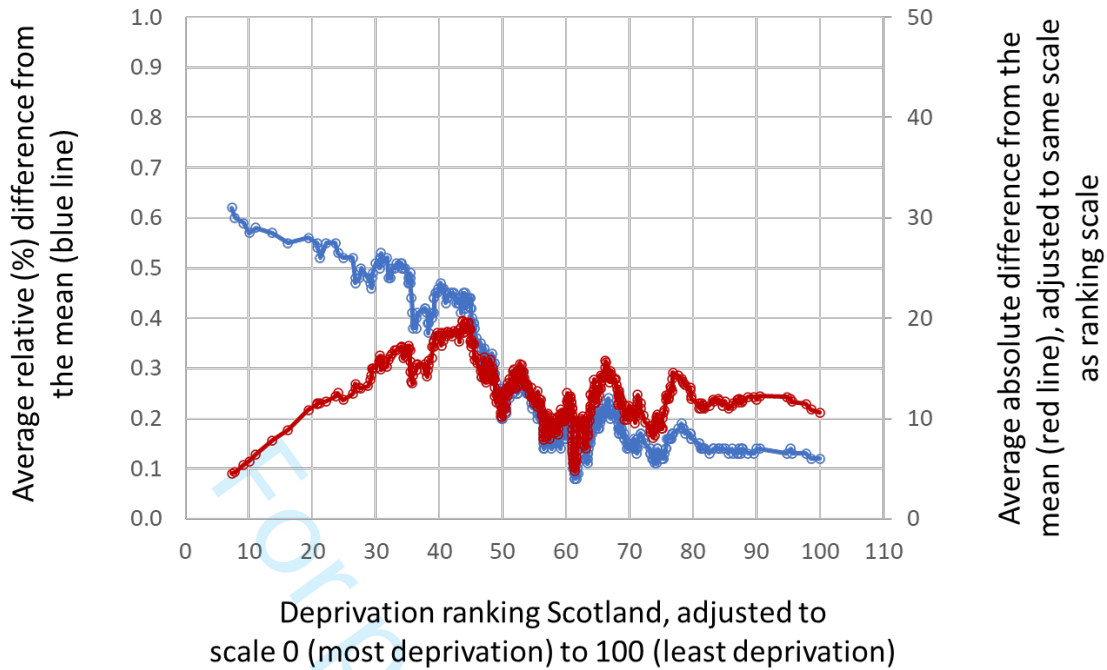


Figure 4 Dispersion of aggregated deprivation ranking, Scotland. The horizontal axis is the ranking from 0 (most deprived) to 100 (least deprived). The red line (right vertical axis) is the average absolute difference of the original ranking at local data zone level from the mean calculated at the truncated 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).

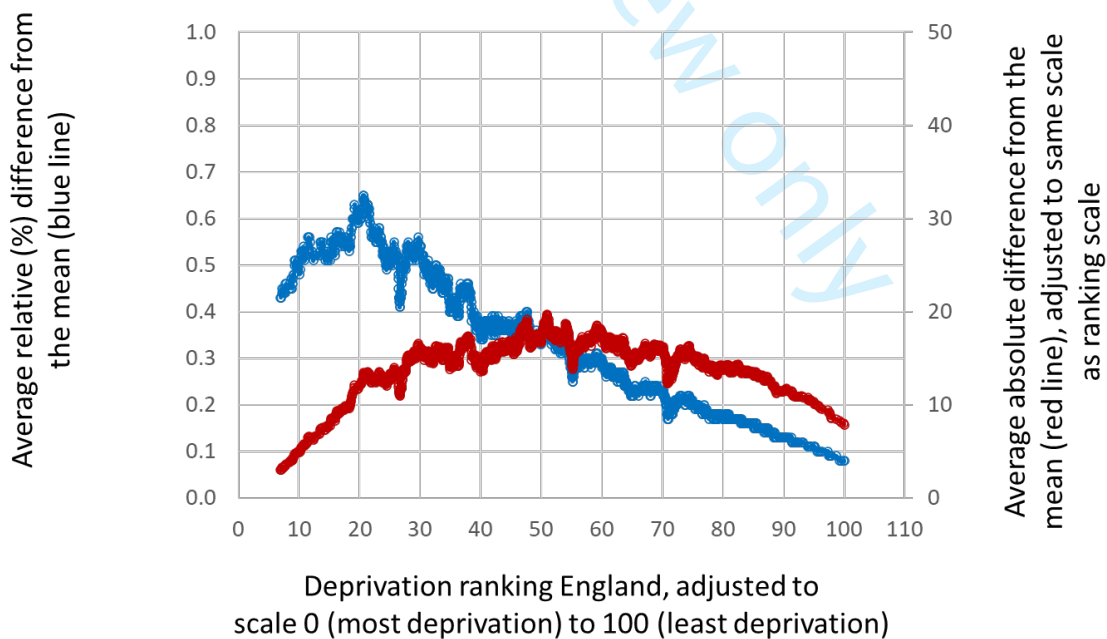


Figure 5 Dispersion of aggregated deprivation ranking, England. For explanation, see legend to Figure 4.

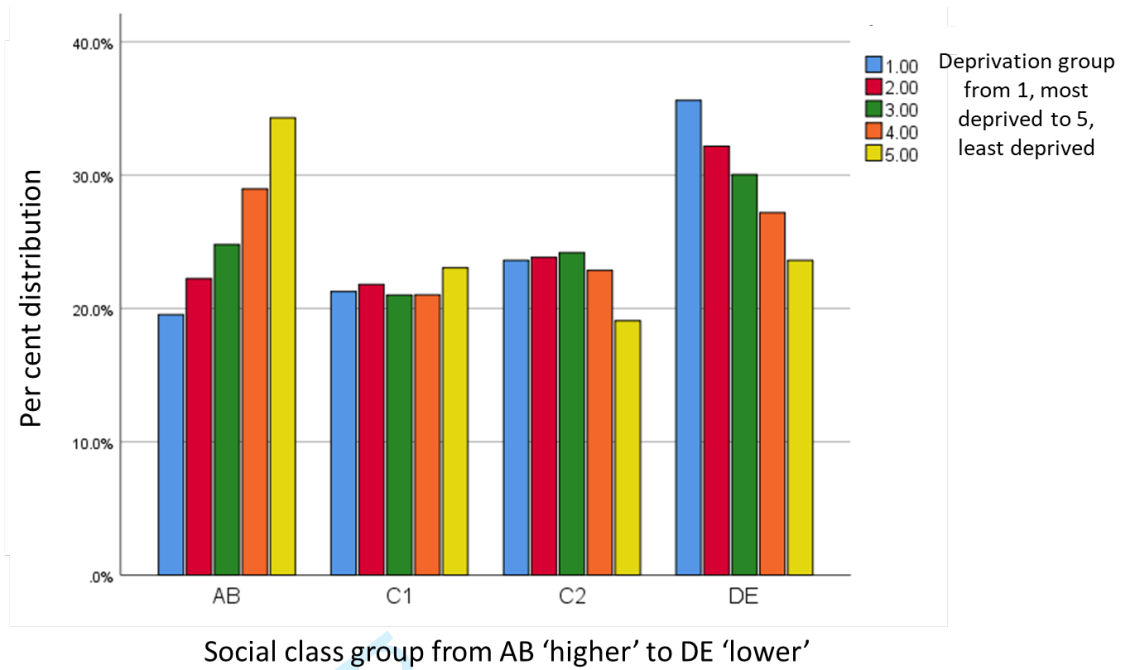


Figure 6 Distribution of deprivation group (from 1, most deprived to 5, least deprived) within social class groupings from AB, relatively higher to DE, relatively lower. Social class groups based on National Readership Survey; 2019. <http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/>.

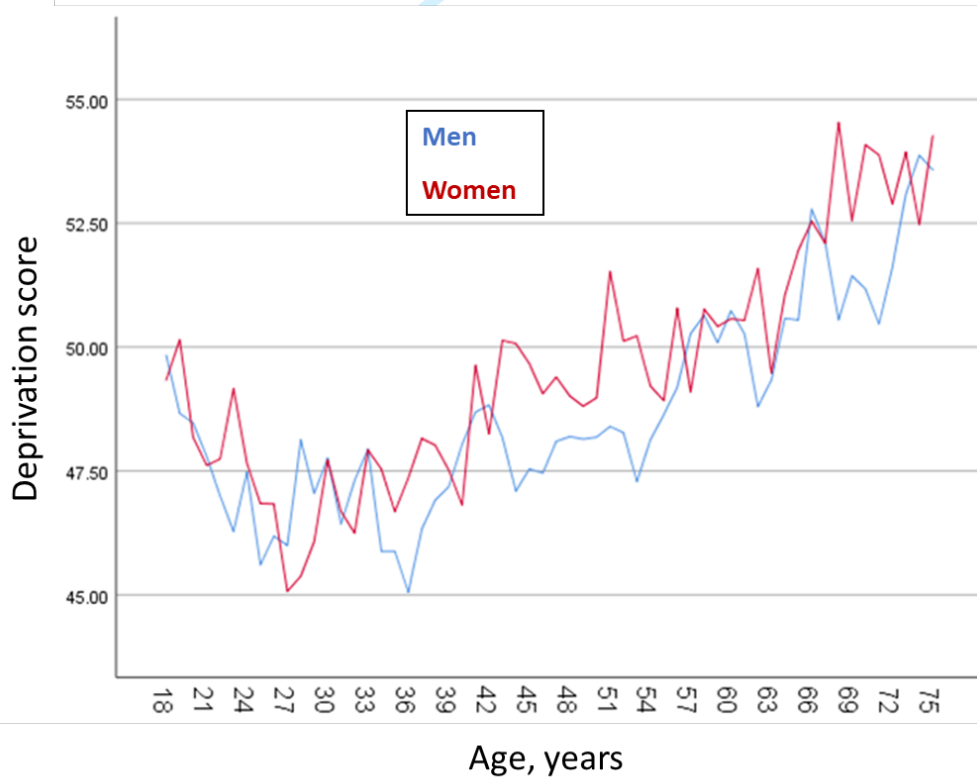


Figure 7 Plot of mean deprivation score (higher the score, the least deprived) by age and gender.

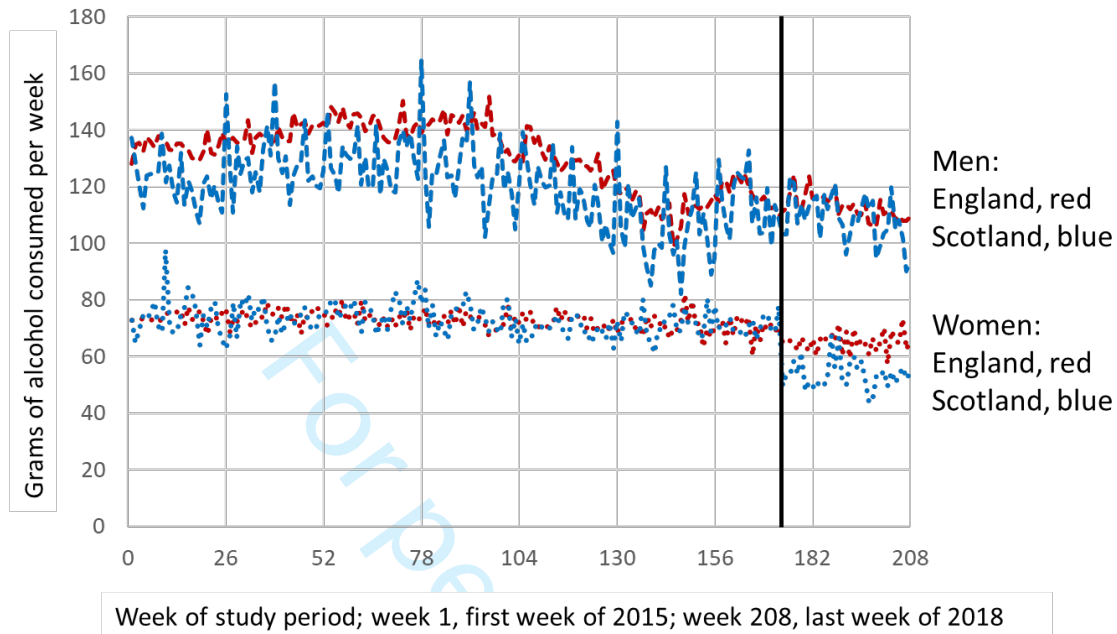


Figure 8 Plots of adjusted dependent variables (grams of alcohol consumed per week), seasonally adjusted using the ratio-to-moving-average method, over time (study week) by England and Scotland for men and women. Vertical black line: introduction of MUP.

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	.

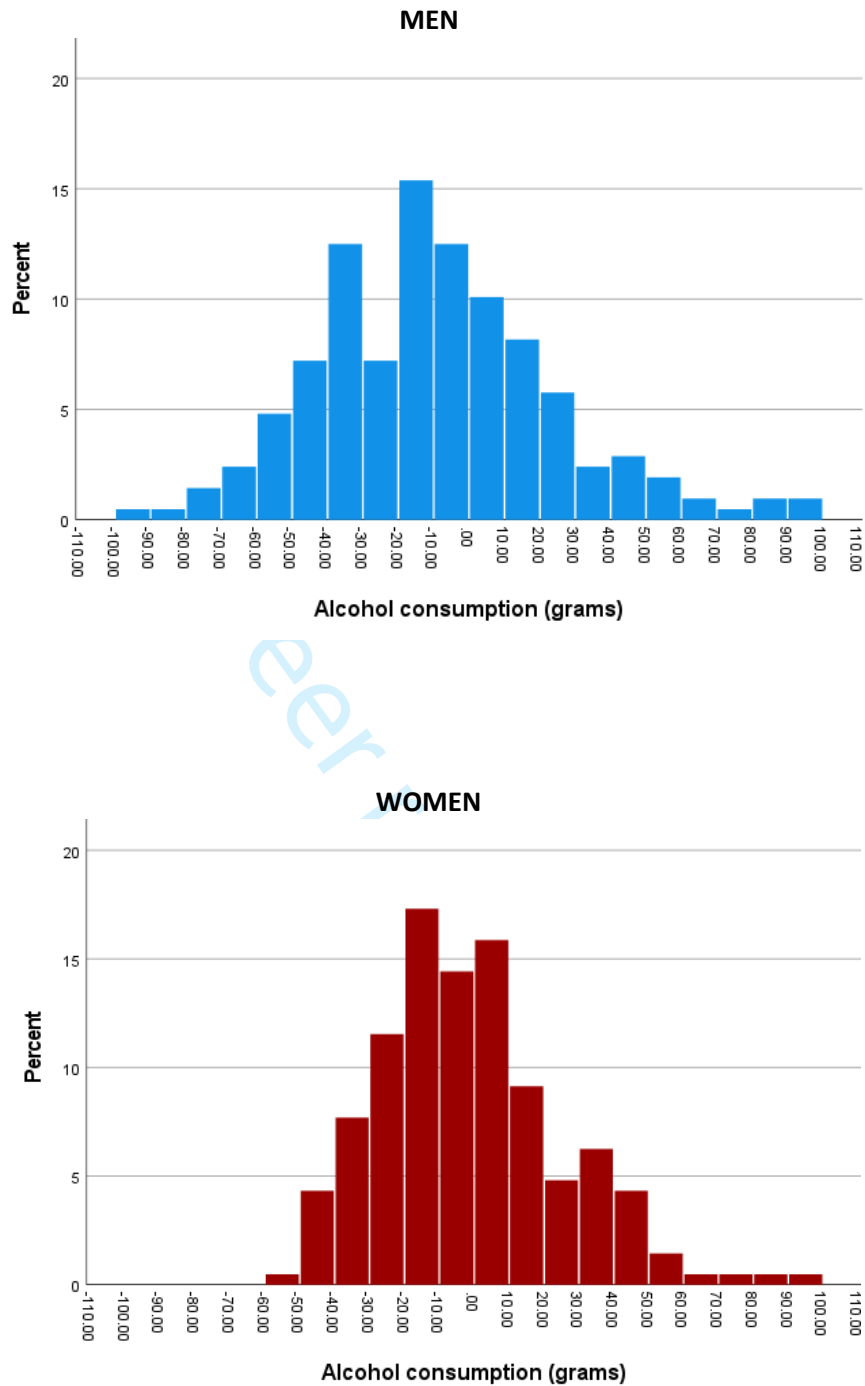


Figure 9 Plots of distributions of differences in total alcohol consumption (grams), Scotland minus England for men (top) and women (bottom).

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.
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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.
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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.

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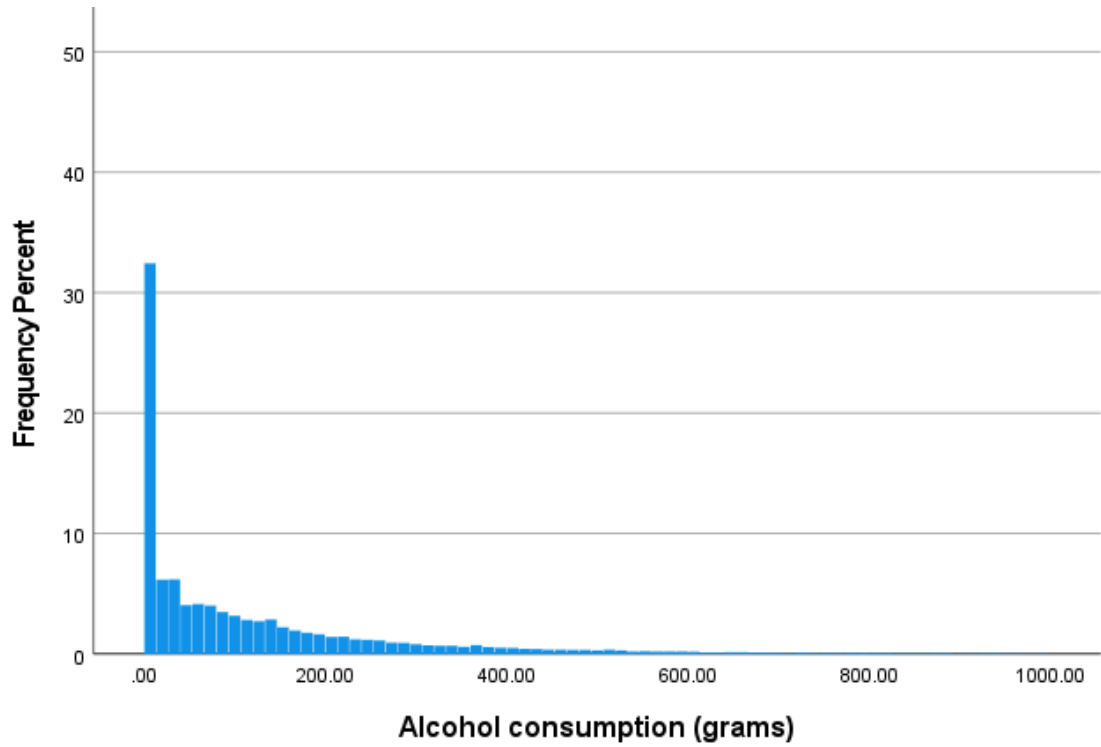


Figure 10 Distribution of weekly alcohol consumption, men.

