



Evaluating the impact of Minimum Unit Pricing (MUP) on sales-based alcohol consumption in Scotland: controlled interrupted time series analyses

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Introduction

Minimum unit pricing (MUP) for alcohol was introduced in Scotland on 1 May 2018, setting a floor price below which alcohol cannot be sold by licensed retailers. Public Health Scotland (formerly NHS Health Scotland) has been tasked with leading the evaluation of MUP through its Monitoring and Evaluating Scotland's Alcohol Strategy (MESAS) work programme.

A portfolio of mixed-methods studies has been developed to assess the impact of MUP across a range of outcomes, including population alcohol consumption. We recently published a report providing descriptive analysis of off-trade alcohol sales data (as a proxy for consumption) for the 12-month period since the implementation of MUP in Scotland.¹

The report showed that the volume of pure alcohol sold per adult in the off-trade decreased by 3.6% in the year after MUP was introduced compared with the previous year. In England & Wales, where the legislation does not apply, off-trade alcohol sales increased by 3.2% over the same time period. Changes differed by drink category: in Scotland decreases were observed across all of the major drink categories, including cider (-19%), spirits (-4%), wine (-3%) and beer (-1%). Per-adult sales of fortified wine, which accounts for less than 4% of the off-trade market in Scotland, increased by 16%. In England & Wales, increases were observed for per-adult sales of cider (8%), beer (7%) and spirits (6%), while decreases were seen for sales of wine (-1%) and fortified wine (-11%). It was also noted that the difference in off-trade alcohol sales between Scotland and England & Wales during the peak sales periods of Christmas and Easter were lower in the year following MUP implementation than in previous years.

The purpose of this report is to advance and strengthen our interpretations from these earlier descriptive analyses by employing a controlled interrupted time series study design. This approach helps to isolate the estimated impact of MUP while controlling for underlying secular and seasonal trends and other covariates, including

changes in disposable income and substitution between drink categories and retail sectors (i.e. off-trade and on-trade).

Research questions

The study addressed the following research questions:

- 1 What was the impact of the introduction of MUP on the volume of pure alcohol sold by off-trade retailers in Scotland in the 12-month period after its implementation?
- 2 To what extent did any impact of the introduction of MUP on the volume of pure alcohol sold in Scotland vary by drink category?

Methods

Study design

We used controlled interrupted time series analytical methods to assess whether the introduction of MUP was associated with a change in the volume of pure alcohol sold per adult in the off-trade in Scotland in the 12-month period after it was introduced, overall and by drink category. Our approach incorporated a number of methodological features to strengthen the interpretation of the impact of MUP. These included:

- Employing multiple approaches to how data for England & Wales, our geographical control, were incorporated into our analyses.
- Adjusting all statistical models for underlying seasonal and secular trends.
- Testing how robust our results were after adjusting our statistical models for covariates that may explain any impact of MUP on off-trade sales. Disposable income and substitution between drink categories and trade sectors were identified for this purpose.
- Performing a range of sensitivity and supplementary analyses to test the robustness of our results to changes in the analytical approach deployed.

Outcome measures

The primary outcome measure in this study was the volume (litres) of pure alcohol sold per adult in the off-trade.

Study time period

We included off-trade alcohol sales data from January 2013 to May 2019. This provided us with data for over five years before, and one year after, the implementation of MUP.

Data

Off-trade alcohol retail sales

Weekly off-trade alcohol sales data were obtained from market research specialists Nielsen for the period January 2013 to May 2019. Data were obtained for Scotland, England & Wales (combined), North East (NE) England and North West (NW) England. Nielsen estimates alcohol sales in Great Britain using electronic sales records from large retailers (retailers with 10 or more retail shops operating under common ownership) and a weighted stratified random sample of smaller 'impulse' retailers (retailers in which the consumer mainly uses the store for impulse or top-up purchases, i.e. not the main grocery shop). A detailed description of the methods used by Nielsen to produce alcohol retail sales estimates is provided in an earlier MESAS report.²

The volume of alcohol sold (litres) was provided across eight alcoholic drink categories: spirits, wine, beer, cider, ready to drink beverages (RTDs), perry, fortified wine and 'other'. The volume of each drink category sold was converted into pure alcohol volume using a category-specific percentage alcohol by volume (ABV) provided by the data suppliers. The ABV used was based on the typical strength of drinks sold within subtypes of the category, except for wine where the same standard ABV was applied across all products due to the diversity of the wine market.

Alcohol sales by discount retailers, Aldi and Lidl, are not included in the Nielsen off-trade alcohol sales estimates. We adjust for their exclusion in supplementary analysis using alcohol volume market share estimates for calendar years 2013 to 2019 provided by Kantar Worldpanel. Linear interpolation was used to calculate weekly alcohol market share estimates for Aldi and Lidl, by drink category, from the annualised data provided.

On-trade alcohol sales data

On-trade alcohol sales data (litres of pure alcohol) were obtained from market research specialists, CGA Strategy, whose estimates are based on a combination of delivery, sales and survey data from a stratified sample of on-trade retailers.² Data were obtained for the same drink categories and geographies as noted for the off-trade. Linear interpolation was used to calculate weekly on-trade sales data per adult by drink category from the four-weekly data provided.

Mid-year population estimates

Per-adult alcohol sales were calculated by dividing pure alcohol volumes (litres of pure alcohol) by the total population aged ≥ 16 years. Mid-year population estimates and projections for Scotland were obtained from National Records of Scotland³ and for England & Wales from the Office for National Statistics.⁴ The NE and NW England regions used in this study were defined by the data providers based on postcode sectors and are not coterminous with the official Government Office Regions. Mid-year population estimates for these areas were therefore based on the aggregation of mid-year population estimates for Lower Super Output Areas within each postcode sector within each region. Weekly population estimates were interpolated linearly from the mid-year estimates.

Disposable household income

Quarterly gross disposable household income data were obtained for Scotland⁵ and the United Kingdom⁶ and expressed per adult aged ≥ 16 years. As equivalent data were not available directly for England & Wales, a proxy measure was created by subtracting Scottish data from the UK data.

Statistical methods

We used controlled interrupted time series regression with seasonal autoregressive integrated moving average (SARIMA) errors as our main statistical method to assess the impact of MUP on off-trade alcohol sales in Scotland. In line with the guidance produced by Beard et al (2019)⁷ and based on our previous approach when evaluating the impact of the Alcohol etc. (Scotland) Act in Scotland 2010,⁸ our analytical strategy consisted of initially modelling the alcohol sales data time series to obtain an adequate preliminary model and then modelling and testing the effect of the intervention with and without adjustment for covariates.

A full description of our statistical methods is provided in Appendix 1.

Comparison with a geographical control

In interrupted time series analyses, data for a control series can be used in various ways. Separate models can be fitted to the intervention and control series, with results compared to assess if there is a change in the level or slope of the data in the intervention series that is not seen in the control series. Alternatively, a single model can be fitted by combining the intervention and control series. In line with Lopez-Bernal et al's (2019)⁹ guidance, we used a two-step approach. First, we used the approach described above in separate analysis of off-trade alcohol sales data in Scotland and England & Wales. Second, we entered the England & Wales time series data as a covariate in the SARIMA models for Scotland to produce a 'controlled' model.