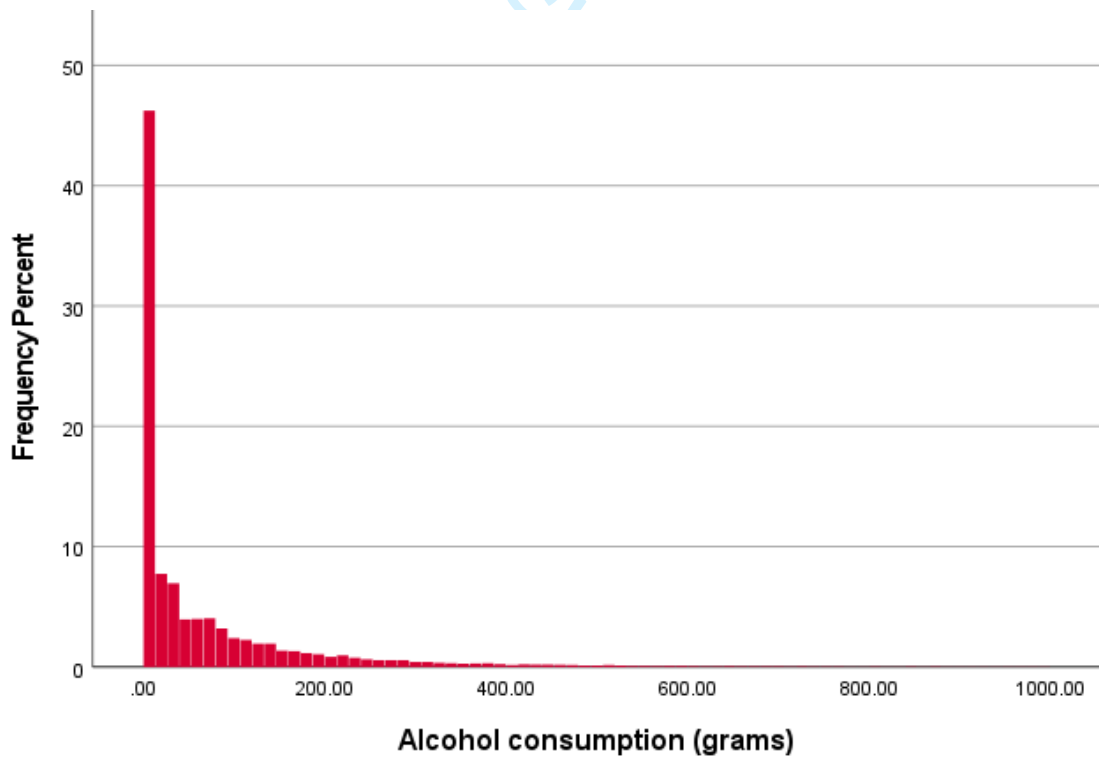


Figure 11 Distribution of weekly alcohol consumption, women.

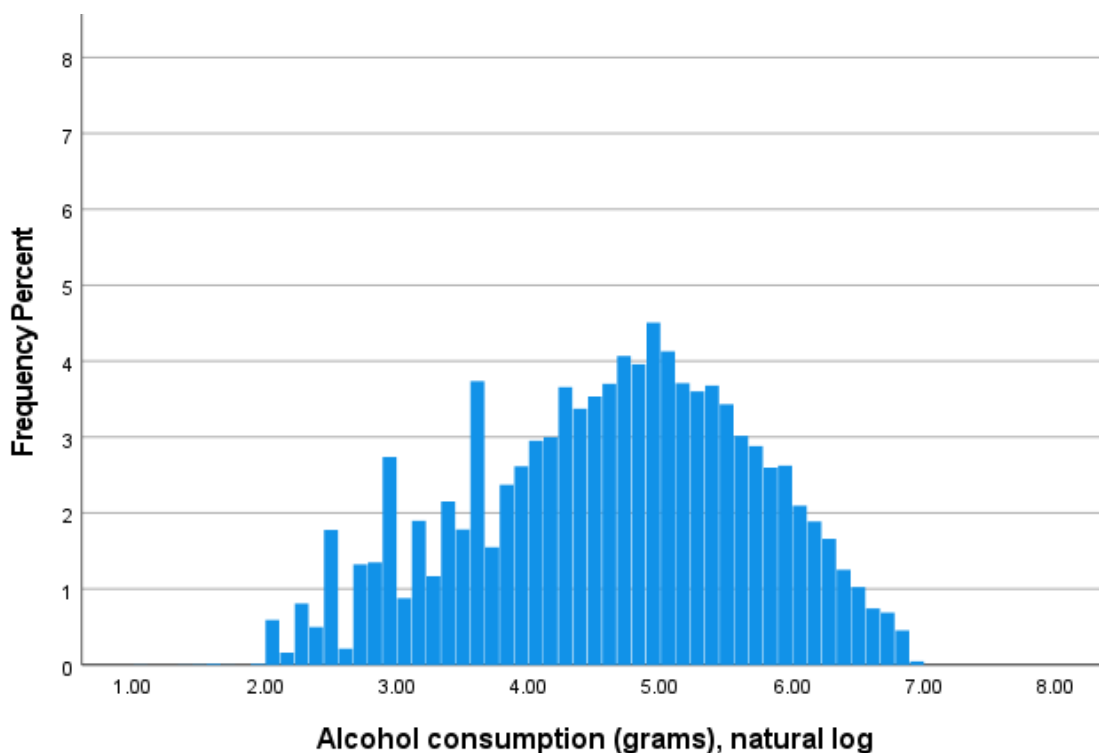


Figure 12 Distribution of weekly alcohol consumption (natural log), men who consumed alcohol during previous week.

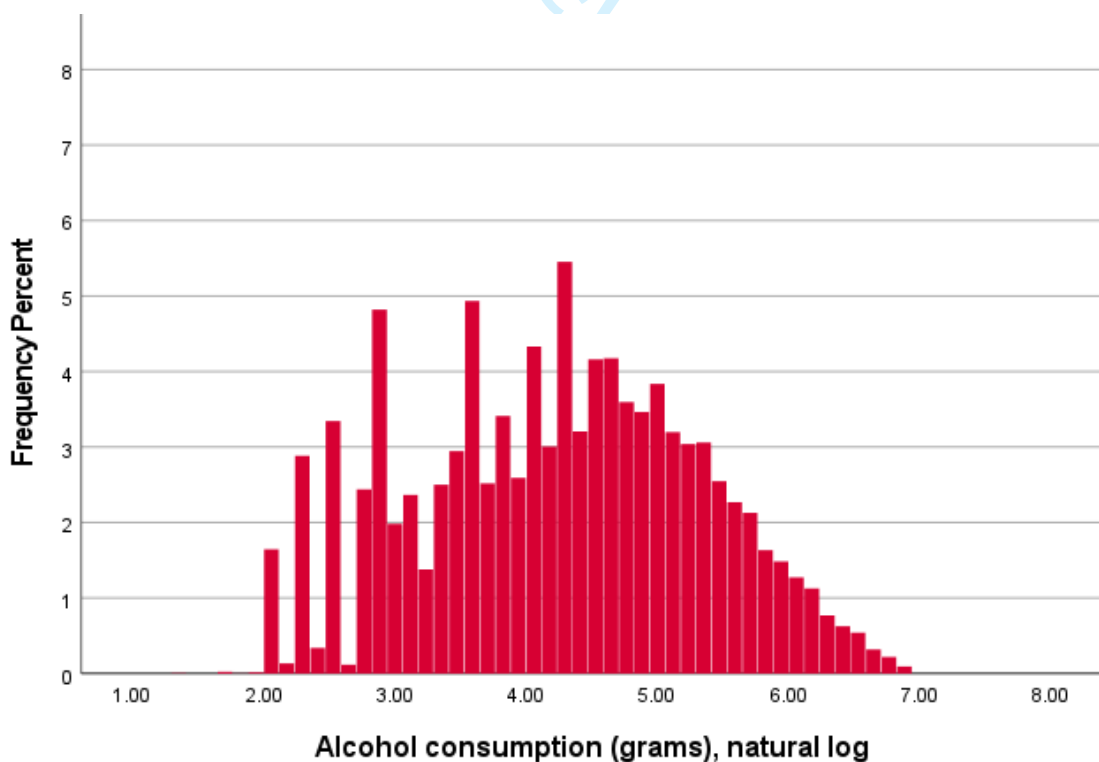


Figure 13 Distribution of weekly alcohol consumption (natural log), women who consumed alcohol during previous week.

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

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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

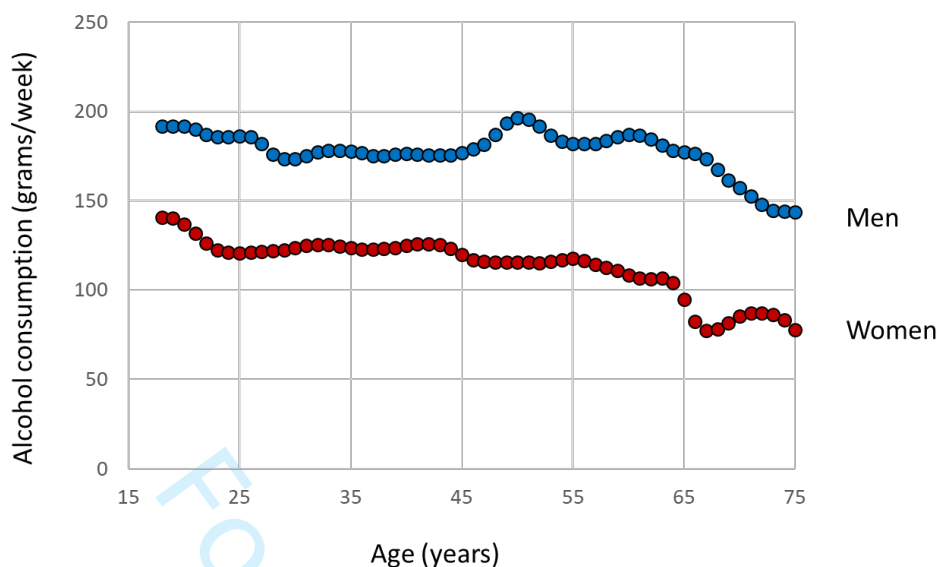


Figure 14. Mean alcohol consumption (grams per week) by age and sex, based on T4253H smoothing¹ across age. In a generalized linear regression equation, [GENLIN alcohol consumption with age, consumption decreased, similarly for both sexes, by 5.1 grams per every 10 years of increasing age (95% confidence interval, CI=4.4 to 5.7 grams).

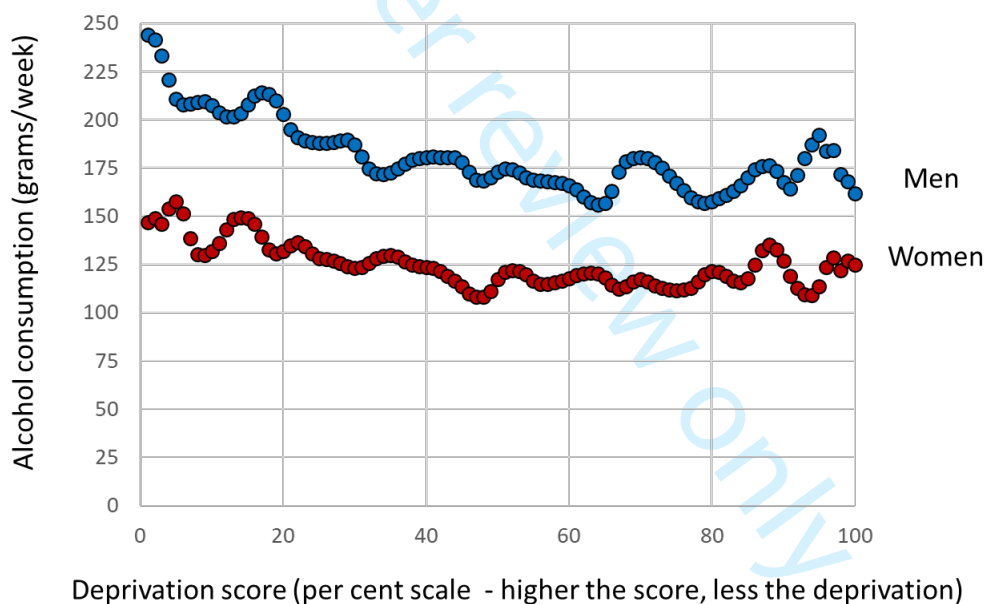


Figure 15. Mean alcohol consumption (grams per week) by deprivation score and sex, based on T4253H smoothing¹ across deprivation score. In a generalized linear regression equation, [GENLIN alcohol consumption with deprivation score, consumption decreased, similarly for both sexes by 1.1 grams per every 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 .)

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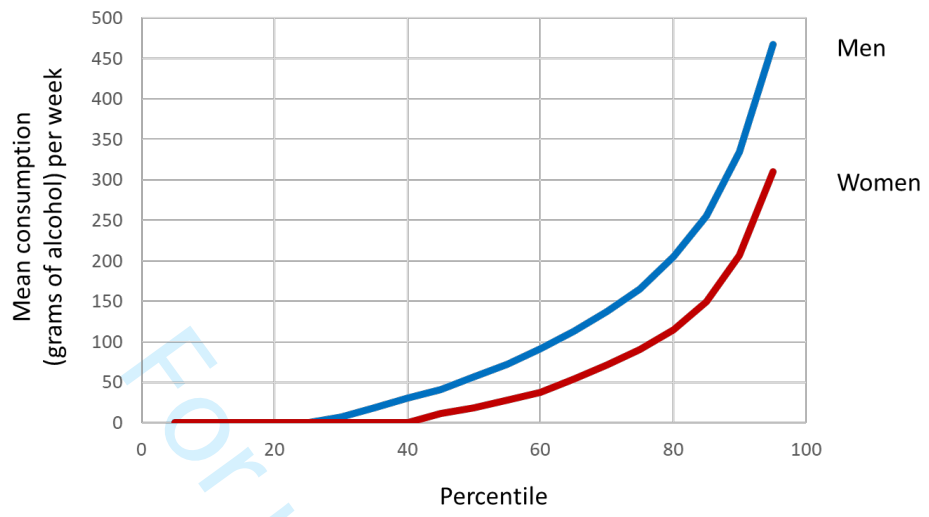


Figure 16. Mean consumption, grams of alcohol per week, by percentile distribution of consumption for men and women.

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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

Consumption percentile	Men			Women		
	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

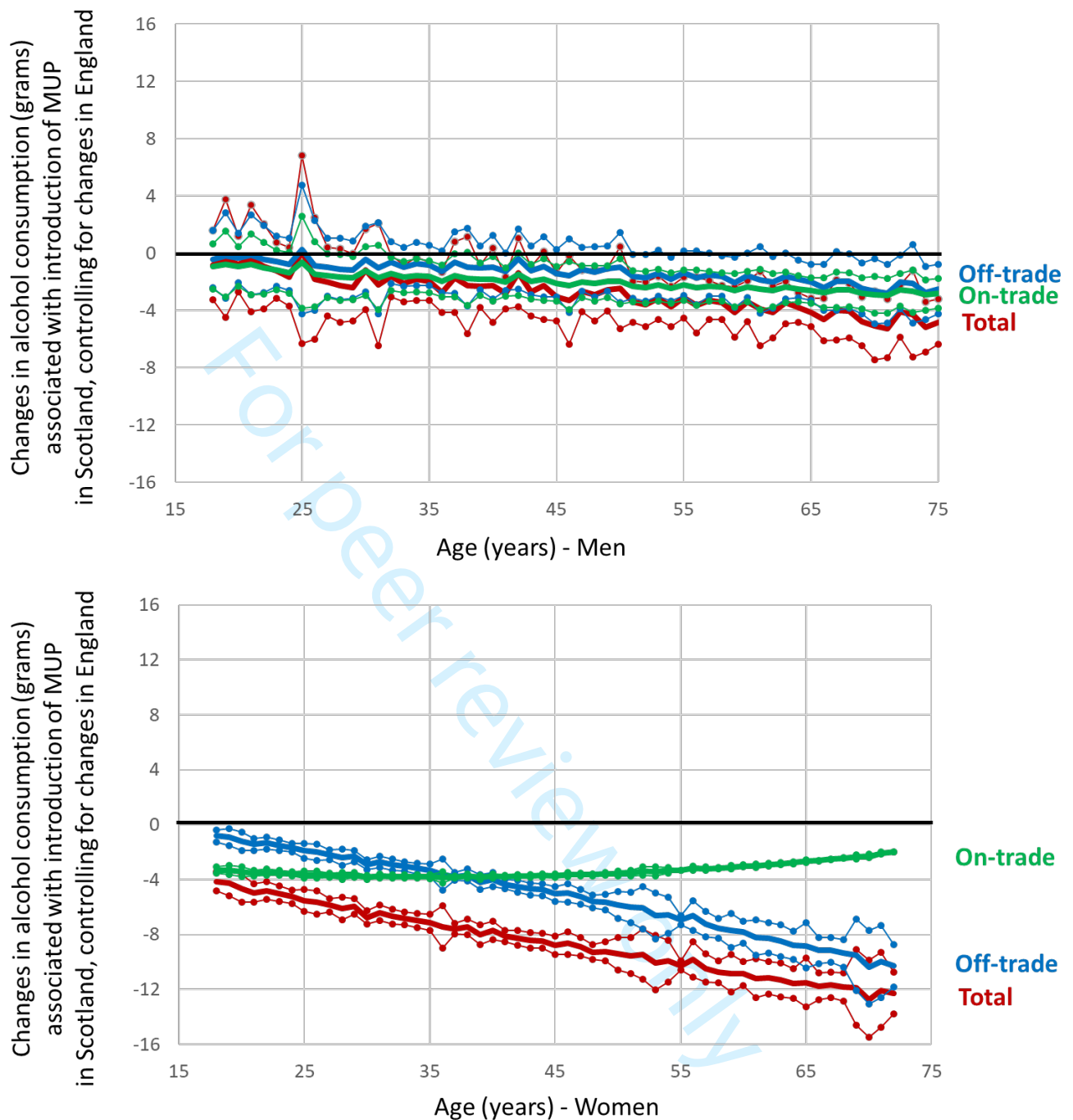


Figure 17 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each 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.