Adjusting the model for covariates

Models were fitted to the off-trade alcohol sales data series with and without adjustment for covariates that plausibly could explain part of any identified relationship between MUP and off-trade sales. We included data for the following covariates in adjusted models:

- Disposable household income
- On-trade alcohol sales (Scotland only)
- Sales of other alcoholic drink categories (in models of specific drink categories for Scotland only)

Sensitivity and supplementary analyses

We performed a number of additional analyses to test the robustness of our results:

- We repeated our analyses using the difference between Scotland and England & Wales at each time point as the outcome series. This was performed for total off-trade alcohol sales and by drink category using both unadjusted and adjusted models.
- We assessed the impact of applying volume market share uplift factors to off-trade alcohol sales data to account for the exclusion of sales by Aldi and Lidl (see Appendix 2). This was performed for total off-trade alcohol sales using separate unadjusted models in Scotland and England & Wales, and in an adjusted, controlled model.
- It has been suggested that Northern England is a more appropriate control group for Scotland than England & Wales due to a more similar socio-demographic make-up and alcohol culture.¹⁰ We therefore repeated our analyses using NW and NE England as geographical controls. This was performed for total off-trade alcohol sales using separate unadjusted models for each region and in an adjusted, controlled model that incorporated the region as a covariate in the model for Scotland.

- We repeated our analyses using only 12 months pre-implementation data as it has been suggested that equal proportions of data before and after an intervention exposure can enhance statistical power.¹¹ This was performed for total off-trade alcohol sales using separate unadjusted models in Scotland and England & Wales, and in an adjusted, controlled model.
- We applied our analytical approach to overall alcohol sales (i.e. off- and on-trade sales combined). This was performed for total sales in an adjusted, controlled model.
- We assessed the impact of MUP on off-trade alcohol sales using an alternative analytical approach. Specifically, we used an Unobserved Components Model (UCM), a form of structural time series method, across the entire outcome series. UCM presents an alternative to SARIMA as it does not assume the data are 'stationary' (i.e. statistical properties of the data series, such as the mean and variance, are constant over time).¹² In addition model output is typically presented as a series of plots of the trend, seasonal and cyclical components making the analysis easier to comprehend compared to the regression output format of a SARIMA model. This was performed for total off-trade alcohol sales using separate unadjusted models for Scotland and England & Wales.
- We also tested whether MUP had an impact on the variability in weekly off-trade alcohol sales. In other words, did MUP affect the frequency and magnitude of peaks and troughs in the data series in the year after it was introduced compared with the pre-intervention period?

Presentation of results

A detailed presentation and description of trends in off-trade alcohol sales in Scotland and England & Wales, overall and by drink category, was provided in our previous report¹; these are not repeated in this report.

Results from all analyses performed are provided in Appendix 3. In the main report, we graphically present the estimated impact of MUP from our primary analyses based on:

- 1 Separate unadjusted, uncontrolled models for Scotland and England & Wales.
- 2 Unadjusted, controlled models (in which the England & Wales series is incorporated in the model for Scotland).
- 3 Adjusted, controlled models (as above but also including as covariates trends in household disposable income, on-trade sales and, for analyses of specific drink categories, off-trade alcohol sales of other drink categories).

To ease visual interpretation, we present our modelled estimates of the impact of MUP (displayed as percentage changes) in two separate figures for the following groups of drink categories:

- total off-trade, wine, spirits and beer
- cider, perry, fortified wine and RTDs.

Note that the separate figures use a different scale.

We provide an indication of uncertainty around our estimates of the impact of MUP using 95% confidence intervals. This is in line with STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidance¹³ and the guidelines produced by Beard et al (2019)⁷ for using time-series analyses in addiction research. In addition, we report results from both uncontrolled and controlled analyses (with equal prominence) as recommended by Lopez-Bernal et al (2019).⁹

Changes to our published protocol

We made the following changes to the pre-specified protocol published in our Statistical Analysis Plan:¹⁴

- We did not perform detailed analyses using overall alcohol sales (i.e. both on- and off-trade combined) as an outcome, despite this being stated as a

primary outcome variable in the protocol. This was for two main reasons. First, MUP was primarily expected to affect alcohol sold in the off-trade due to lower prices than in the on-trade. Second, we accounted for trends in on-trade sales in our adjusted models. As such, rerunning all models for all drink categories using combined on- and off-trade alcohol sales as an outcome variable was deemed unnecessary. Instead, as noted above, we performed supplementary analysis to assess the impact of MUP on total combined sales in a single controlled and adjusted model.

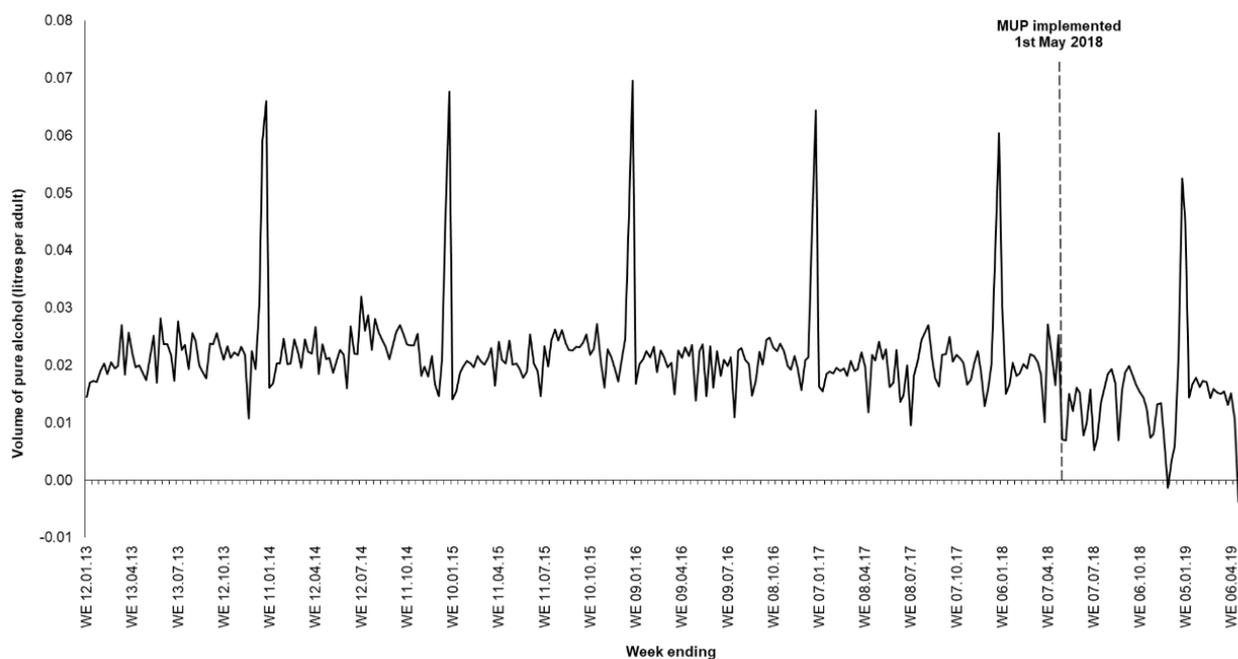
- Linked to the above, we did not perform separate analyses of on-trade alcohol sales, which was specified as a secondary outcome variable in our protocol. This will be undertaken in the final sales-based consumption study that will use data for a three-year post-implementation period.
- We did not repeat our analyses expressing alcohol sales per adult drinker instead of per adult (i.e. excluding non-drinkers from the denominator). Data on the prevalence of non-drinking in Scotland and England & Wales is not yet available for a full calendar year after MUP was introduced. This will be undertaken in the final sales-based consumption study that will use data for a three-year post-implementation period.
- We did not perform falsification tests with alternative legislation dates, or tests for structural breaks as part of our sensitivity analyses. This will be undertaken in the final sales-based consumption study that will use data for a three-year post-implementation period.
- We did not decompose the time series for each outcome. This was planned to ease visual interpretation of trends; however, we argue this was provided by the detailed presentation and interpretation of trends in the previous descriptive report.¹

Results

Descriptive trends

Figure 1 plots the difference in the volume of pure alcohol sold per adult in Scotland and England & Wales from January 2013 to May 2019. Throughout the study time period, per adult off-trade alcohol sales in Scotland were higher than in England & Wales (apart from weeks 30 and 50 in the post-intervention period). However, in the year after MUP was introduced, the difference in weekly off-trade alcohol sales reduced compared with previous years; to illustrate, in 49 out of 52 weeks in the post-MUP year, the difference in off-trade alcohol sales between Scotland and England & Wales was lower than in the corresponding week in the pre-MUP year.