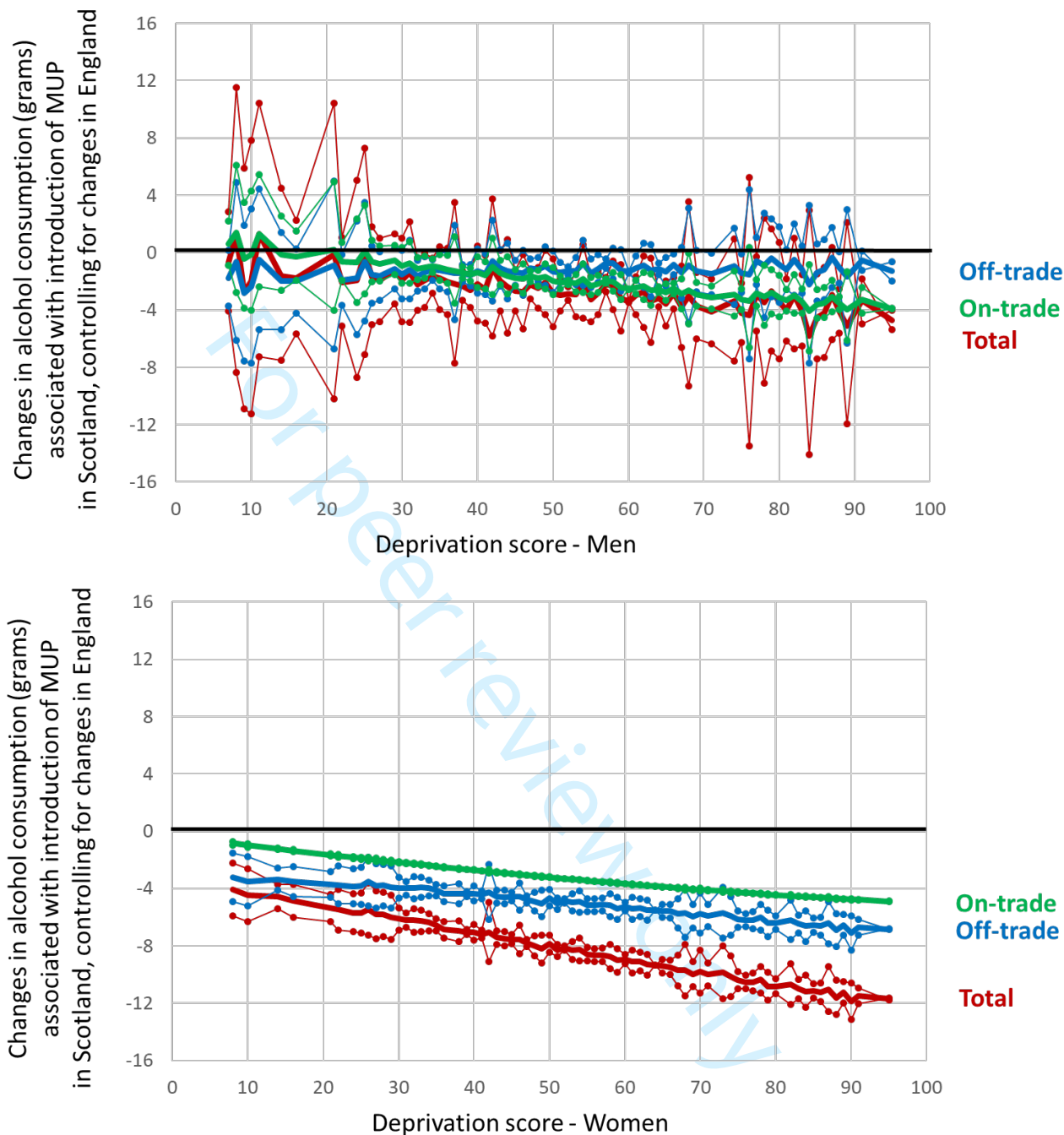


Figure 18 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each 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.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	“controlled interrupted time series analysis” included in title and abstract, p1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract adheres to these criteria, p2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction describes the importance of the need for empirical studies of the impact of minimum unit price by sex of drinker, p4
Objectives	3	State specific objectives, including any prespecified hypotheses	Objectives included as issues to answer in last paragraph of introduction, p4
Methods			
Study design	4	Present key elements of study design early in the paper	Included in first paragraph of methods, p5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	All included in the description of the data source, p5
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Fully described for interrupted time series analysis in the description of the data source, p5
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
Variables	7	<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	All dependent and independent variables described in the section statistical analyses, p6-7
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	
Data sources/	8*	<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	Fully described in both sections
		Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	

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measurement		data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	data sources and statistical analyses, p5-7
Bias	9	Describe any efforts to address potential sources of bias	Dependent variables are data from timeline follow-back surveys, p5
Study size	10	Explain how the study size was arrived at	Number of observations prior to and post introduction of minimum unit price meet all criteria required for interrupted time series analyses and are based on weekly data for the four years 2015-18.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why.	Fully described in the statistical analyses section, p6-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Detailed descriptions of the interrupted time series analyses are described in the statistical analysis section, p6-7.
		(b) Describe any methods used to examine subgroups and interactions	How the data were split into groups of respondent characteristics is described in the methods, p5-6.
		(c) Explain how missing data were addressed	No missing data, p5
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(e) Describe any sensitivity analyses	For the interrupted time series analysis, we undertook sensitive analysis, using respondents from Northern England, as opposed to England (used in main analysis), as control. For the before and after analysis, we first used logged normal data as dependent variable; for a sensitivity analysis, we used square-rooted data.

Continued on next page

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	All respondents and all weeks included in analyses, p5-7
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Distribution of demographic characteristics of households described in methods. No confounders added to model, p5
		(b) Indicate number of participants with missing data for each variable of interest	No missing data.
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Not applicable
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	Not applicable
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Not applicable
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Estimates given with 95% confidence intervals. No confounders included in models (see above), p8-12
		(b) Report category boundaries when continuous variables were categorized	Category groupings for respondent characteristics described, p5.
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not relevant
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Additional analyses for respondent groupings described, p9-12.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Included in first paragraph of discussion, p12.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Main limitations (e.g., use of survey data) fully described in discussion, p13-14.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity	Included in Conclusion paragraph, p9

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of analyses, results from similar studies, and
other relevant evidence

Generalisability	21	Discuss the generalisability (external validity) of the study results	Included conclusion paragraph, p14-15
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Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	No funding was received in support of the study, p15
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*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-054161.R3
Article Type:	Original research
Date Submitted by the Author:	17-Mar-2022
Complete List of Authors:	Rehm, Jürgen; CAMH, Social and Epidemiological Research O'Donnell, Amy; Newcastle University Kaner, Eileen; Newcastle University Jane Llopis, Eva; Maastricht University; Ramon Llull University Manthey, Jakob; Technische Universität Dresden, Institute of Clinical Psychology and Psychotherapy Anderson, Peter; Newcastle University; Maastricht University
Primary Subject Heading:	Public health
Secondary Subject Heading:	Addiction
Keywords:	PUBLIC HEALTH, SOCIAL MEDICINE, Substance misuse < PSYCHIATRY

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

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Words: 6500

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 50p per UK unit (6.25p per gram) 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 (e.g., at home), and in on-trade (e.g., 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 grams (95% CI=1.29-10.60 grams), a drop in off-trade consumption of 3.27 grams (95%CI=-0.01-6.56 grams), and a drop in on-trade consumption of 2.67 grams (95%CI=-1.48-6.82 grams). Associated reductions were larger for women than for men and were greater amongst heavier as opposed to 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 amongst older respondents and those living in less deprived areas. The introduction of MUP was not associated with a reduction in consumption amongst 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.

Funding: No funding was received in support of this study.

Strengths and limitations of this study

- The study uses a large commercial data set 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 the sex, level of alcohol consumption, age, social grade, and level of residential deprivation of respondents.
- The sample of respondents is not a random sample, 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.

peer review only

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 World Health Organization 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 (that is, 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 (e.g.,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 grams) of pure alcohol (ethanol) sold (6.25 pence per gram) beginning on May 1, 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 studies¹¹ 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 £0.50 GB 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 Alcovision survey,¹⁴ a continuous retrospective online timeline follow-back (TLFB) diary survey, allows us to specifically investigate gender-based impact of MUP in Scotland using England as a control group. In addition to allowing us to disaggregate consumption by socio-demographic 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 socio-economic strata who would be most affected by MUP.

METHODS

Study design

As 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 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 Kantar Worldpanel (KWP) Alcovision survey,¹⁴ an ongoing cross-sectional online timeline follow-back (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 seven days, including details on brands and volumes drunk, and whether these are consumed off-trade (for example, at home) or on-trade (for example 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 geographic 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 18-34-year-olds from both England and Scotland, (see Supplement Figures 1-2, page 1). In the data set we analysed, 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).

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 English¹⁷ and the Scottish¹⁸ Indices of Multiple Deprivation to group respondents into levels of residential deprivation (for details, see Supplement, pages 2-5, and Supplement 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 data set that we analyzed, we had records of all drinks consumed during the seven-day time-period, but not specified by day of week. Drinks were categorized within 19 categories, which we collapsed, grouped, and coded as beers, ciders, wines, spirits, fortified wines, and ready-to-drink products. In the data set we analyzed, detailed product description was provided for beers, including alcohol-free beers, but not for the other beverages. For non-beer products, the alcohol by volume (ABV) averages of the categories obtained from household purchase data over the same four 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 grams pure alcohol). We summed consumption into grams of alcohol by drink group per week for each individual survey respondent.

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3 In addition to the five deprivation groups, we also grouped individuals into: (i) four age groups (18-24;
4 25-44; 45-64; and 65+ years); and (ii) four occupation-based social grade groups (AB ['highest'], C1,
5 C2, DE ['lowest']), based on the National Readership Survey.²⁰
6

7
8 For the interrupted time-series analyses, we prepared weekly data by averaging consumption across
9 all respondents for each of the 208 weeks in the study period, separately for men and women, and
10 separately for total consumption, off-trade consumption, and on-trade consumption. We plotted the
11 seasonally adjusted total consumption over time (study week) by England and Scotland (Supplement
12 Figure 8, page 6). We observed parallel trends between England and Scotland prior to the introduction
13 of MUP, illustrating the appropriateness of England as a control area (tests for parallel trends, see
14 Supplement Table 1, page 6).
15

16
17 To analyse the potential impact of MUP in reducing alcohol consumption by levels of consumption,
18 we calculated, separately for men and women, and for each country (Scotland and England) and for
19 each week (from week 1 to week 208) the average consumption for separate percentiles of
20 consumption, ranging from 5% to 95% within 5% intervals.
21

22 **Statistical analyses**

23 **Primary interrupted time series analyses**

24 As primary analyses, interrupted time series regressions²¹ were undertaken with the weekly
25 consumption data averaged across all respondents, and separately for men and women, over the full
26 208 weeks, where week 1 is the first week of 2015, and week 208 is the last week of 2018. As with our
27 previous analyses,^{9,10} we created three new dependent variables of Scotland minus England (net
28 effect) for each of the weeks for: (i) the average consumption of all grams of all alcohol per week,
29 separately for men and women; (ii) the average consumption of all grams of all alcohol per week
30 consumed off-trade (e.g., at home), separately for men and women; and, (iii) the average
31 consumption of all grams of all alcohol per week consumed on-trade (e.g., in pubs, bars or
32 restaurants), separately for men and women.
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36 For each of the three dependent variables, we examined the distribution visually and with Q-Q plots
37 and found all variables, being the differences Scotland minus England (net effect) for the means of
38 consumption by respondent for each of the 208 weeks, to be normally distributed (see Supplement
39 Figure 9, page 7). We adjusted the dependent variables for any seasonality, using the ratio-to-moving-
40 average method.²² Based on Durbin-Watson tests²³ (range 1.53 to 2.18), there was no evidence of
41 autocorrelation, and based on Augmented Dickey-Fuller tests,²⁴ the series were found to be stationary
42 (see Table 1 in Results section). We examined the immediate and permanent level changes due to the
43 event, the introduction of MUP in Scotland, at Week 174. The event variable was entered as a dummy
44 variable, coded with 0 for each week before the event and with 1 for each week from the event
45 forwards. Thus, in our generalized linear regression models, which we ran separately for men and for
46 women, the dependent variables were the difference in reported consumption of grams of alcohol
47 between Scotland and England (net effect). The independent variables were the dummy-variable
48 event, and time (each week from 1 to 208). Interrupted Time Series Regression Equation 1 and SPSS
49 syntax is presented in Supplement Box 1, page 8.
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53 To test if MUP had an associated differential impact by sex of respondent, we re-ran Interrupted Time
54 Series Regression Equation 1 for the total sample (both men and women) adding sex of respondent
55 and the interaction term sex*introduction of MUP to the model (see Supplement Box 1, page 8).
56

57
58 We repeated Interrupted Time Series Regression Equation 1 separately for each of the: four age
59 groups; four social grade groups; and five deprivation groups (thus, comparing same groups in England
60 and Scotland). For these analyses, we transformed the continuous variables into their z-scores and

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3 used the z-scores as the dependent variables, so that the results could be compared between groups
4 in terms of standard deviations, rather than original units. This allowed us to compare the relative
5 importance of the regression coefficients, and thus changes, across the socio-demographic
6 characteristics of the respondents.
7

8
9 For the analyses by the separate consumption percentiles, for each separate percentile, we also
10 created a difference in consumption by subtracting the mean consumption, Scotland minus England.
11 We repeated Interrupted Time Series Regression Equation 1 separately for each of the 19 percentiles
12 (from 5% to 95%) and plotted the coefficient and 95% confidence intervals associated with the event
13 (introduction of MUP) by the percentile, separately for men and women.
14

15 **Sensitivity analysis**

16 We repeated Interrupted Time Series Regression Equation 1, using men and women resident in
17 Northern England as control for Scotland, rather than residents from all of England.
18

19 **Secondary before-and-after analyses**

20 The secondary before-and-after analyses were done with individual-respondent seven-day
21 consumption data summed across each week, separately for men and women to better understand
22 variation in the associated impact of MUP by age and deprivation, for each individual age and each
23 individual deprivation score rather than by the four age groups and the five deprivation groups used
24 in the interrupted time series analyses. For these analyses, we did not compute a new dependent
25 variable (Scotland minus England), but rather used the original data by country. We examined the
26 distribution of the dependent variables and found them to be highly dispersed (see Supplement
27 Figures 10-11, page 11). We excluded all respondents with zero consumption during the previous
28 week, and then took the natural log of the consumption data, resulting in a normal distribution of the
29 natural logged data (see Supplement Figures 12-13, page 12). In our models, the independent
30 variables were: the event variable (introduction of MUP), coded as a dummy variable as above for the
31 interrupted time-series analysis; country as a factor (England or Scotland); age as a dummy coded
32 variable for each individual age year; deprivation as a dummy coded variable for each deprivation
33 score rounded to an integer; and, time (weeks) as a covariate. For each of the dependent variables,
34 we ran two separate models, one for age, and one for deprivation score. Before-and-After analysis
35 Regression Equation 2 and the SPSS syntax are presented in Supplement Box 2, pages 8-9.
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40 From the results of the regression model, and for each individual age and for each individual
41 deprivation score, we took the difference in the marginal means (and the 95% confidence interval of
42 the differences), [Scotland*MUP*age /or/ deprivation score] minus [England*MUP*age /or/
43 deprivation score], this difference representing the added associated impact of MUP in Scotland over
44 and above that in England for each individual age and for each individual deprivation score. We plotted
45 the differences of the marginal means as above (with their 95% confidence intervals) by each age and
46 each integer deprivation ranking respectively, for men and women separately. We extracted the mean
47 values of the changes (y-axes) from the plots and performed a linear regression of these values
48 respectively by age and deprivation score, separately for men and women to test how the differences
49 in the marginal means between Scotland and England (net effect) differed by age and deprivation
50 score. The Before-and-After Analysis Regression Equation 3 and SPSS syntax are presented in
51 Supplement Box 3, page 9. We tested the difference in slopes between men and women for total
52 consumption by repeating Regression Equation 3 for the total sample (both men and women), adding
53 the interaction term sex*age /or/ deprivation score as an additional independent variable to the
54 model. Finally, given the relationship between age and deprivation score (Supplement Figure 7, page
55 5), we also tested if any relationship between changes in alcohol consumption associated with MUP
56 and age of the respondent differed by deprivation group. We tested this by adding an interaction term
57 age*deprivation group to the regression model (See Supplement Box 4, page 10).
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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 normalize 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 normalizing the data. We tested this by adding an interaction term 'type of normalization (natural log or square root) * age/or/deprivationscore to the regression model (See Supplement Box 5, page 10).