Figure 1: Difference in volume (litres) of pure alcohol sold per adult in the off-trade between Scotland and England & Wales, January 2013 to May 2019



Controlled interrupted time series

Figures 2a and 2b present the estimated impact of the introduction of MUP on overall off-trade alcohol sales, and by drink category. The results are summarised below and in Tables A1 to A4 (Appendix 3).

Total off-trade alcohol sales

In unadjusted analysis, the introduction of MUP was associated with a 2.6% (95% confidence interval (CI): -4.1% to -1.0%) reduction in the total volume of pure alcohol sold per adult in Scotland. In England & Wales, there was a 2.3% (0.9% to 3.6%) increase over the same time period. In the unadjusted, controlled model, MUP was associated with a 4.2% (-5.3% to -3.0%) reduction in total off-trade alcohol sales in Scotland. A similar estimate was produced when the controlled model was adjusted for disposable income and substitution (-4.2% (-5.4% to -3.0%)).

Spirits (32.5% of off-trade market share in post-MUP year)

In unadjusted analysis, the introduction of MUP was associated with a 2.4% (-5.0% to 0.2%) reduction in the volume of pure alcohol sold per adult as spirits in Scotland. In England & Wales, there was a 3.8% (1.5% to 6.2%) increase over the same time period. In the unadjusted, controlled model, MUP was associated with a 6.2% (-7.5% to -4.8%) reduction in off-trade spirits sales in Scotland. A smaller reduction was estimated when the controlled model was adjusted for disposable income and substitution (-4.7% (-6.7% to -2.5%)).

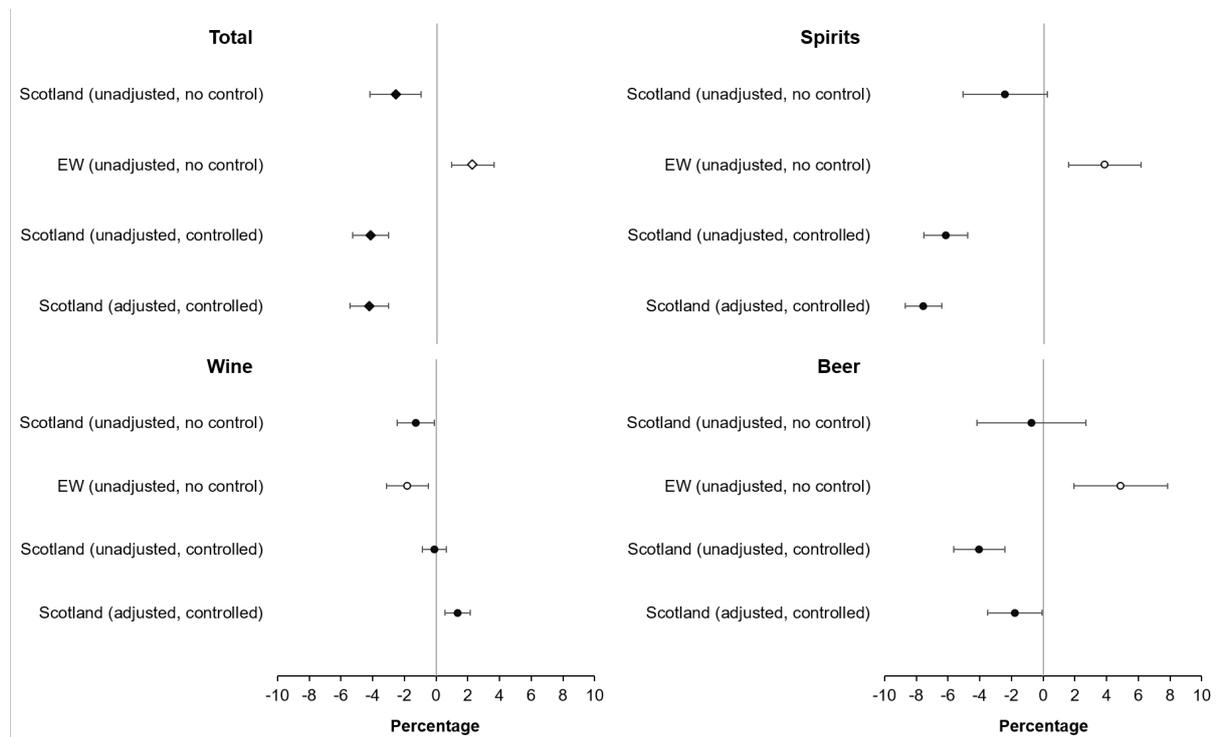
Wine (31.9% of off-trade market share in post-MUP year)

In unadjusted analysis, the introduction of MUP was associated with a 1.3% (-2.4% to -0.1%) reduction in the volume of pure alcohol sold per adult as wine in Scotland. In England & Wales, there was a 1.8% (-3.1% to -0.5%) decrease over the same time period. In the unadjusted, controlled model, the estimated effect of MUP on off-trade wine sales was close to zero (-0.1% (-0.8% to 0.6%)). After adjustment for disposable income and substitution, MUP was associated with a 1.3% (0.4% to 2.2%) increase in off-trade wine sales in Scotland when controlling for sales in England & Wales.

Beer (24.0% of off-trade market share in post-MUP year)

In unadjusted analysis, there was little evidence to suggest that the introduction of MUP was associated with a change in the volume of pure alcohol sold per adult as beer in Scotland (-0.7% (-4.1% to 2.7%)). However, in England & Wales, there was a 4.9% (1.8% to 8.0%) increase in off-trade beer sales over the same time period. In the unadjusted, controlled model, MUP was associated with a 4.0% (-5.6% to -2.4%) reduction in off-trade beer sales in Scotland. A smaller reduction was estimated when the controlled model was adjusted for disposable income and substitution (-1.9% (-3.6% to -0.2%)).

Figure 2a: Change (%) in off-trade alcohol sales in the year after MUP was implemented in Scotland for all alcohol, spirits, wine and beer.



Note: EW = England & Wales. ‘Controlled’ models include trends in off-trade alcohol sales in England & Wales as a covariate. ‘Adjusted’ models include trends in household disposable income, on-trade sales and, for analyses of specific drink categories, off-trade alcohol sales of other drink categories as covariates. All models are adjusted for underlying seasonal and secular trends.

Cider (6.4% of off-trade market share in post-MUP year)

In unadjusted analysis, the introduction of MUP was associated with a 17.4% (-20.1 to -14.7%) reduction in the volume of pure alcohol sold as cider per adult in Scotland. In England & Wales, there was an 11.4% (9.5% to 13.4%) increase over the same time period. In the unadjusted, controlled model, MUP was associated with a 21.9% (-23.5% to -20.3%) reduction in off-trade cider sales in Scotland, which reduced after adjustment for disposable income and substitution (-18.8% (-20.5% to -17.1%)).

Fortified wine (3.5% of off-trade market share in post-MUP year)

In unadjusted analysis, the introduction of MUP was associated with a 6.7% (3.1% to 10.5%) increase in the volume of pure alcohol sold as fortified wine per adult in Scotland. In England & Wales, there was a 6.0% (-8.2% to -3.8%) decrease over the same time period. In the unadjusted, controlled model, MUP was associated with a 4.8% (0.4% to 9.3%) increase in off-trade fortified wine sales in Scotland, which increased slightly after adjustment for disposable income and substitution (5.7% (1.3% to 10.3%)).

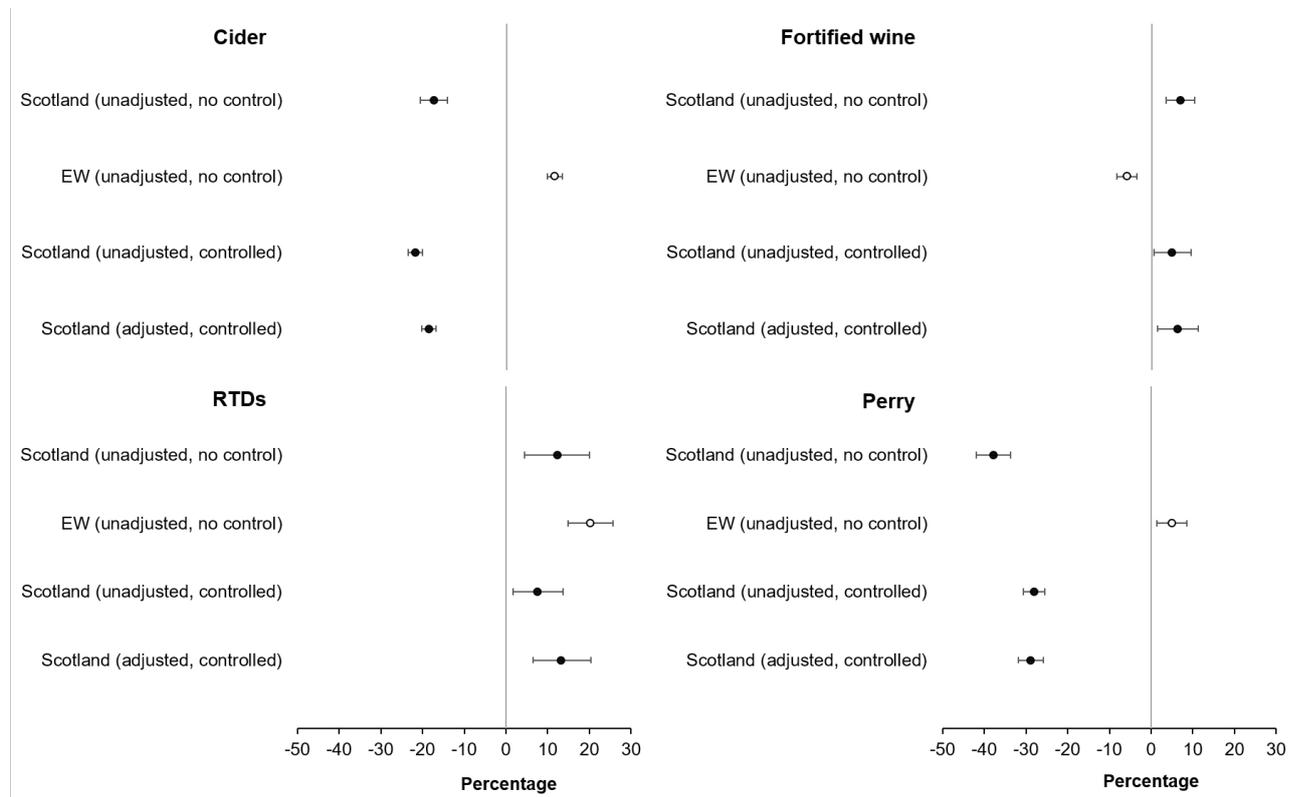
RTDs (1.2% of off-trade market share in post-MUP year)

In unadjusted analysis, the introduction of MUP was associated with a 12.3% (3.8% to 21.4%) increase in the volume of pure alcohol sold as RTDs per adult in Scotland. In England & Wales, there was a 20.2% (13.9% to 26.9%) increase over the same time period. In the unadjusted, controlled model, MUP was associated with a 7.5% (1.7% to 13.7%) increase in off-trade RTD sales in Scotland, which increased after adjustment for disposable income and substitution (13.4% (6.8% to 20.5%)).

Perry (0.4% of off-trade market share in post-MUP year)

In unadjusted analysis, the introduction of MUP was associated with a 37.8% (-40.4% to -35.2%) reduction in the volume of pure alcohol sold as perry per adult in Scotland. In England & Wales, there was a 5.0% (1.2% to 8.9%) increase over the same time period. In the unadjusted, controlled model, MUP was associated with a 28.1% (-30.6% to -25.4%) reduction in off-trade perry sales in Scotland. A similar estimate was produced when the controlled model was adjusted for disposable income and substitution (-28.9% (-31.8% to -25.8%)).

Figure 2b: Change (%) in off-trade alcohol sales in the year after MUP was implemented in Scotland for cider, fortified wine, RTDs and perry



Note: EW = England & Wales. ‘Controlled’ models include trends in off-trade alcohol sales in England & Wales as a covariate. ‘Adjusted’ models include trends in household disposable income, on-trade sales and, for analyses of specific drink categories, off-trade alcohol sales of other drink categories as covariates. All models are adjusted for underlying seasonal and secular trends.

Sensitivity and supplementary analyses

Repeating our controlled analyses using the difference in off-trade alcohol sales between Scotland and England & Wales as the outcome series produced similar results to our main controlled models for total sales (Figure 3). There were some inconsistencies in the magnitude of the estimated effect for particular drink categories, but the direction of effect was mostly consistent between approaches for both unadjusted and adjusted models (Tables A5 and A6).

The estimated reduction in per-adult off-trade sales in Scotland associated with the introduction of MUP was larger when the Aldi and Lidl alcohol market share was applied to the data. In England & Wales, uplift for Aldi and Lidl produced a larger estimated increase in per-adult off-trade sales in the post-MUP year (Table A7). This is likely due to the fact that the alcohol market share in Aldi and Lidl fell in Scotland in the post-MUP year, while it increased in England & Wales. Nonetheless, the estimated net reduction in off-trade alcohol sales associated with MUP in the adjusted controlled model was similar to the main analysis (Figure 3).

Using off-trade alcohol sales in NW England as the geographical control produced similar results to our main analyses (Table A8; Figure 3). Comparing the post-MUP time period with the pre-MUP time period was associated with a slightly higher increase in off-trade alcohol sales in NE England than England & Wales. The estimated impact of MUP on off-trade alcohol sales in Scotland was therefore higher in the controlled model that incorporated data from NE England instead of England & Wales.