Power calculations are reported in the supplement, Page 13.

Analyses were performed with SPSSv26 (IBM Corp 2019).²⁵ For our regression models, we used generalized 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.

Ethical approval

Ethical approval was not required, as our analyses are based on a publicly available commercial data set.

RESULTS

Overall, 106,490 respondents (53,347 women and 53,143 men) contributed to the data set (for details of numbers of respondents by country, before and after the introduction of MUP and by socio-demographic 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).

For all respondents (English and Scottish), the mean reported consumption per week was 125.8 grams for men (66.4% consumed off-trade) and 71.3 grams 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 grams per every 10 years of increasing age (95% confidence interval, CI=4.4 to 5.7 grams) (see Supplement Figure 14, page 19). Consumption decreased by only a small amount with decreasing deprivation, 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), (see Supplement Figure 15, page 19).

Interrupted time-series analyses – main findings

Figure 1 plots the differences in consumption of alcohol (grams) Scotland minus England (net effect) for each of the 208 weeks, 2015-2018. Table 1 gives 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 grams per week (95%CI=1.3 to 10.6 grams) (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 grams per week, 95%CI=2.9 to 14.3 grams) rather than by men (a reduction of 3.3 grams 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 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 grams per week (95%CI=1.9 to 15.7grams).

Figure 1 here

Table 1. Unstandardized coefficients from interrupted time series analyses (95% confidence intervals) for all respondents, and separated for men and women, 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. 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.

		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	0.003 (-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)	-.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)	0.417 (-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)

Interrupted time-series analyses – sensitivity analyses

Table 2 gives 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 grams per week (95%CI=2.6 to 9.2 grams) (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 grams per week (95%CI=1.0 to 11.0 grams), 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 grams 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 grams, 95%CI = 5.8 to 21.5), but not for women (of 4.8 grams, 95%CI = -4.0 to 13.7).

Table 2 Sensitivity analysis, using Northern England as a control for Scotland. Unstandardized coefficients from interrupted time series analyses (95% confidence intervals) for all respondents, and separated 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.

		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 (-.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 -.591)	.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 (-.034 to 5.165)	2.846 (-.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)

Figure 2 here

Figure 3 displays 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 standardized coefficients, allowing for relative, rather than absolute comparisons across the groups (for numerical data, see Supplement Tables 10-12, pages 23-25).

Figure 3 here

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3 By age group (top graph), there was a pattern of greater associated drops in all consumption and in
4 off-trade consumption for both men and women with increasing age. For younger men, there was an
5 increase in off-trade consumption, which was offset by decreases in on-trade consumption in the same
6 group. There appeared no clear or consistent discernible pattern by social grade (middle graph), or by
7 deprivation group (bottom graph). The secondary before-and-after analyses provide more detail of
8 the associated impact of MUP by individual age and deprivation ranking.
9

10 11 **Secondary before-and-after analyses**

12 Figure 4 plots the associated changes in alcohol consumption (in grams of alcohol) following
13 introduction of MUP for all consumption, off-trade consumption, and on-trade consumption by
14 gender and individual age. For men, reductions in consumption following the introduction of MUP
15 became greater with increasing age for both total consumption (linear regression coefficient across
16 age (RC) =-0.088 (95%CI=-0.094 to -0.083) and off-trade consumption (RC =-0.092 (95%CI=-0.097 to -
17 0.088); for on-trade consumption, reductions in consumption became very slightly smaller with
18 increasing age (RC =0.0038 (95%CI=0.0026 to 0.0050). For younger men (those aged less than 30
19 years), the introduction of MUP was not associated with a decrease in consumption, more so the
20 younger the age, as upper 95% confidence intervals were greater than zero. For women, a similar
21 pattern emerged, with reductions in consumption across all ages. Reductions in both total (RC =-0.070
22 (95%CI=-0.072 to -0.067) and off-trade consumption became slightly greater with increasing age (RC
23 =-0.087 (95%CI=-0.090 to -0.085), whereas reductions in on-trade consumption became very slightly
24 smaller with increasing age (RC =0.0179 (95%CI=0.0176 to 0.0182). The coefficient for the interaction
25 term, sex*by age (with women as reference category), was -0.019 (95%CI=-0.025 to -0.013) indicating
26 that the reduction in consumption was slightly greater with increasing age for men rather than for
27 women.
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33 **Figure 4 here**

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37 Figure 5 plots the associated changes in alcohol consumption (in grams of alcohol) following the
38 introduction of MUP for all consumption, off-trade consumption, and on-trade consumption by
39 gender and individual deprivation ranking. For men, reductions in consumption following the
40 introduction of MUP became greater with less deprivation, more so for total (RC =-0.102 (95%CI=-
41 0.108 to -0.097) and off-trade consumption (RC =-0.082 (95%CI=-0.087 to -0.078) than for on-trade
42 consumption (RC =-0.020 (95%CI=-0.022 to -0.019), with an indication that those living in the most
43 deprived areas (bottom two-fifths) showed no decrease in consumption, more so the greater the
44 deprivation (as upper 95% confidence intervals were greater than zero). For women, a similar pattern
45 emerged, with reductions in consumption across all deprivation scores. Reductions in consumption
46 following the introduction of MUP became larger with less deprivation for total consumption (RC =-
47 0.050 (95%CI=-0.051 to -0.049), off-trade consumption (RC =-0.035 (95%CI=-0.036 to -0.034), and on-
48 trade consumption (RC =-0.0151 (95%CI=-0.0155 to -0.0147). The coefficient for the interaction
49 term, sex*deprivation score (with women as reference category), was -0.053 (95%CI=-0.059 to -0.046)
50 indicating that the reduction in consumption was slightly greater with less deprivation for men rather
51 than for women.
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56 **Figure 5 here**

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58 The age-related patterns of Figure 4 were independent of deprivation. Before-and-After Analysis
59 Regression Equation 4 found no interaction between age in years and deprivation group in the changes
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3 in total alcohol consumption (Scotland minus England, net effect) associated with the introduction of
4 MUP: for men, the coefficient for the interaction was -2.2^{-5} , 95%CI -5.5^{-3} to 5.4^{-3} ; for women, the
5 coefficient was 1.6^{-3} , 95%CI -1.1^{-3} to 4.2^{-3} . In other words, the slopes between changes in alcohol
6 consumption by age for men and women plotted in Figure 4 were almost identical across the five
7 deprivation groups.
8

9 **Before-and-after analyses – sensitivity analyses**

10 We repeated the before-and-after analyses, using the square root (as opposed to logged) grams of
11 alcohol consumption as the dependent variable, with similar patterns of findings to Figures 4 and 5
12 (see Supplement Figures 17 and 18, Pages 26-27). There were, however, differences in the slopes. For
13 total consumption, Before-and-After Analysis Regression Equation 5 found, with age, that the slope
14 for logged grams of alcohol was slightly steeper for men (regression coefficient of the interaction term,
15 'type of normalization*age = -0.017 (95% CI = -0.025 to -0.008), but slightly less steep for women
16 (regression coefficient of the interaction term = 0.082 (95% CI = 0.078 to 0.087) than the slope for the
17 square root of consumption. There were similar findings in the differences in slopes for dependence
18 score; the slope for logged grams of alcohol being slightly steeper for men (regression coefficient of
19 the interaction term, 'type of normalization*dependence score = -0.059 (95% CI = -0.068 to -0.050)
20 for men, and slightly less steep for women (regression coefficient of the interaction term = 0.040 (95%
21 CI = 0.038 to 0.043).
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26 **DISCUSSION**

27
28 We found that the introduction of MUP in Scotland was associated with a change in overall reported
29 alcohol consumption in line with the predicted direction. Compared to respondents from England,
30 Scottish respondents reported a 6.2% drop in alcohol consumption (95% CI=2.3% to 8.4%) associated
31 with MUP. Sensitivity analyses using respondents from Northern England, with more similar drinking
32 levels to Scotland than England as a whole,²⁶ found an almost identical associated drop in alcohol
33 consumption. The drop in consumption was larger for heavier as opposed to lighter drinkers, with the
34 exception of the top 5% of heaviest drinking men for whom there was an increase in consumption
35 associated with the introduction of MUP.
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38 Against expectations, we found that associated drops in consumption were greater for women than
39 for men, both in the main (using all of England as a control) and in the sensitivity (using Northern
40 England as a control) analyses. Men and women also responded differently by age. Based on both the
41 interrupted time series analysis and the before-and-after analysis, for men, the size of the associated
42 drop in consumption became smaller with decreasing age, with younger men showing no associated
43 decrease in consumption. For women, the associated drop in consumption also became smaller with
44 decreasing age, although less so than for men.
45
46

47 We included two potential measures of socio-economic disadvantage: social grade and an index of
48 residential deprivation based on multiple measures of income, employment, education, health, crime,
49 access to housing, and environmental quality,^{17,18} noting that the risk of alcohol-related harm
50 increases both the more socio-economically disadvantaged the individual is, and, over and above that,
51 the more socially disadvantaged the residential area in which the individual resides.²⁷ It should be
52 noted that estimates of the indices of residential deprivation differ between Scotland and England,
53 and thus, in absolute terms, they may not be the same. However, in our analyses we compare relative
54 deprivation; for example, comparing the bottom fifth of deprivation of Scotland with the bottom fifth
55 of deprivation of England, noting that relative deprivation, itself, is a key determinant of ill-health.²⁸
56 Based on the interrupted time series analyses, for both men and women, there was no discernible
57 pattern by social grade or deprivation group. However, based on the secondary before-and-after
58 analyses (both main and sensitivity), the size of the associated drop in consumption for men became
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3 smaller with increasing deprivation, with men living in the most deprived areas having no associated
4 decrease in consumption. For women, the associated drop in consumption also decreased slightly with
5 decreasing deprivation score, although less so than for men.
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7
8 The drop in consumption of 6.2% is a little lower than the 7.6% drop we found in our previous analysis
9 of household purchase data in both the short⁹ and medium term.¹⁰ As with the present study based
10 on survey data, our previous analyses of household purchase data also found that drops in
11 consumption were greater amongst households with higher rather than lower usual purchases of
12 alcohol.^{9,10} However, with our previous analyses of household purchase data, we could not test the
13 impact of MUP on purchases by age or gender, as the purchase data were for the household as a whole
14 and not attributable to individual household family members. Nor did those analyses report the
15 impact of MUP by the social grade of the household or the level of deprivation in which the household
16 was located. The findings presented in this paper thus provide a more nuanced understanding of the
17 differential impact of MUP on different population sub-groups. Specifically, what we identified in the
18 present analysis is the top 5% of heavy drinking men did not reduce their consumption in association
19 with MUP; rather, our results suggest an increase in associated consumption amongst this group. For
20 women, there was an upturn in changes in alcohol consumption in the heaviest drinking percentiles
21 (Figure 2); that the lower 95% confidence interval for women did not cross zero could be due to the
22 relatively small numbers of respondents in each of the 19 consumption percentiles (Supplement Table
23 9, page 22).
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26
27 We do not know why, for both younger men (those aged less than 32 years), and for those living in
28 residential areas in the bottom two-fifths of deprivation, there was no decrease in consumption
29 associated with MUP, compared to older men and those living in less deprived areas. It has been
30 suggested that some very heavy drinkers (as we found for the top 5% of heavy drinking men) would
31 be less prone to the potential impact of MUP,²⁹ and in potential need of additional support to cope
32 with the impact of MUP³⁰. Responses to MUP might vary by individual and psychosocial factors,
33 including socio-economic disadvantage, which may interact with the situational availability of
34 alcohol.³¹ This is clearly an area for further study.
35

36
37 Before we discuss the implications of the results, it is important to mention potential strengths and
38 limitations of our study. We based our analysis on a large sample of 53,347 women and 53,143 men
39 from England and Scotland, that, apart from the oversampling of 18–34-year-olds, was, in general,
40 representative of the sex and age structure of the population (Supplement Figures 1-2, page 1). The
41 sample was neither more nor less deprived than the population of England or Scotland as a whole
42 (Supplement Figure 3, page 3). A strength of the interrupted time series analyses is the large number
43 of data points (weekly consumption) before (n=173) and from the introduction of MUP onwards
44 (n=25), considered more than sufficient for interrupted time series analyses.²² A second strength
45 overall and for the before-and-after analyses is the large sample size, 88,894 respondents prior to the
46 introduction of MUP and 17,596 respondents thereafter. A third strength is the use of a location
47 control, both all of England, and Northern England in sensitivity analysis. Location controls allow for
48 other extraneous factors beyond the intervention to be controlled for, for example, an unusual heat
49 wave during the months of June, July and August that affected all Great Britain.³²
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53 For limitations, first, all results are based on subjective reports of drinking. While such subjective
54 reports tend to underestimate consumption as measured by sales or other recorded data in general
55 in all European countries (e.g.,³³), there is no reason to believe that underreporting should differ by
56 country or region, or before or after the introduction of the MUP. The timeline follow-back survey
57 method has been criticized for the limited time-period of drinking it covers, thus missing heavy
58 episodic drinking occasions among participants with a low frequency of such occasions. This limitation
59 for classifying individuals is actually a strength when it comes to the characterization of population
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3 averages, however, where the shorter the time period, the smaller the biases due to memory, and the
4 more accurate the population average.³⁴ Second, as with all survey-based research on alcohol, this
5 research cannot claim full representativeness.³⁵ Statistical theory stipulates such representativeness
6 needs to be based on probabilistic sampling design (i.e., all residents from England and Scotland need
7 to be assigned a probability > 0) combined with high response rates unaffected by systematic non-
8 response.³⁶ However, these conditions can no longer be reached in modern surveys involving alcohol,
9 no matter which methodology is used.^{35, 37-39} Instead, post-stratification based on sex, age, social
10 grade, and geographical region was used to allow for generalizations to be made for the general
11 population. The quota sample was derived from Kantar's managed access panel. Data were not
12 available and not attainable on the number of respondents approached to achieve the 30,000
13 respondents surveyed each year, and this information is not mentioned in existing publications based
14 on the Alcovision survey, e.g.,^{15,16}. Unlike the household purchase data which records purchases
15 wherever they are made, and thus accounts for cross-border purchases, we are unable to account for
16 any cross-border purchasing or drinking the respondents might have engaged in. If this was significant
17 (and, a study on licensing compliance would suggest that it is not⁴⁰), one might hypothesize that the
18 estimated sizes of the associated impact with MUP in reducing alcohol consumption would differ
19 between using Northern England or all of England as a control, which was not the case. Finally, as we
20 only had data to end of 2018, we have been unable to examine the impact of MUP beyond the
21 immediate term.
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26 In our analysis, we used both interrupted time series analysis and before-and-after analyses. With the
27 interrupted time series analysis, we used England (or Northern England) as a location control, creating
28 new dependent variables, the differences between Scotland and England. Interrupted time series
29 analysis is an appropriate methodology for investigating the impact of a newly introduced natural
30 experiment (the introduction of MUP) that takes into account seasonal variation and autocorrelation
31 of the data over time.²² The before-and-after analysis is simply comparing the means before and after
32 the introduction of MUP. Results of before-and-after analyses are often presented along with
33 interrupted time series analyse, as we have done previously with household purchase data.⁹ Whilst
34 we add in an interaction term of country* event (introduction of MUP), which should take into account
35 common events outside of MUP that occurred in both Scotland and England, our analyses are unable
36 to control for seasonal variation, when comparing the longer time period before the introduction of
37 MUP and the eight month period following the introduction of MUP.
38
39

40 Externally validated indicators,^{35, 39} using sales^{41, 42} or household purchasing data as the basis,^{9,10}
41 corroborate our results that, in comparison to England over the same and longer time periods, the
42 introduction of the MUP was associated with a decrease in alcohol consumption. Finally, the
43 reductions in alcohol consumption in Scotland were part of an overall national strategy or framework
44 for alcohol policy, where all measures had already been extensively covered in the press. It cannot be
45 excluded that the actual reductions may have been due in part to the media reports surrounding the
46 introduction of the MUP rather than to the floor pricing itself (for an example of an alcohol policy
47 measure where the media impact seems to be stronger, see⁴³). However, it is highly unlikely that
48 media reports would produce exactly this abrupt and permanent pattern—i.e., a drop in consumption
49 starting exactly at the date of introduction of MUP and lasting for the time-period studied, in
50 comparison to a control group.
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53
54 Despite these potential limitations, most research corroborates the results of our study that the MUP
55 resulted in a reduction of overall alcohol consumption compared to England or Northern England.^{9, 10,}
56 ^{41, 42} Overall, research was based on a number of designs including purchasing data from households
57 or sales records. Our results here were based on a control group design, where the intervention was
58 only introduced in one group, thus strengthening our confidence in a real effect.⁴⁴
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3 When the Minister for Public Health, Sport, and Wellbeing introduced the 2018 alcohol policy
4 framework,⁶ he emphasized that the implementation of the MUP was strongly motivated by an
5 interest in decreasing health inequalities through a reduction in alcohol consumption among the
6 heaviest and most vulnerable drinkers. Our results indicate that this goal may not be fully realized:
7 first, we found that women, who are less heavy drinkers in our data, and in almost all surveys
8 worldwide to date,⁴⁵ reduced their consumption more than men; second, the 5% of heaviest drinking
9 men had an increase in consumption associated with MUP; and, third, younger men and men living in
10 more deprived areas had no decrease in consumption associated with MUP. These results are
11 surprising—as modelling studies would have suggested otherwise (e.g.; ^{11, 14}).