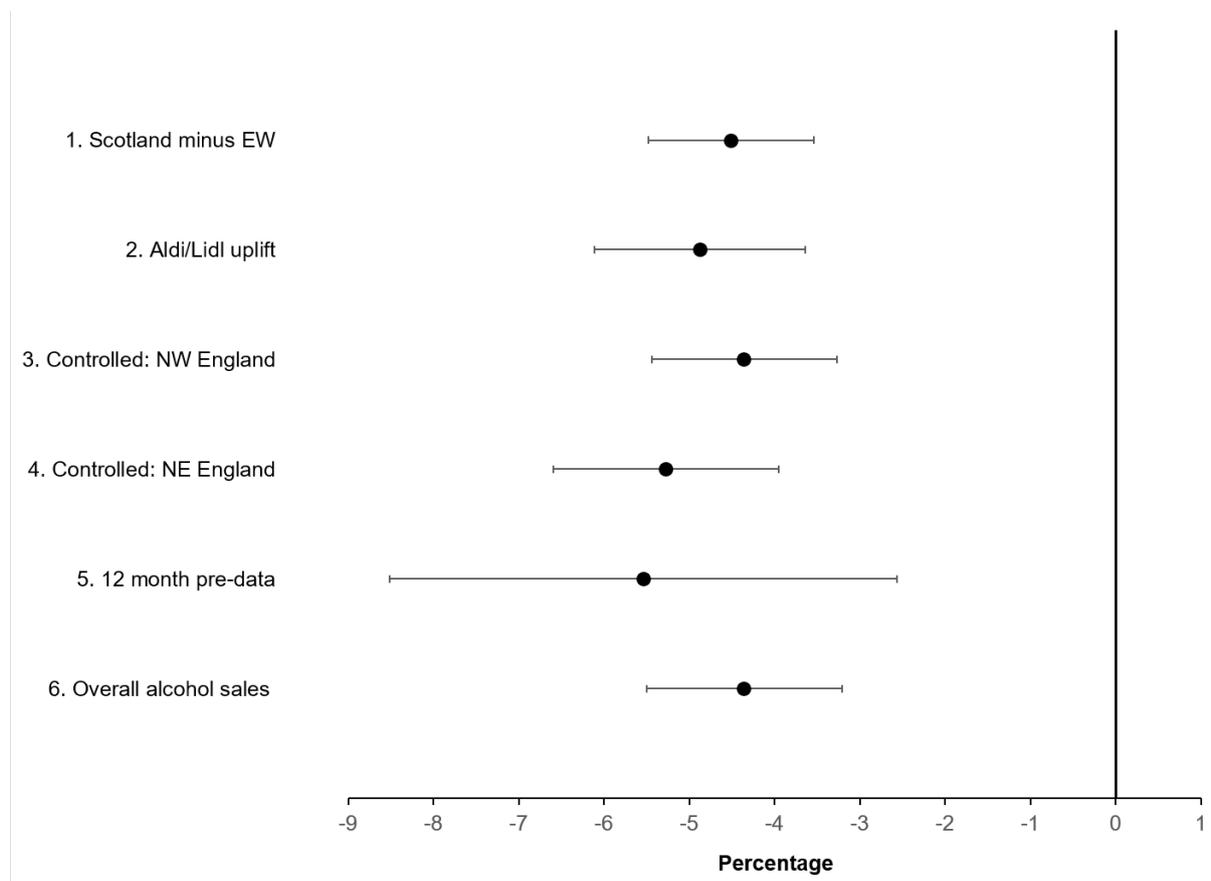
Repeating our analyses using only 12 months pre-implementation data produced much more uncertain estimates. In the adjusted, controlled model, the estimated effect of MUP was slightly higher than our main analysis and also those produced from other sensitivity analyses (Figure 3, Table A9).

Fitting an UCM to the data (a form of structural time series), instead of a SARIMA model, produced very similar estimates of the MUP effect size in unadjusted models for Scotland and England & Wales (Figure 3; Table A10). The uncertainty around the effect size (i.e. the 95% confidence interval) was typically larger in the UCM analysis. These findings were observed for total off-trade alcohol sales and across separate drink categories (data not shown).

Applying the same analytical approach to all alcohol sales (i.e. off- and on-trade sales combined) produced similar results to the controlled, adjusted model in the main analysis (Table A11; Figure 3).

Our test of whether MUP had an impact on the variability of weekly off-trade sales in Scotland did not suggest a statistical difference in the frequency and magnitude of peaks and troughs in the post-MUP period (Table A12). This analysis did not incorporate data for England & Wales.

Figure 3: Change (%) in off-trade alcohol sales in the year after MUP was implemented in Scotland estimated from sensitivity and supplementary analyses.



Note: EW = England & Wales. NE = North East England. NW = North West England. Models 1, 2, 5 and 6 incorporate off-trade alcohol sales in England & Wales as control. All models include trends in on-trade sales (excluding model 5) and household disposable income as covariates and are adjusted for underlying seasonal and secular trends.

Discussion

Main findings

This study provides evidence that the introduction of MUP in Scotland on 1 May 2018 was associated with a reduction in the total volume of pure alcohol sold off-trade per adult in Scotland in the following 12-month period. In England & Wales, where the legislation does not apply, per-adult alcohol sales increased over the same time period. Based on the controlled interrupted time series results presented in this report, the best estimate of the net reduction in per-adult off-trade sales in Scotland as a result of MUP is between 4 and 5%. As we accounted for underlying trends in our analyses, as well as other covariates that may explain part of the effect of MUP on off-trade sales, it is reasonable to conclude that MUP caused the reductions observed.

The largest relative net reductions in per-adult off-trade alcohol sales were observed for cider and perry. Smaller net reductions were seen for spirits and beer; however, these account for a greater share of the off-trade market and so made an important contribution to the fall in total off-trade sales in Scotland in the year after MUP was introduced. The reductions observed in these drink categories was partly offset by off-trade sales of wine, fortified wine and RTDs, which all increased in the post-MUP year; fortified wine and RTDs account for a relatively small share of the off-trade alcohol market.

Strengths of this study

There are a number of key features of our study design that help to strengthen the interpretation of our findings. First, we used alcohol sales data (converted to pure alcohol volumes and expressed per adult) as our proxy for population consumption, which is considered the most objective and reliable approach for monitoring and evaluation.¹⁵ In previous work, we have interrogated the appropriateness of the data used in this study specifically for the purposes of estimating population consumption in Scotland. By identifying and quantifying potential sources of bias, we are confident that they provide one of the best sources of data available. Nonetheless,

triangulation of our findings with those based on other approaches to estimating consumption, such as the consumer panel data used in a recent study by O'Donnell et al (2019)¹⁶ (and discussed below), will be an important element of the overall MUP evaluation.

Second, our study design incorporated data for England & Wales as a geographical control series. By comparing with, and controlling for, the change in off-trade alcohol sales in England & Wales in the 12-month period after MUP was introduced in Scotland, we can be more confident that the observed reduction in Scotland was due to MUP rather than another factor (i.e. confounding). Beer provides a good illustration of this point. A large proportion (56%) of off-trade beer was sold at below 50 pence per unit (ppu) of alcohol in the calendar year before MUP was implemented (the price at which MUP in Scotland was set).¹⁷ Yet, we did not observe an MUP effect on off-trade beer sales in Scotland in the uncontrolled, unadjusted analyses. However, the UK experienced a heat wave in the summer of 2018 following MUP being introduced in Scotland which, alongside other key events during this period, would be expected to increase off-trade beer sales. Indeed, in England & Wales, we estimated that off-trade beer sales increased by 4.9% in the year after MUP came into effect, compared with a 0.7% reduction in Scotland. Thus, the legislation was associated with lower off-trade beer sales in Scotland than would have been the case in the absence of MUP.

Third, we were able to take into account underlying trends in the data series through the analytical method employed. This allowed us to strengthen the interpretations we made in our descriptive analysis and more confidently isolate the impact of MUP. For example, based on our descriptive analyses, we reported that off-trade sales of fortified wine increased by 16% in the year after MUP was introduced.¹ However, we also noted that this was a continuation of an already upward trend. Using SARIMA in this study, thereby adjusting for this existing trend, we found that MUP was associated with an increase of less than half of this magnitude. In addition to underlying trends, we also adjusted our models for the potential influence of changes in disposable income. This was an important step because alcohol affordability is affected not only by the price of alcohol, but also the purchasing power of

consumers. Similarly, it is plausible to expect consumers to respond to increased prices of their preferred alcohol by switching between drink categories, or between retail sectors (i.e. from off-trade to on-trade).¹⁸ We found our estimated effects to be robust to including substitution as a covariate in our statistical models.

Fourth, we performed a range of sensitivity and supplementary analyses to test the robustness of our main findings to changes in the model specification and analytical method employed. We observed similar findings across these different approaches, which substantiates the interpretations presented.

Finally, before commencing our analyses, we published a detailed statistical analysis plan to set out how we intended to analyse our data and report our findings, which is considered to represent good practice.⁷

Limitations of this study

Although alcohol sales data provide an objective estimate of population consumption, they cannot be disaggregated to assess how sales differ across population subgroups. Modelling suggested that consumption among the heaviest drinkers, who typically consume the cheapest alcohol, was likely to be affected most by the introduction of MUP in Scotland, particularly those living in low-income households. The recent findings by O'Donnell et al¹⁶ provided support for this, suggesting that reduced alcohol purchasing in Scotland was driven, as hypothesised, by reductions among households purchasing the highest volumes of alcohol. While it was not possible to assess such differential impacts with the retail sales data we have used, the drink categories most affected – cider and spirits (previously sold at low cost) – are those consumed in greater quantities by heavier drinkers and those living in areas with higher levels of socioeconomic deprivation.^{19 20} The comprehensive mixed-methods evaluation being led by Public Health Scotland (formerly NHS Health Scotland) includes a range of studies that will provide insights into how MUP has affected the consumption level and/or behaviour of different population subgroups. This includes a recently published qualitative study among 50 children and young people who reported being drinkers before and after MUP was introduced, which suggested no obvious impact of MUP on consumption

behaviour. Nonetheless, quantitative inferences could not be drawn from the purposive sample. In addition, this population subgroup is likely to account for a negligible proportion of all alcohol sold in Scotland.²¹

In addition to the lack of disaggregation of sales data for population subgroups, we were also unable to disaggregate sales by off-trade retailers into the separate off-trade channels. Nielsen's 'grocery multiple' data constitutes most of the major supermarkets, which account for approximately 80% of the off-trade alcohol market; sales estimates for this channel are likely to be highly accurate as they are based on census data. The 'impulse' data accounting for the remaining alcohol sold through the off-trade, constitutes symbol groups (e.g. Spar, Londis) and independent convenience stores and off-licences; sales estimates for this channel are based on a sample of retailers, thereby increasing uncertainty. It was noted in the baseline report of the Economic Impact study that we have commissioned as part of the MUP Evaluation that smaller convenience stores viewed MUP as offering a chance to 'level the playing field' with larger supermarkets.²² Unfortunately, we could not examine this with the data used in this study. As part of our evaluation, we will continue to seek alternative sources of intelligence to enhance our understanding of any differential impact of MUP on sales among different categories of alcohol retailers, triangulating with additional data sources where possible.

This is the first study to statistically analyse the impact of MUP on population alcohol consumption for the full 12-month period after it was introduced in Scotland.

Nonetheless, it is important to consider both short and longer-term effects of new public policy as any short-term impact may not be sustained. For example, when we evaluated the impact of the Alcohol etc. (Scotland) Act 2010 legislation on off-trade alcohol sales in Scotland, we observed a decrease in total off-trade sales in the year after the legislation was implemented; however, when we updated our analyses to include data for a further year, the effect was weakened (though the effect on off-trade wine sales remained).⁸ As such, we will build on this work by applying the same methodological approach to off-trade alcohol sales data for the three-year post-MUP period when these data become available.

Interpretation

Our results are broadly consistent with a recent study by O'Donnell et al, which assessed the impact of MUP on alcohol purchases (as a proxy for consumption) in Scotland in the eight-month post-implementation period using household consumer panel data (a household member uses a barcode scanner to record all grocery purchases being brought into the home).¹⁶ These data tend to underestimate population consumption estimates when compared with the retail sales data used in our study, but produce higher estimates than those based on more traditional self-reported survey methods (author's own calculations). As with our study, the authors employed a controlled interrupted time series design using purchases in England & Wales as a geographical control. The results showed that the introduction of MUP was associated with a net reduction (i.e. Scotland minus England & Wales) in alcohol purchases of 9.5g of alcohol per adult per household per week, equivalent to a reduction of 7.6%. Our best estimate of the MUP effect was smaller in magnitude, at between 4% and 5%. A reduction in purchases was observed for beer, spirits, cider and wine in the study by O'Donnell and colleagues.¹⁶ While we observed reduced off-trade wine sales associated with MUP in an uncontrolled, unadjusted model for Scotland, the association reversed direction in the controlled, adjusted model (this seemed to be primarily due to adjustment for off-trade sales on other drink categories; post-hoc analysis not shown). Besides the data used and time period analysed, other differences between the methods employed may explain variations in findings. For example, as noted earlier, we adjusted our models for trends in disposable income and any substitution effect.

The impact of MUP on off-trade alcohol sales in Scotland is most likely explained by the policy's effect on alcohol prices. In our recent report, we found that the average sales price of alcohol increased by 5ppu, an increase of 7%.¹ This is similar to the increase reported by O'Donnell et al in the eight-month period post-MUP. Increasing the price of alcohol, thereby reducing its affordability, is one of the most effective measures for reducing population alcohol consumption and is considered a 'best-buy' policy by the World Health Organization.²³ In Canada, which has different forms of minimum pricing in different provinces, sales-based consumption reduced

by an average of 3.4% in British Columbia²⁴ and 8.4% in Saskatchewan for a 10% increase in minimum prices.²⁵ A reduction in consumption as observed in this study using sales data is also consistent with results from scenario modelling used to inform the development of MUP in Scotland.²⁶ The Sheffield Alcohol Policy Model used self-reported consumption estimates from the Scottish Health Survey alongside the extensive evidence base linking price changes and consumption²⁷ and estimated that a 50ppu MUP introduced in Scotland would reduce population consumption by 3.5% after the first year. While this is broadly consistent with the results of this study, direct comparisons between the modelled and observed effect sizes should be treated with caution as different measures of consumption have been used and the modelling is based on consumption in 2016.

Attributing our findings to changes in price is further supported by the fact that the drink categories for which we estimated net reductions in off-trade sales in Scotland were also those that had the highest proportion of their sales at below 50ppu before MUP was introduced.¹⁷ They were also the drink categories with largest increases in average sales price after MUP was implemented (perry, cider, spirits and beer increased by 54%, 28%, 11% and 11%, respectively). In contrast, wine, fortified wine, and RTDs were typically sold at prices above the 50ppu threshold before MUP was introduced and off-trade sales of these drink categories increased in association with MUP after accounting for sales in England & Wales and other covariates.

The inclusion of NW and NE England as additional control series was pre-planned as it has been suggested that these are more appropriate regions for comparison with Scotland than England & Wales overall. It has also been suggested that an unintended consequence of MUP in Scotland might be to increase cross-border shopping i.e. alcohol consumers purchasing lower priced alcohol in the north of England for consumption in Scotland. It was not possible to directly examine this in our study. However, the increase in per-adult off-trade alcohol sales in the northern English regions was broadly similar to that observed for England & Wales overall. Furthermore, in our previous descriptive analyses of these data, we observed that the ratio of off-trade sales between the northern regions and the rest of England & Wales in the post-MUP year was similar to that seen in the years prior to

MUP implementation.¹ It is therefore highly unlikely that cross-border purchasing could account for the net effect of MUP reported here. This assertion is supported by two previous MUP studies that, while acknowledging cross-border purchasing took place and may have increased for some stores near the English border post-MUP, did not provide evidence that it was a substantial issue.^{22 28} Nonetheless, we will continue to source intelligence on cross-border purchasing throughout the duration of the MUP evaluation.