12
13
14 We can only speculate about the reasons for the increase in the five per cent of the heaviest drinking
15 men. Several studies have found that overall, heavier drinkers, including people with alcohol use
16 disorders, react less to price than the general population, i.e., they react more price inelastic and their
17 consumption is determined by other factors (see reviews and meta-analyses^{46, 47}). However, while
18 this may explain lower reductions, it cannot explain an increase in consumption. Such a polarization
19 with increasing consumption of the heaviest drinkers in overall decreasing consumption levels has
20 now been observed in several studies, often in adolescents and young adults^{48, 49}. These studies
21 indicate that such polarization means a deviation from the standard collective theory of all subgroups
22 changing in the same direction,⁵⁰ but fall short on good explanations as to why this is the case.

23
24
25 The results may also imply a diminished impact on alcohol-attributable hospitalisations and mortality,
26 which have been shown to be strongly associated with heavy drinking in men and in those of lower
27 socioeconomic status.⁵¹⁻⁵⁴ Indeed, a large, controlled study on emergency department visits following
28 the introduction of MUP did not show any reduction in alcohol-related emergency department visits.⁵⁵

29
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31 Before any further conclusions can be drawn, we need to corroborate our sex-, age-, heavy drinking-
32 and socioeconomic status-related findings in different studies. This seems important as different
33 conclusions about MUPs impact may result for other countries. If indeed the findings of our study are
34 corroborated, then additional and/or different pricing mechanisms may need to be considered to
35 reduce alcohol-attributable hospitalizations and mortality. For instance, several harms from alcohol
36 use are specifically linked to on-trade drinking, such as public disorder and violence.⁵⁶ Recent
37 experiences in Lithuania have shown substantial reductions in all-cause mortality following a taxation
38 increase, that mainly affected men.⁵⁷

39
40
41 **Acknowledgements:** We thank Kantar Worldpanel for providing the raw data and reviewing the
42 method description as it describes the data collection. Kantar Worldpanel provided the raw data at no
43 cost to Newcastle University under a direct contract. Through its own contracted work as a market
44 research company, Kantar Worldpanel received reimbursement from AB InBev to cover the costs of
45 the data. Kantar Worldpanel has similar commercial relationships with other customers who pay to
46 have data collected on food and non-food items available for sale in supermarkets and other retail
47 outlets covered by the WorldPanel. Kantar Worldpanel and no other entity had any role in the study
48 design, data analysis, data interpretation or writing of the manuscript. Professor Kaner, supported by
49 a National Institute for Health Research (NIHR) Senior Investigator award, is Director of the NIHR
50 Applied Research Collaboration, North East and North Cumbria. Dr. O'Donnell is a National Institute
51 for Health Research (NIHR) Advanced Fellow. The views expressed in this article are those of the
52 authors and not necessarily those of NIHR, or the Department for Health and Social Care.

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54
55 **Contributors:** JR conceptualised the paper and prepared the initial draft of the introduction and
56 discussion. PA undertook the analyses and prepared the draft of the methods and results and
57 submitted the paper. PA, AO'D, EJ-L, JR, JM and EK refined the various versions of the full paper and
58 approved the final manuscript for submission. The corresponding author attests that all listed authors
59
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3 meet authorship criteria and that no others meeting the criteria have been omitted. All authors had
4 access to the data used for analyses, and PA, AO'D and EJ-L verified the raw data sets received from
5 Kantar WorldPanel and are the guarantors for the data used for the analyses.
6

7
8 **Competing interests:** All authors have completed the ICMJE uniform disclosure form at
9 www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted
10 work; within the previous five years, PA declares receipt of funds from AB InBev Foundation to provide
11 evidence-based public health comment on the proposed content and evaluation of the Foundation's
12 global drinking goals, outside of the submitted work; the remaining authors declare no financial
13 relationships with any organisations in the previous five years that might have an interest in the
14 submitted work; all authors declare no other relationships or activities that could appear to have
15 influenced the submitted work.
16

17
18 **Data sharing:** No additional data available. Kantar WorldPanel data cannot be shared due to licensing
19 restrictions.
20

21 **Affirmation:** PA and AO'D affirm that the manuscript is an honest, accurate, and transparent account
22 of the study being reported; that no important aspects of the study have been omitted; and that any
23 discrepancies from the study as initially planned have been explained.
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3 **Figure 1** Plots of average weekly alcohol consumption Scotland minus England (net effect) for all respondent,
4 by week of study period for total alcohol consumption, off-trade consumption (e.g., at home) and on-trade
5 consumption (e.g., in pubs, bars and restaurants), with T4253H smoothing⁵⁸. Black vertical line: introduction of
6 MUP. Data used for primary Interrupted Times Series analyses.
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9 **Figure 2** Associated changes in the difference in consumption (Scotland minus England, net effect) following
10 the introduction of MUP by drinking percentile distribution of total consumption. Blue lines: men; red lines:
11 women. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no
12 change). Results from primary Interrupted Times Series analysis.
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15 **Figure 3** Associated changes in consumption following introduction of MUP for all consumption, off-trade
16 consumption, and on-trade consumption (Scotland minus England, net effect) by age group, top graph; social
17 grade group, middle graph; and, deprivation group, bottom graph for men (blue) and women (red). Consumption
18 changes are standardized coefficients (units of standard deviations) from primary interrupted time series
19 analyses with 95% confidence intervals.
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22 **Figure 4** Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated
23 with the introduction MUP in Scotland, controlling for changes in England for each age year. Plots of men and
24 women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner
25 lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change). The changes are derived from
26 the secondary before and after analysis, regression equation 2; they represent, for each age, the difference in
27 the marginal means (and 95% confidence intervals of the differences) for [Scotland*event (introduction of MUP)
28 *age (dummy coded variable for each age)] minus [England*event (introduction of MUP) *age (dummy coded
29 variable for each age)].
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32 **Figure 5** Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated
33 with the introduction MUP in Scotland, controlling for changes in England for each deprivation score (on a 100%
34 scale). Plots of men and women for total consumption, off-trade consumption, and on-trade consumption.
35 Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., no change).
36 The changes are derived from the secondary before and after analysis, regression equation 2; they represent,
37 for each deprivation score (the higher the deprivation score, the less deprived), the difference in the marginal
38 means (and 95% confidence intervals of the differences) for [Scotland*event (introduction of MUP) *deprivation
39 score (dummy coded variable for each deprivation score)] minus [England*event (introduction of MUP)
40 *deprivation score (dummy coded variable for each deprivation score)].
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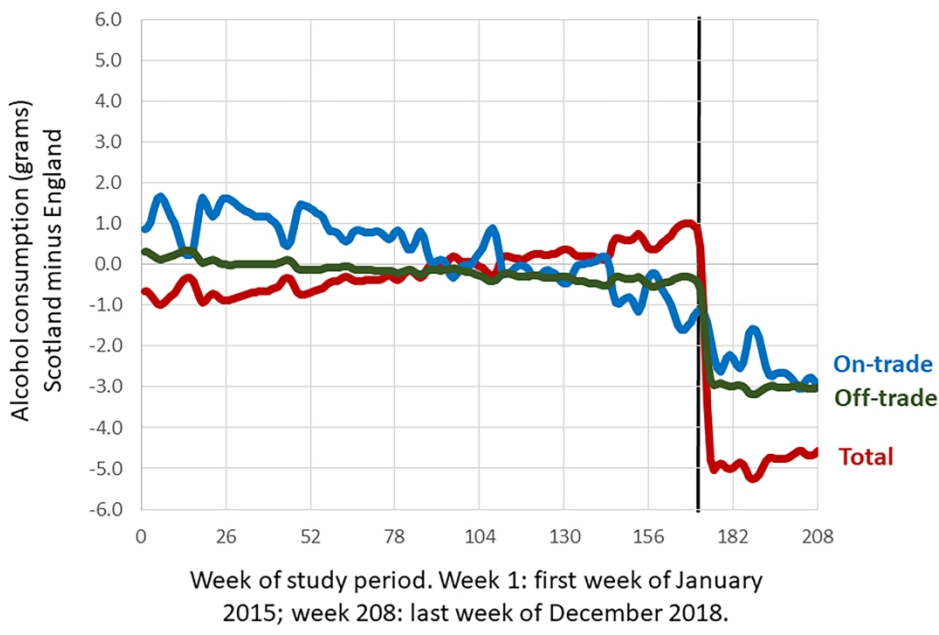


Figure 1

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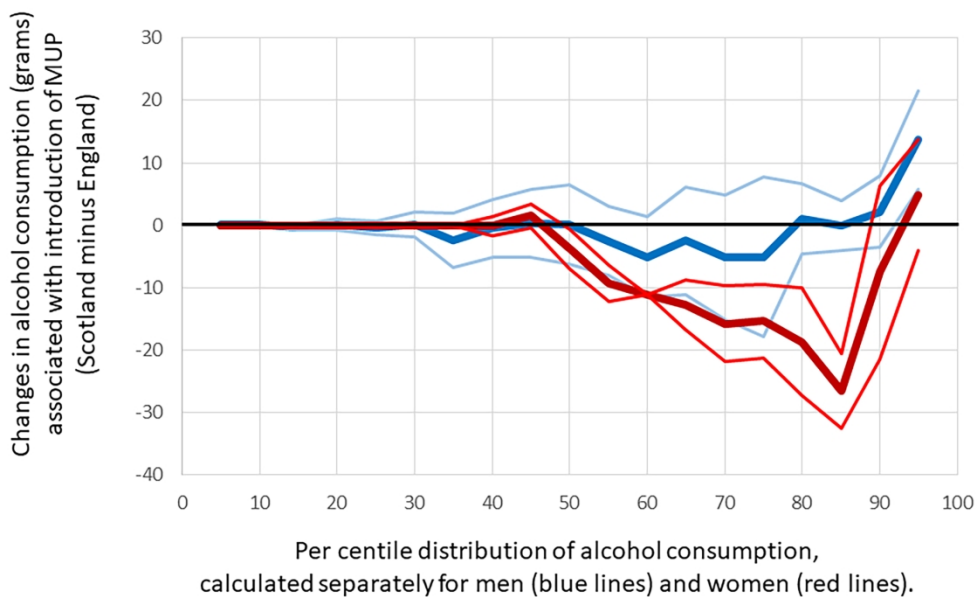


Figure 2

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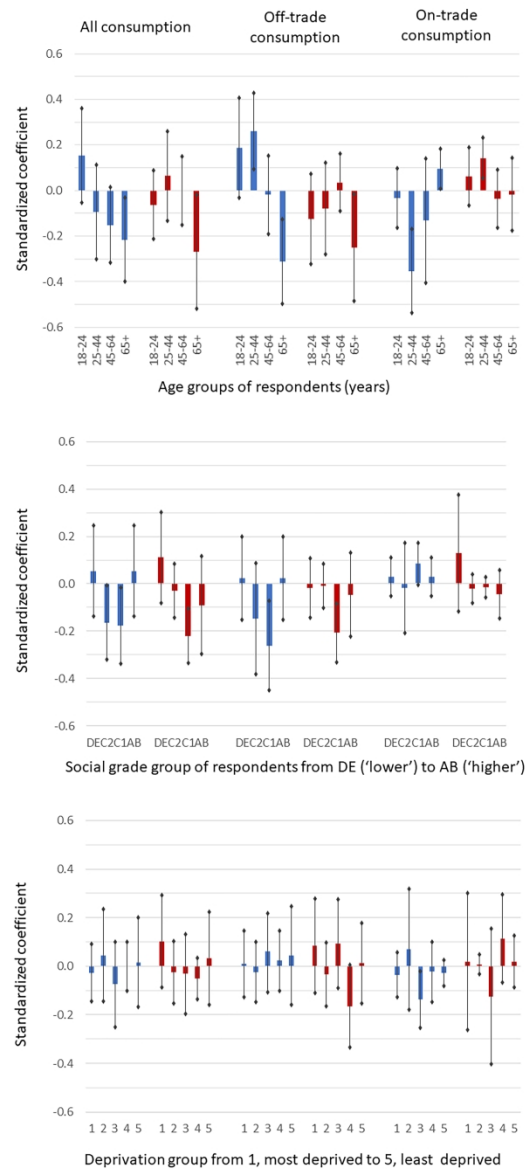


Figure 3 Associated changes in consumption following introduction of MUP for all consumption, off-trade consumption, and on-trade consumption (Scotland minus England, net effect) by age group, top graph; social grade group, middle graph; and, deprivation group, bottom graph for men (blue) and women (red).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

219x455mm (300 x 300 DPI)

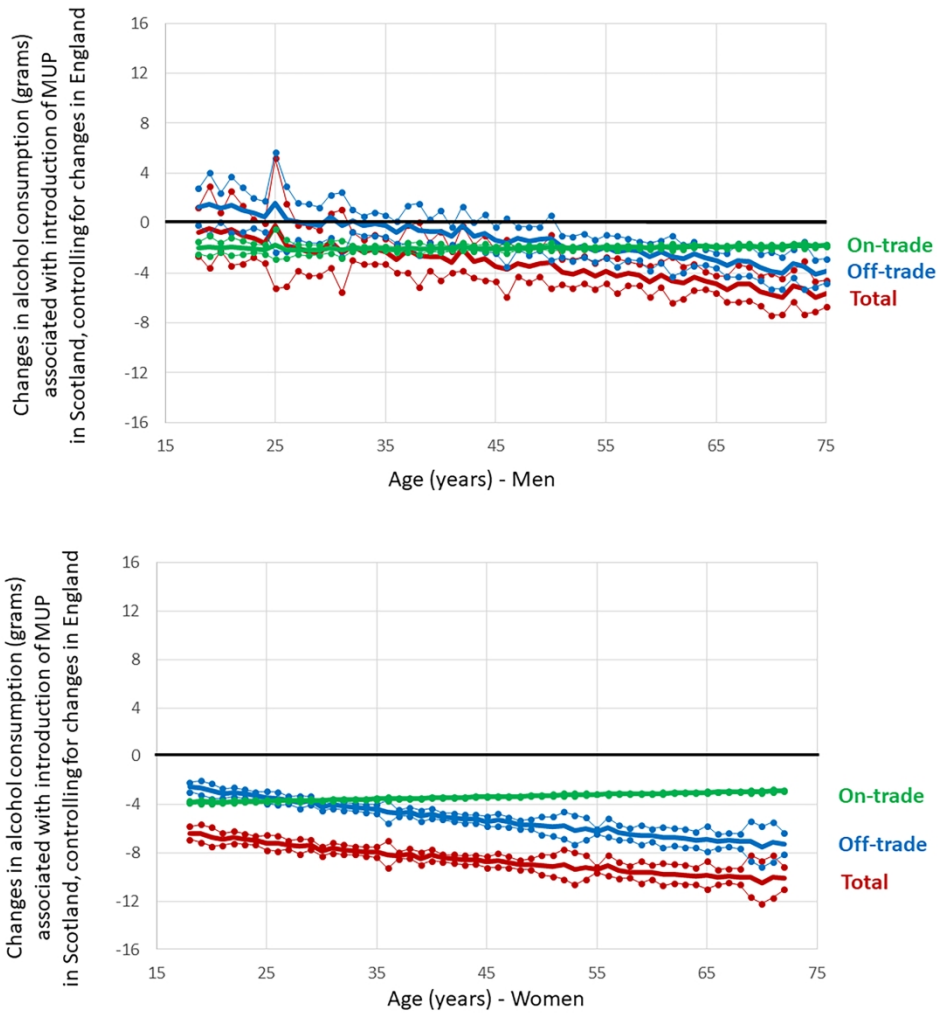


Figure 4 Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated with the introduction MUP in Scotland, controlling for changes in England for each age year. Plots of men and women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., 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% confidence intervals 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)].

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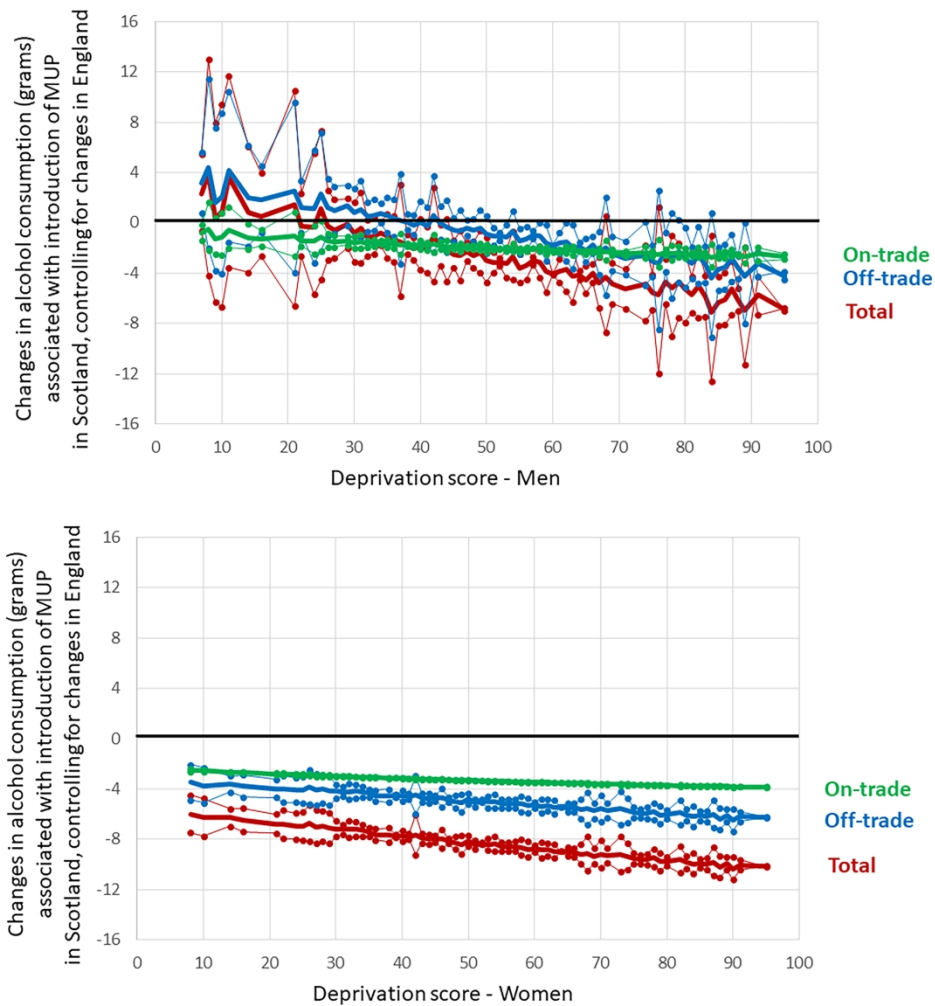


Figure 5 Plots of the changes in alcohol consumption (grams per week, with 95% confidence intervals) associated with the introduction MUP in Scotland, controlling for changes in England for each deprivation score (on a 100% scale). Plots of men and women for total consumption, off-trade consumption, and on-trade consumption. Thicker lines: means; thinner lines: 95% confidence intervals. Horizontal black line set at zero (i.e., 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% confidence intervals 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)].