Conclusion

The results from this study suggest that the introduction of MUP in Scotland was associated with reduced off-trade alcohol sales, largely driven by a decrease in off-trade sales of spirits, beer, cider and perry. Our analyses controlled for trends in England & Wales, where the legislation does not apply, as well as underlying trends and other covariates, thereby strengthening the assertion that MUP caused these effects. We conclude that MUP has been effective in reducing population consumption levels in Scotland in the one year period after it was implemented.

Appendix 1: Detailed description of statistical methods

Preparing the data

We assessed whether the outcome measures have a normal distribution using Kernel Density plots. As our primary outcome measure, weekly off-trade alcohol sales per adult, was not normally distributed, these data were transformed using the natural logarithm. This is often an important step for meeting the assumption of a normal distribution when performing ARIMA modelling.

Diagnosing autocorrelation and non-stationarity

The presence of serial and seasonal autocorrelation and non-stationarity was diagnosed using autocorrelation (AC) and partial autocorrelation functions (PAC). These enabled any significant correlation between error terms at different lag periods and the number of autoregressive (AR) and moving average (MA) terms to be identified and accounted for. Inclusion of deterministic terms was sufficient to address non-stationarity in the mean and variance of the off-trade sales series meaning that differencing was not required.

Selecting the baseline model

Candidate SARIMA models were investigated using plots and AC/PAC plots of the stationary data series. The most appropriate and parsimonious model was selected using the Akaike Information Criterion (AIC) and Bayesian Information Criteria (BIC) statistics.²⁹ Lagged effects of MUP were not explored in light of findings from other studies in the MUP Evaluation portfolio which have shown that the legislation has been complied with and implemented effectively.²⁸ Similarly, our preliminary analysis of data on the average sales price of off-trade alcohol did not suggest that there was an anticipatory effect prior to MUP being introduced in Scotland compared with England & Wales.¹

Testing the effect of the intervention

We estimated the magnitude and uncertainty of the effect of MUP implementation on off-trade alcohol sales by including a binary explanatory variable in our SARIMA models, with the value of zero for the time before MUP is introduced (January 2013 to April 2018) and the value of one after the introduction of MUP (May 2018 to April 2019). Models were all fitted assuming a change in level. This was based on a comparison of AIC and BIC statistics of separate models testing for either: a change in level only; a change in trend only; a change in level and trend.

Assessment of model fit

For all models, standard diagnostic tests were performed to ensure that the residuals of the fitted models were not significantly different from those expected from white noise or a random series.²⁶ In addition, AIC and BIC statistics were obtained and compared, and R^2 values were obtained by performing linear regression analyses using predicted values as the explanatory series and observed values as the outcome series.

Software

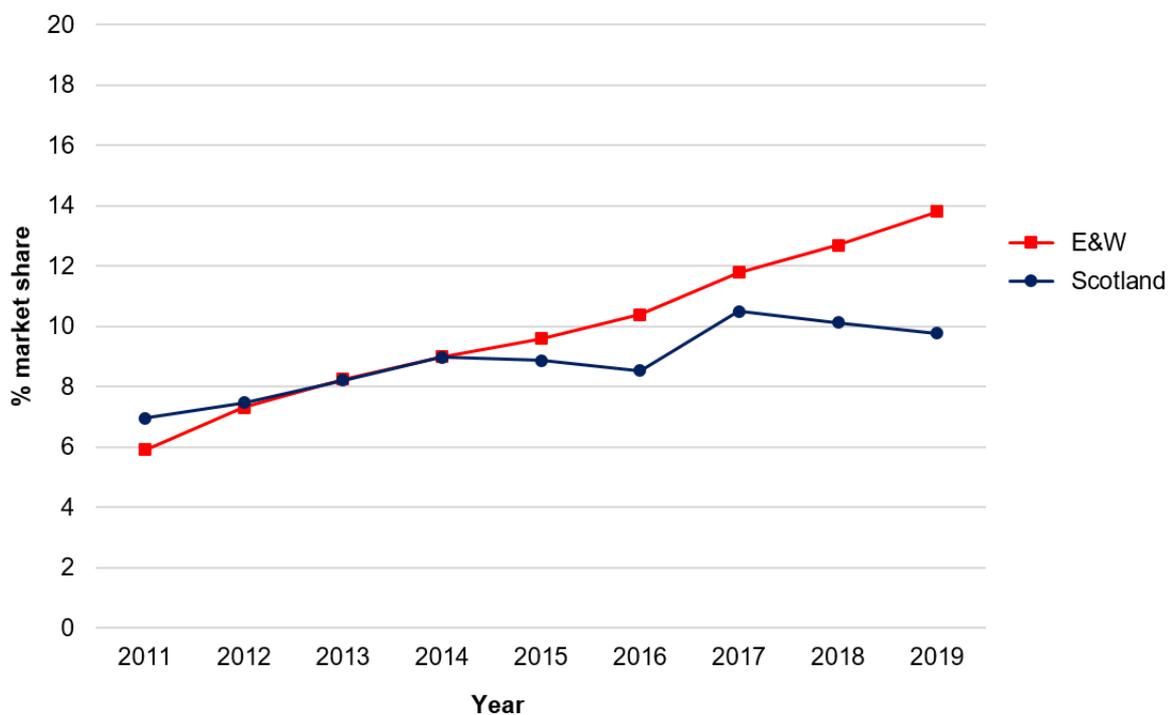
Analysis were performed using the following statistical software:

- MATLAB (Version 9.7 update 1) for all SARIMA modelling
- Python 3.7 for Unobserved Components Model analysis (using the UCM procedure in the 'statsmodels' package).

Appendix 2: Alcohol market share of Aldi and Lidl

Nielsen off-trade alcohol sales data do not include data for the discount stores Aldi and Lidl. In order to account for the proportion of alcohol sold within the discount retail sector, adjustment factors have been applied to off-trade sales estimates. Adjustment factors are based on the market share of Aldi and Lidl sales volumes drawn from Kantar Worldpanel consumer panel data, which were provided for Scotland and England & Wales for calendar years 2011 to 2019. Figure A1 shows the Aldi and Lidl market share estimates in Scotland and England & Wales for all alcohol between 2011 and 2019.

Figure A1: Aldi and Lidl market share estimates in Scotland and England & Wales for all alcohol, 2011–2019



Appendix 3: Results tables

Table A1: Change (%) in off-trade alcohol sales in the year after MUP was implemented in Scotland, by drink category (unadjusted, no control)

Drink category	MUP effect (%)		95% CI		p value
All	-2.6	-4.1	to	-1.0	0.001
Spirits	-2.4	-5.0	to	0.2	0.067
Beer	-0.7	-4.1	to	2.7	0.675
Wine	-1.3	-2.4	to	-0.1	0.034
Cider	-17.4	-20.1	to	-14.7	<0.001
Perry	-37.8	-40.4	to	-35.2	<0.001
Fortified wine	6.7	3.1	to	10.5	<0.001
RTDs	12.3	3.8	to	21.4	0.004

Note: RTDs = Ready to Drink drinks. All models are adjusted for underlying seasonal and secular trends.

Table A2: Change (%) in off-trade alcohol sales in the year after MUP was implemented in England & Wales, by drink category (unadjusted, no control)

Drink category	MUP effect (%)		95% CI		p value
All	2.3	0.9	to	3.6	0.001
Spirits	3.8	1.5	to	6.2	0.001
Beer	4.9	1.8	to	8.0	0.002
Wine	-1.8	-3.1	to	-0.5	0.007
Cider	11.4	9.5	to	13.4	<0.001
Perry	5.0	1.2	to	8.9	0.008
Fortified wine	-6.0	-8.2	to	-3.8	<0.001
RTDs	20.2	13.9	to	26.9	<0.001

Note: RTDs = Ready to Drink drinks. All models are adjusted for underlying seasonal and secular trends.

Table A3: Change (%) in off-trade alcohol sales in the year after MUP was implemented in Scotland, by drink category (unadjusted, controlled)

Drink category	MUP effect (%)		95% CI		p value
All	-4.2	-5.3	to	-3.0	<0.001
Spirits	-6.2	-7.5	to	-4.8	<0.001
Beer	-4.0	-5.6	to	-2.4	<0.001
Wine	-0.1	-0.8	to	0.6	<0.001
Cider	-21.9	-23.5	to	-20.3	<0.001
Perry	-28.1	-30.6	to	-25.4	<0.001
Fortified wine	4.8	0.4	to	9.3	<0.001
RTDs	7.5	1.7	to	13.7	<0.001

Note: RTDs = Ready to Drink drinks. Models include trends in off-trade alcohol sales in England & Wales as a covariate. All models are adjusted for underlying seasonal and secular trends.

Table A4: Change (%) in off-trade alcohol sales in the year after MUP was implemented in Scotland, by drink category (adjusted, controlled)

Drink category	MUP effect (%)		95% CI		p value
All	-4.2	-5.4	to	-3.0	<0.001
Spirits	-4.7	-6.7	to	-2.5	<0.001
Beer	-1.9	-3.6	to	-0.2	0.03
Wine	1.3	0.4	to	2.2	0.003
Cider	-18.8	-20.5	to	-17.1	<0.001
Perry	-28.9	-31.8	to	-25.8	<0.001
Fortified wine	5.7	1.3	to	10.3	0.01
RTDs	13.4	6.8	to	20.5	<0.001

Note: RTDs = Ready to Drink drinks. All models: include trends in off-trade alcohol sales in England & Wales as a covariate; include trends in household disposable income, on-trade sales and, for analyses of specific drink categories, off-trade alcohol sales of other drink categories as covariates; are adjusted for underlying seasonal and secular trends.

Table A5: Change (%) in difference between off-trade alcohol sales in Scotland and England & Wales in the year after MUP was implemented in Scotland, by drink category (unadjusted)

Drink category	MUP effect (%)		95% CI		p value
All	-4.8	-6.1	to	-3.4	<0.001
Spirits	-3.3	-4.9	to	-1.8	<0.001
Beer	-5.1	-6.2	to	-4.0	<0.001
Wine	1.1	0.5	to	1.6	<0.001
Cider	-25.1	-26.6	to	-23.6	<0.001
Perry	-28.9	-31.3	to	-26.3	<0.001
Fortified wine	-5.2	-15.6	to	6.5	<0.001
RTDs	3.7	-2.1	to	9.8	<0.001

Note: RTDs = Ready to Drink drinks. All models are adjusted for underlying seasonal and secular trends.

Table A6: Change (%) in difference between off-trade alcohol sales in Scotland and England & Wales in the year after MUP was implemented in Scotland, by drink category (adjusted)

Drink category	MUP effect (%)		95% CI		p value
All	-4.5	-5.5	to	-3.5	<0.001
Spirits	-4.2	-5.7	to	-2.7	<0.001
Beer	-5.2	-6.0	to	-4.5	<0.001
Wine	-3.0	-3.8	to	-2.2	<0.001
Cider	-19.6	-21.2	to	-18.0	<0.001
Perry	-9.7	-12.0	to	-7.2	<0.001
Fortified wine	-4.6	-6.4	to	-2.8	<0.001
RTDs	-5.3	-6.0	to	-4.6	<0.001

Note: RTDs = Ready to Drink drinks. All models: include trends in household disposable income, on-trade sales and, for analyses of specific drink categories, off-trade alcohol sales of other drink categories as covariates; are adjusted for underlying seasonal and secular trends.

Table A7: Change (%) in off-trade alcohol sales (all alcohol) in the year after MUP was implemented in Scotland after uplift for Aldi and Lidl

Model	MUP effect (%)	95% CI		p value
Scotland (unadjusted, no control)	-3.3	-5.2	to -1.5	<0.001
EW (unadjusted, no control)	2.5	1.1	to 4.0	<0.001
Scotland (adjusted, controlled)	-4.9	-6.1	to -3.6	<0.001

Note: EW = England & Wales. ‘Controlled’ models include trends in off-trade alcohol sales in England & Wales as a covariate. ‘Adjusted’ models include trends in household disposable income and on-trade sales. All models are adjusted for underlying seasonal and secular trends.

Table A8: Change (%) in off-trade alcohol sales (all alcohol) in NE England, NW England and Scotland (with NE England and NW England as control) in the year after MUP was implemented in Scotland.

Model	MUP effect (%)	95% CI		p value
North East (NE) (unadjusted, no control)	2.9	1.3	to 4.6	<0.001
North West (NW) (unadjusted, no control)	1.9	0.0	to 3.9	0.046
Scotland (adjusted, NE control)	-5.3	-6.6	to -3.9	<0.001
Scotland (adjusted, NW control)	-4.4	-5.4	to -3.3	<0.001

Note: ‘Controlled’ models include trends in off-trade alcohol sales in England & Wales as a covariate. ‘Adjusted’ models include trends in household disposable income and on-trade sales. All models are adjusted for underlying seasonal and secular trends.

Table A9: Change (%) in off-trade alcohol sales (all alcohol) in the year after MUP was implemented in Scotland using only 12 month pre-MUP data

Model	MUP effect (%)	95% CI		p value
Scotland (unadjusted, no control)	3.0	-22.9	to 37.7	0.836
EW (unadjusted, no control)	6.2	-10.4	to 25.9	0.485
Scotland (adjusted, controlled)	-5.5	-8.5	to -2.6	<0.001

Note: 'Controlled' models include trends in off-trade alcohol sales in England & Wales as a covariate. 'Adjusted' models include trends in household disposable income and on-trade sales. All models are adjusted for underlying seasonal and secular trends.

Table A10: Change (%) in off-trade alcohol sales (all alcohol) in the year after MUP was implemented in Scotland using the Unobserved Components Method (UCM)

Model	MUP effect (%)	95% CI		p value
Scotland (unadjusted, no control)	-2.5	-4.7	to -0.4	<0.001
EW (unadjusted, no control)	2.6	0.0	to 5.3	0.050

Note: Models adjusted for underlying seasonal and secular trends.

Table A11: Change (%) in all alcohol sales (off- and on-trade sales combined) in the year after MUP was implemented in Scotland

Model	MUP effect (%)	95% CI		p value
Scotland (adjusted, controlled)	-4.4	-5.5	to -3.2	<0.001

Note: Models adjusted for underlying seasonal and secular trends.

Table A12: Change (%) in the variability of off-trade alcohol sales in the year after MUP was implemented in Scotland

Model	MUP effect (%)	95% CI	p value
Scotland (adjusted, no control)	0.1	-0.1 to 0.4	0.278

Note: Residuals from a SARIMA on off-trade alcohol sales in Scotland were squared. An ARIMA model was then run on the squared residuals with MUP as the only covariate.

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