270x284mm (300 x 300 DPI)

SUPPLEMENT

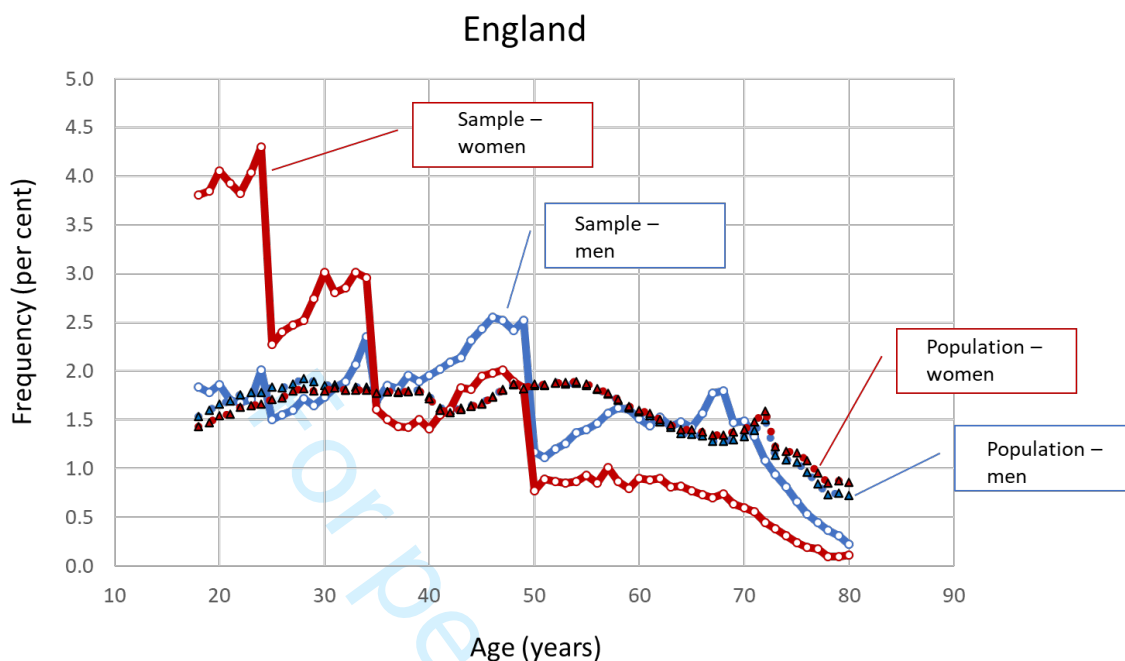


Figure 1 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for range 18-80 years), England. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and Northern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

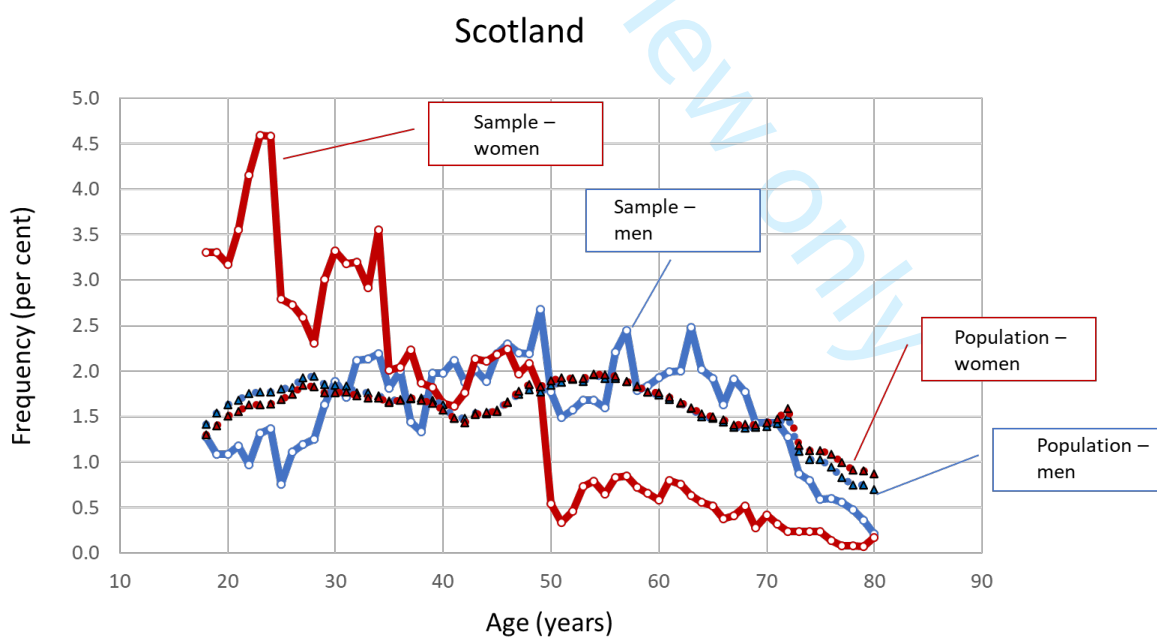


Figure 2 Per cent distribution (vertical axis) for analyzed sample and total population for men and women, by age (years, horizontal axis, for age range 18-80 years), Scotland. Total population data from: Office for National Statistics; population estimates for the UK, England and Wales, Scotland and 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).

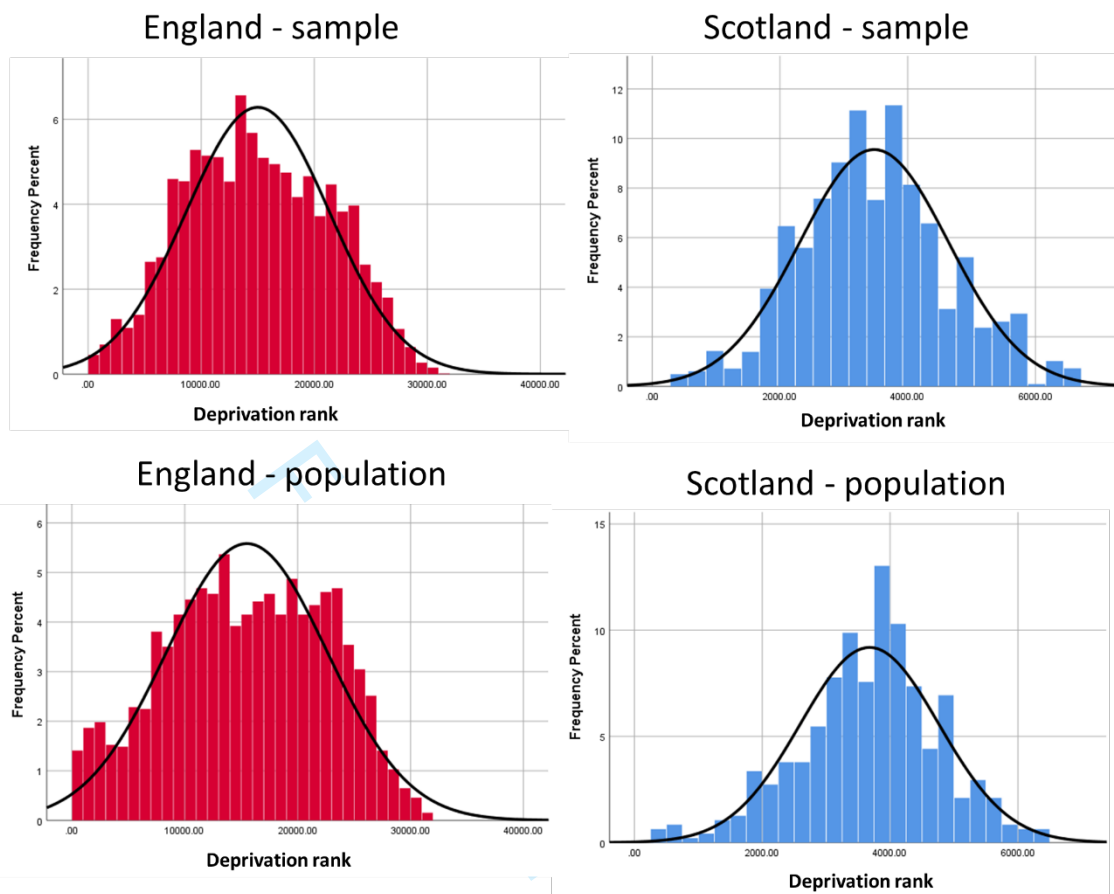


Figure 3 Per cent distribution (vertical axes) for analyzed sample and total population by deprivation rank (horizontal axes), England and Scotland. Data for total population from GOV.UK. National Statistics: English indices of deprivation 2019. <https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019>;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

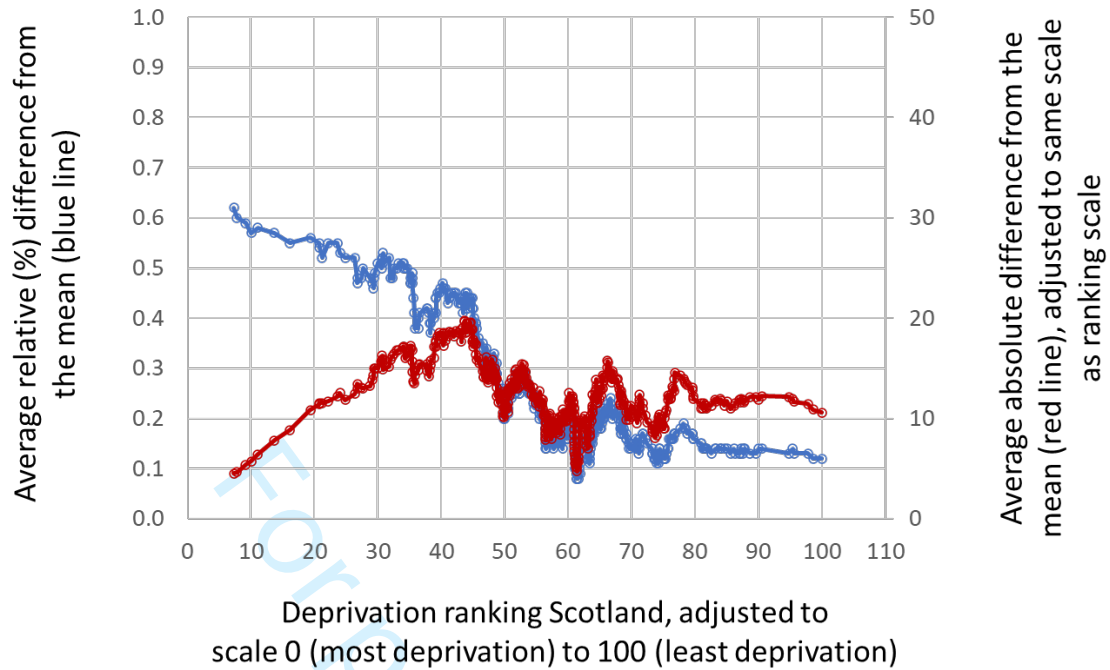


Figure 4 Dispersion of aggregated deprivation ranking, Scotland. The horizontal axis is the ranking from 0 (most deprived) to 100 (least deprived). The red line (right vertical axis) is the average absolute difference of the original ranking at local data zone level from the mean calculated at the truncated 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).

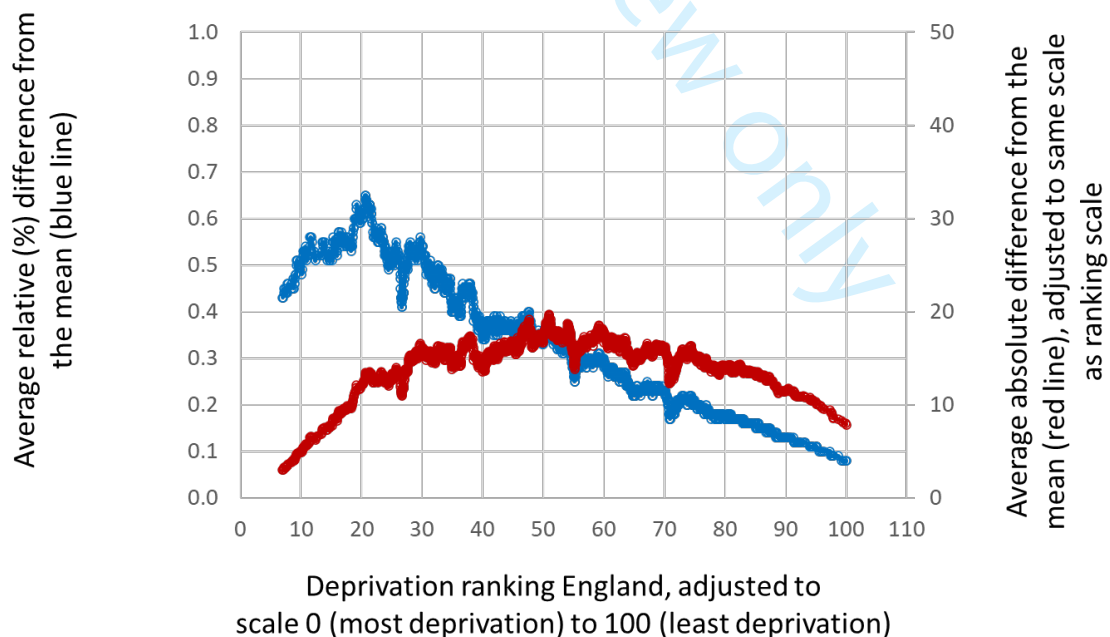


Figure 5 Dispersion of aggregated deprivation ranking, England. For explanation, see legend to Figure 4.

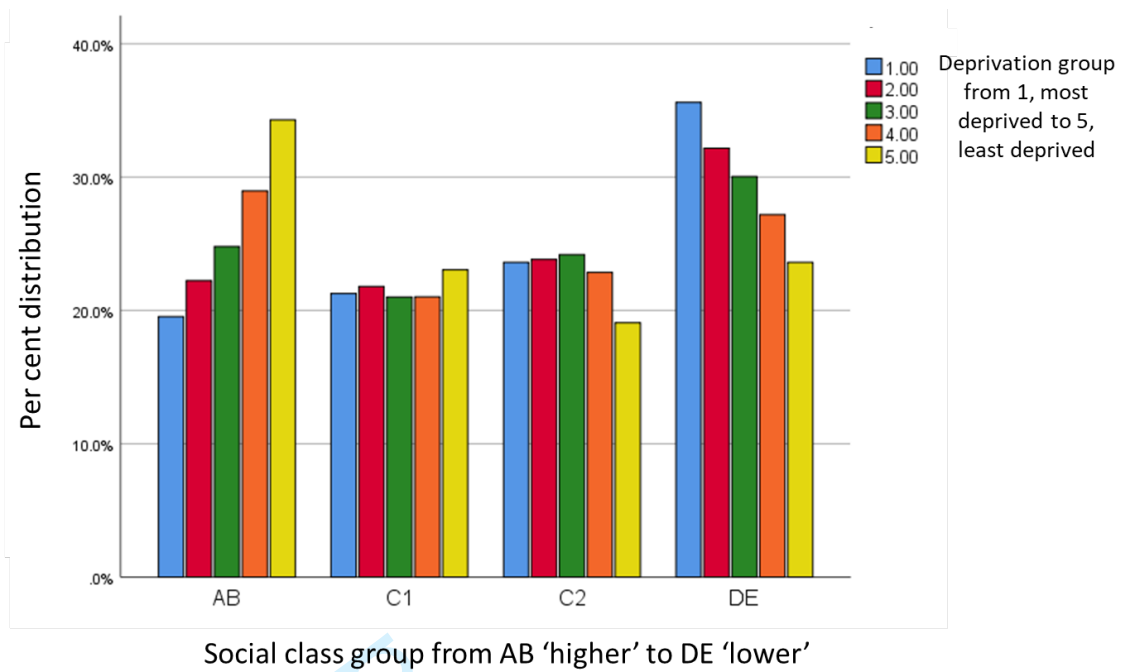


Figure 6 Distribution of deprivation group (from 1, most deprived to 5, least deprived) within social class groupings from AB, relatively higher to DE, relatively lower. Social class groups based on National Readership Survey; 2019. <http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/>.

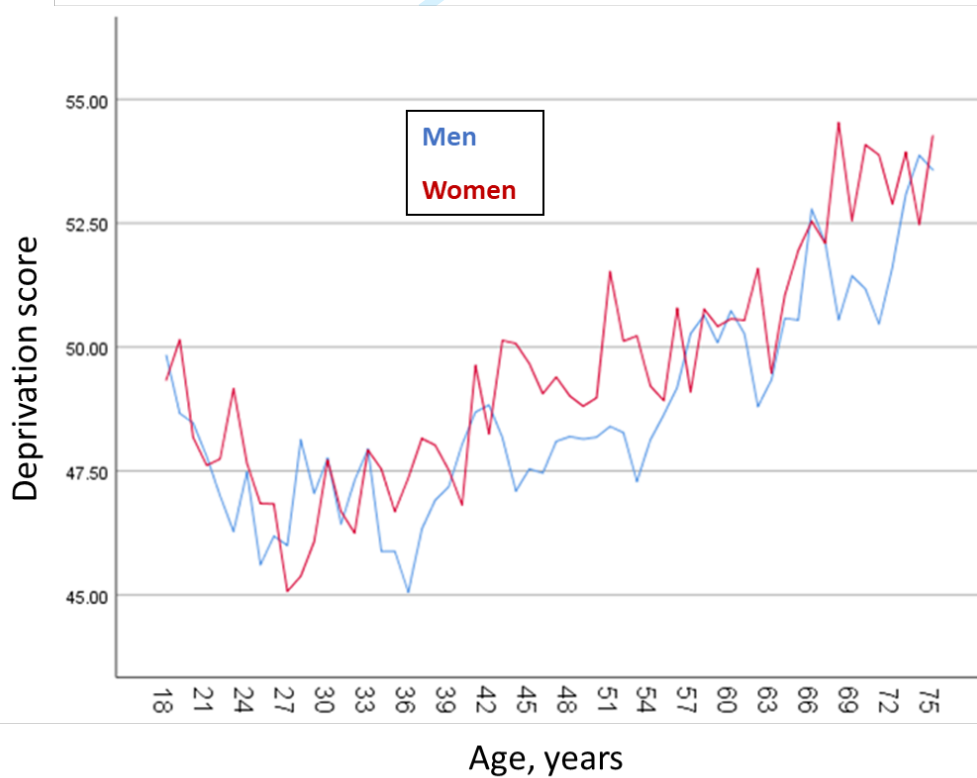


Figure 7 Plot of mean deprivation score (higher the score, the least deprived) by age and gender.

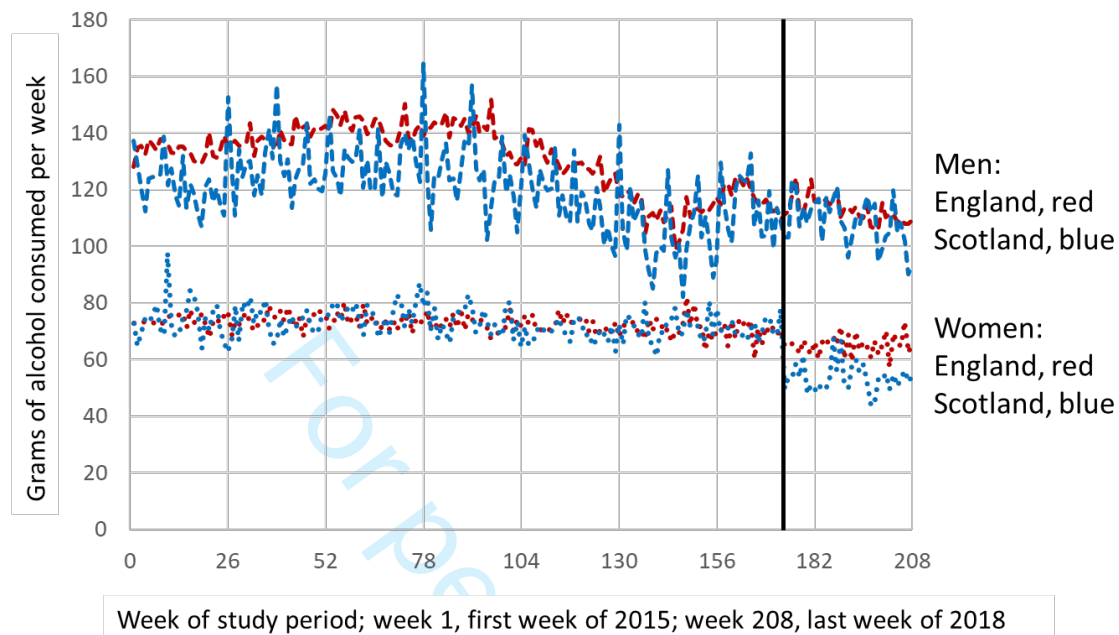


Figure 8 Plots of adjusted dependent variables (grams of alcohol consumed per week), seasonally adjusted using the ratio-to-moving-average method, over time (study week) by England and Scotland for men and women. Vertical black line: introduction of MUP.

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	.

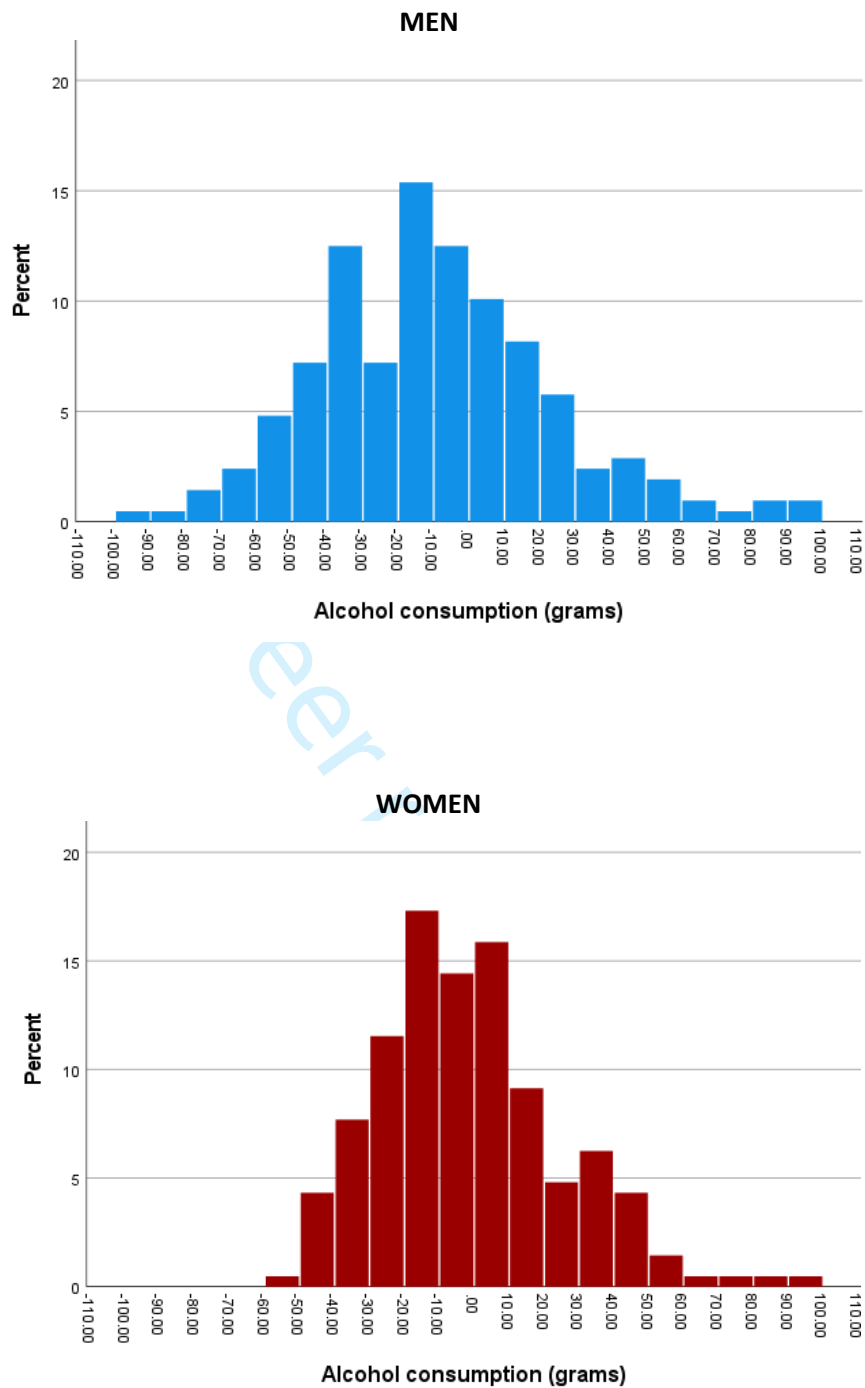


Figure 9 Plots of distributions of differences in total alcohol consumption (grams), Scotland minus England for men (top) and women (bottom).

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
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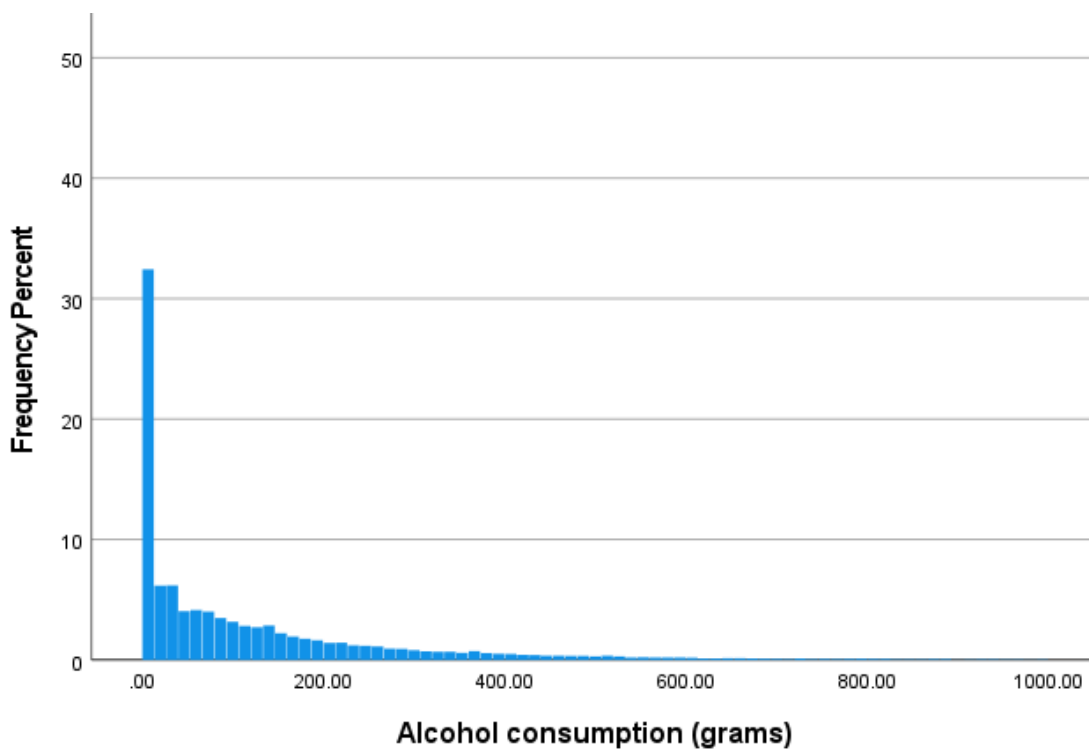


Figure 10 Distribution of weekly alcohol consumption, men.

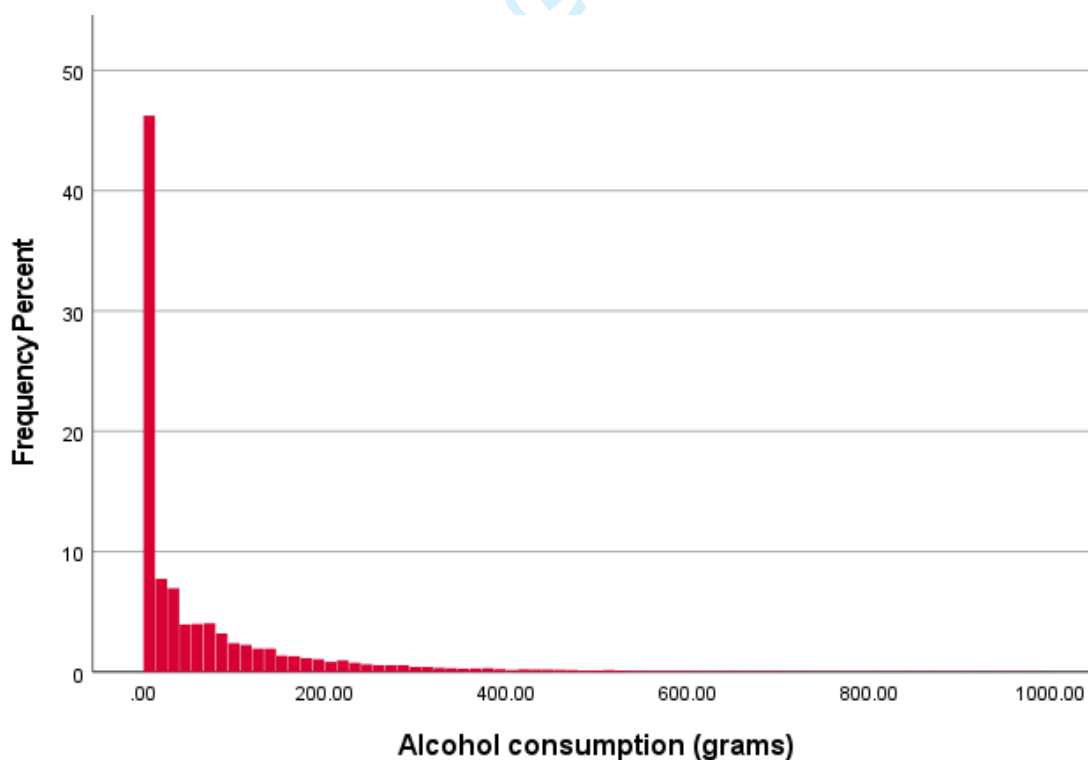


Figure 11 Distribution of weekly alcohol consumption, women.

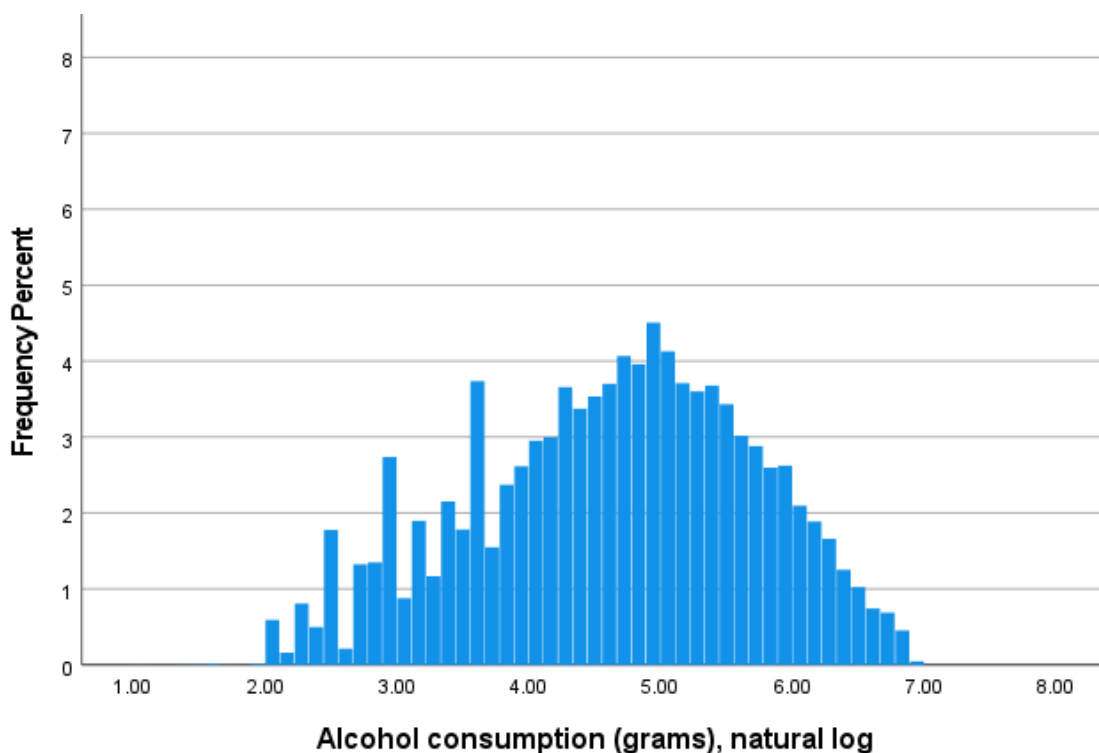


Figure 12 Distribution of weekly alcohol consumption (natural log), men who consumed alcohol during previous week.

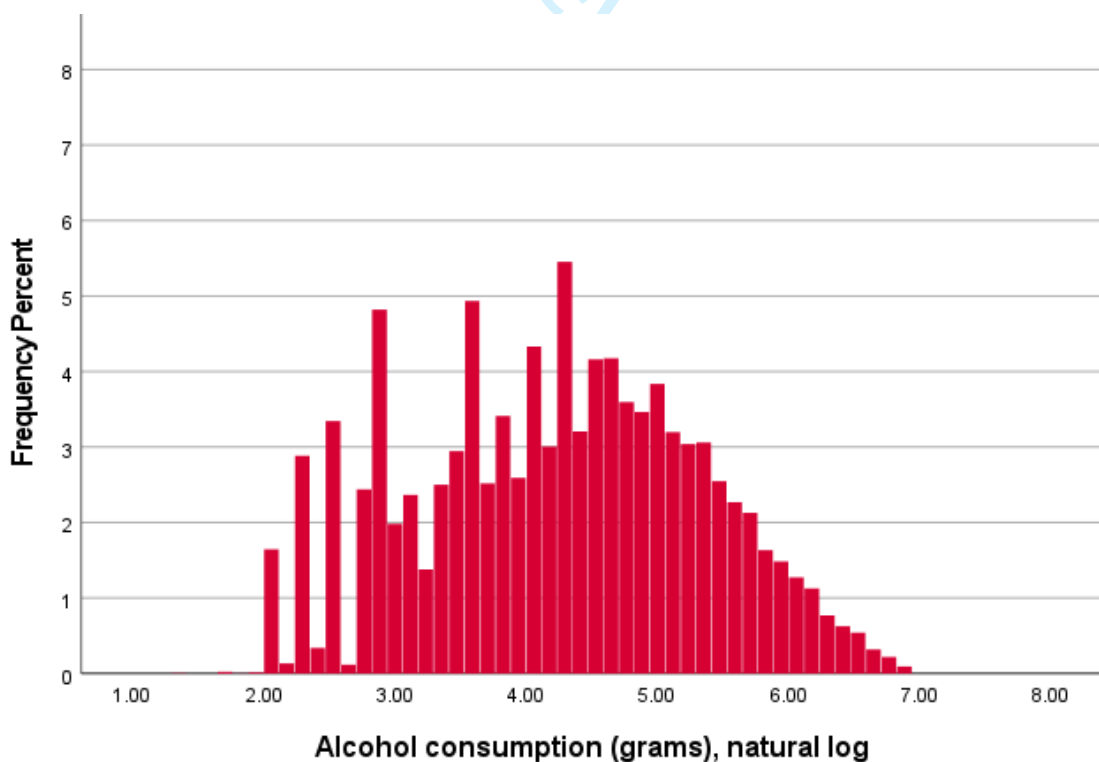


Figure 13 Distribution of weekly alcohol consumption (natural log), women who consumed alcohol during previous week.

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

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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

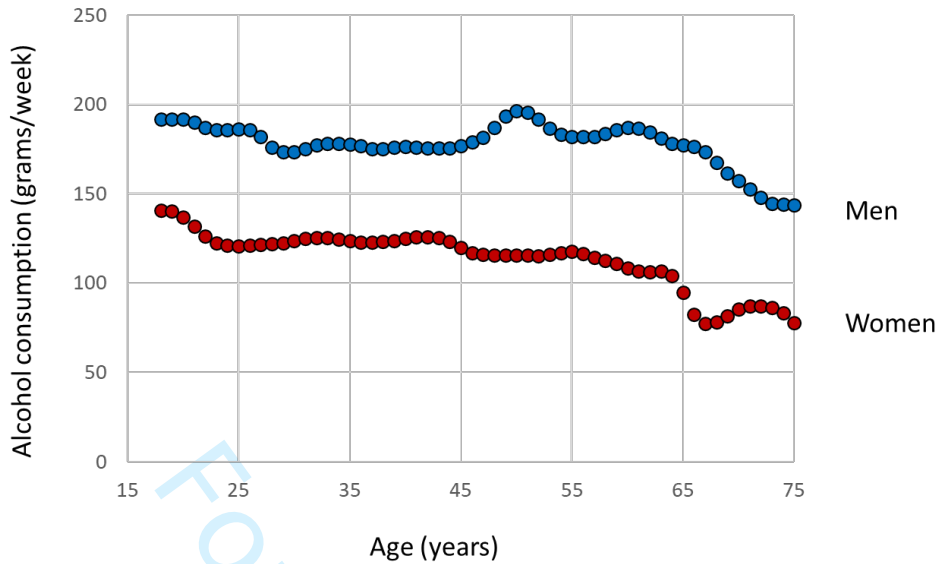


Figure 14. Mean alcohol consumption (grams per week) by age and sex, based on T4253H smoothing¹ across age. In a generalized linear regression equation, [GENLIN alcohol consumption with age, consumption decreased, similarly for both sexes, by 5.1 grams per every 10 years of increasing age (95% confidence interval, CI=4.4 to 5.7 grams).

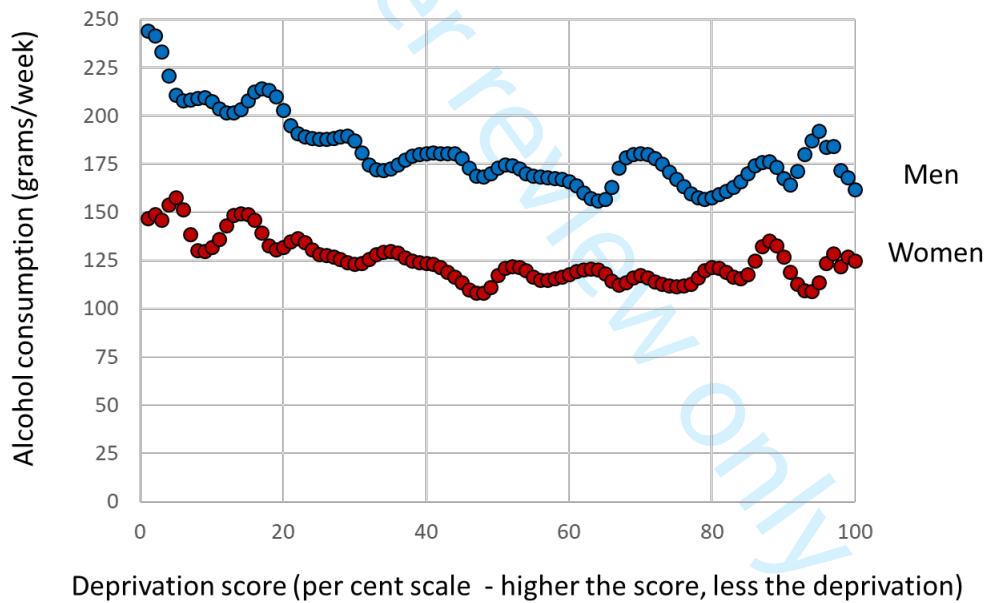


Figure 15. Mean alcohol consumption (grams per week) by deprivation score and sex, based on T4253H smoothing¹ across deprivation score. In a generalized linear regression equation, [GENLIN alcohol consumption with deprivation score, consumption decreased, similarly for both sexes by 1.1 grams per every 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 .)

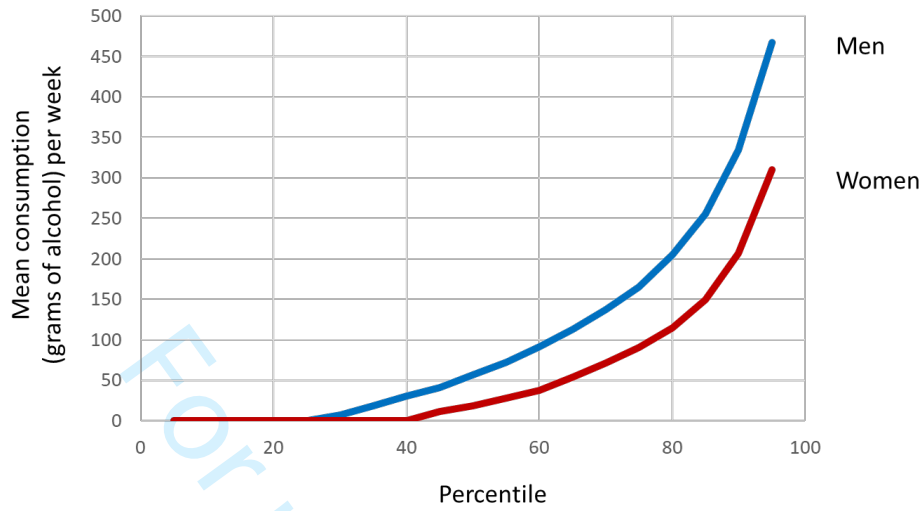


Figure 16. Mean consumption, grams of alcohol per week, by percentile distribution of consumption for men and women.

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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

Consumption percentile	Men			Women		
	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

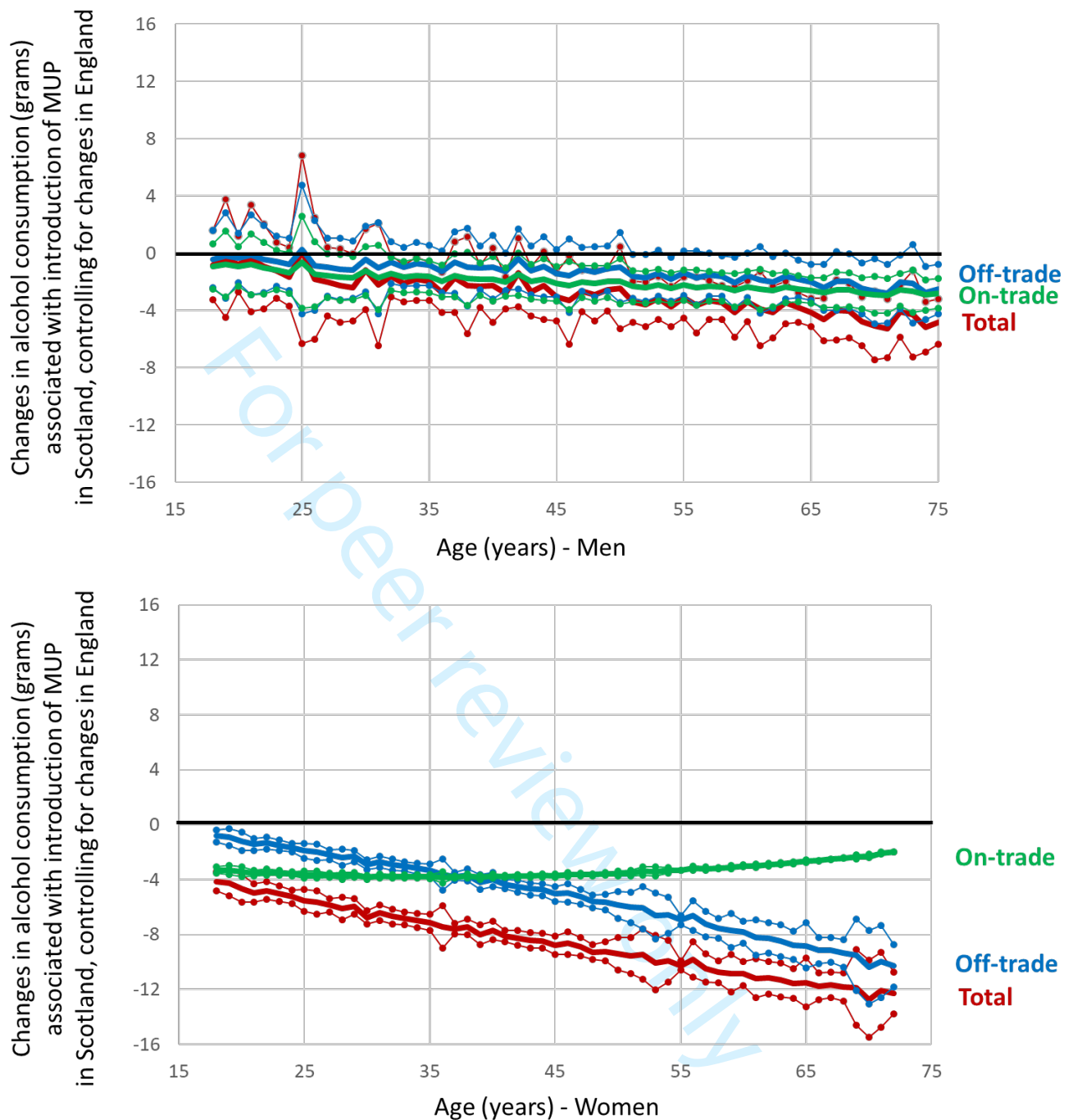


Figure 17 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each 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.

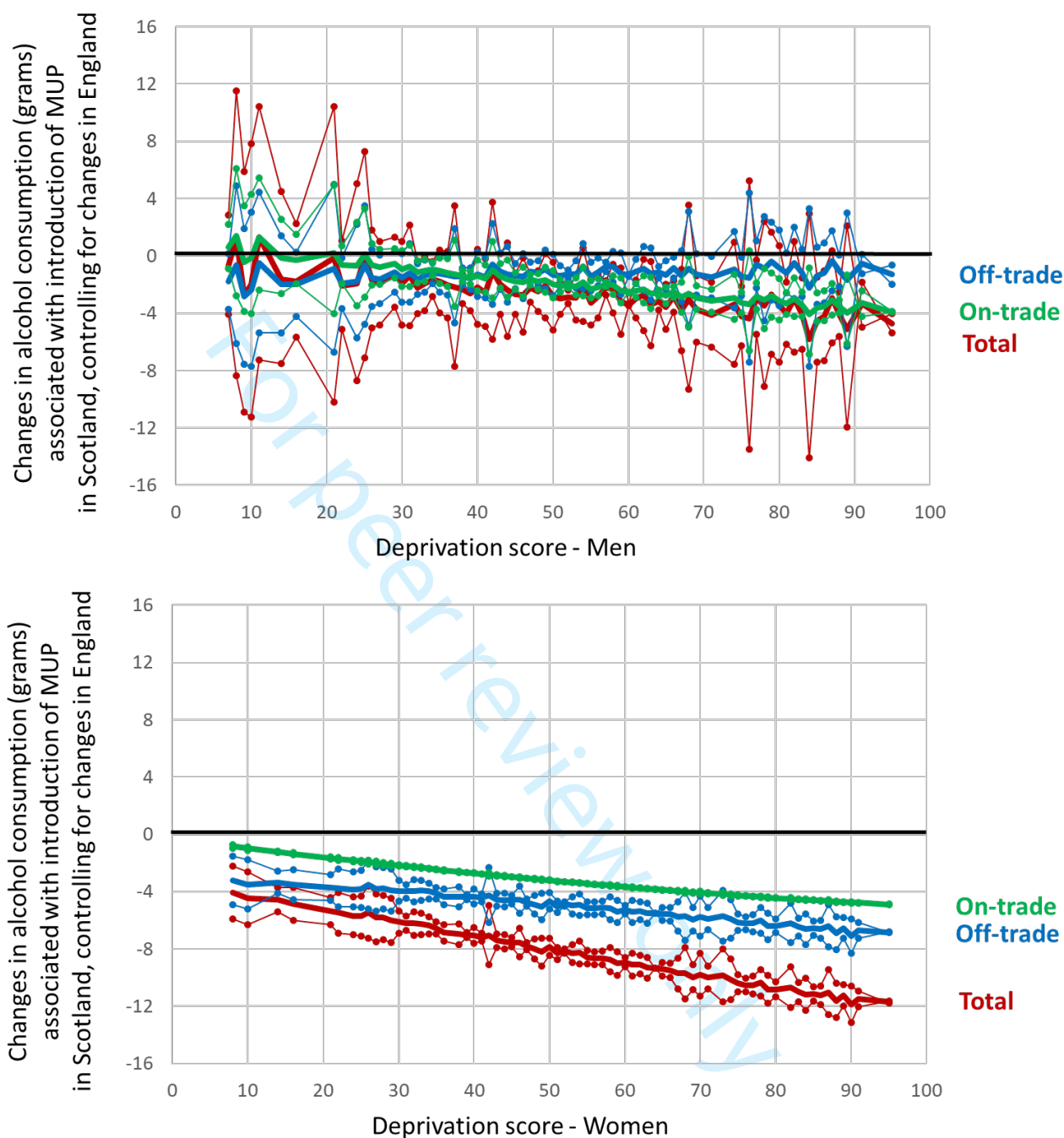


Figure 18 Plots of the means (95% CI) of the predicted values of the dependent variables (changes in alcohol consumption per week in grams associated with the introduction of MUP in Scotland, controlling for changes in England) derived from the regression models of the before and after analyses for each 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.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	"controlled interrupted time series analysis" included in title and abstract, p1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract adheres to these criteria, p2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction describes the importance of the need for empirical studies of the impact of minimum unit price by sex of drinker, p4
Objectives	3	State specific objectives, including any prespecified hypotheses	Objectives included as issues to answer in last paragraph of introduction, p4
Methods			
Study design	4	Present key elements of study design early in the paper	Included in first paragraph of methods, p5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	All included in the description of the data source, p5
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Fully described for interrupted time series analysis in the description of the data source, p5
		<i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	
Variables	7	<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	All dependent and independent variables described in the section statistical analyses, p6-7
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed	
Data sources/	8*	<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	Fully described in both sections
		Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	

measurement		data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	data sources and statistical analyses, p5-7
Bias	9	Describe any efforts to address potential sources of bias	Dependent variables are data from timeline follow-back surveys, p5
Study size	10	Explain how the study size was arrived at	Number of observations prior to and post introduction of minimum unit price meet all criteria required for interrupted time series analyses and are based on weekly data for the four years 2015-18.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why.	Fully described in the statistical analyses section, p6-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Detailed descriptions of the interrupted time series analyses are described in the statistical analysis section, p6-7.
		(b) Describe any methods used to examine subgroups and interactions	How the data were split into groups of respondent characteristics is described in the methods, p5-6.
		(c) Explain how missing data were addressed	No missing data, p5
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(e) Describe any sensitivity analyses	For the interrupted time series analysis, we undertook sensitive analysis, using respondents from Northern England, as opposed to England (used in main analysis), as control. For the before and after analysis, we first used logged normal data as dependent variable; for a sensitivity analysis, we used square-rooted data.

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Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	All respondents and all weeks included in analyses, p5-7
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Distribution of demographic characteristics of households described in methods. No confounders added to model, p5
		(b) Indicate number of participants with missing data for each variable of interest	No missing data.
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Not applicable
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	Not applicable
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Not applicable
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Estimates given with 95% confidence intervals. No confounders included in models (see above), p8-12
		(b) Report category boundaries when continuous variables were categorized	Category groupings for respondent characteristics described, p5.
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not relevant
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Additional analyses for respondent groupings described, p9-12.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Included in first paragraph of discussion, p12.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Main limitations (e.g., use of survey data) fully described in discussion, p13-14.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity	Included in Conclusion paragraph, p9

of analyses, results from similar studies, and
other relevant evidence

Generalisability	21	Discuss the generalisability (external validity) of the study results	Included conclusion paragraph, p14-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	No funding was received in support of the study, p15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.