Appendix G: Evaluation of the short-term impact of the Alcohol Act on alcohol-related deaths and hospital admissions in Scotland

Monitoring and Evaluating Scotland's Alcohol Strategy: 5th annual report. NHS Health Scotland, March 2015

Contents

1. Background

The Alcohol etc. (Scotland) Act (henceforth the 'Alcohol Act') was implemented in Scotland on 1st October 2011 and introduced new regulations concerning the sale and promotion of alcohol in the off-trade (i.e. retailers that sell alcohol for consumption off the premises such as supermarkets and other licensed shops).[1] The key provisions included in the Alcohol Act are summarised in Box A below.[i]

Box A: Key provisions in the Alcohol Act

Ban on multi-buy promotions
This provision prohibits any promotion where the price of a single product in a multi-pack or multi-buy offer is sold for less than the price of buying the same product on its own. For example, promotional offers such as 'buy one get one free' and 'three bottles of wine for £10' (when each bottle costs more than £3.33).

Restriction on the location of alcohol promotions
This provision prohibits the promotion of alcohol to within the single area of the premises where alcohol is sold.

Age verification scheme
This provision imposes a requirement for all premises selling alcohol to have an age verification policy, with the age set at a minimum of 25. In other words, retailers must challenge any person who looks under the age of 25 to provide identification, proving he or she is at least 18 years of age.

The ban on multi-buy promotions, often referred to as the 'ban on quantity discounts' or 'multi-buy discount ban' was generally considered to be the component of the Alcohol Act most likely to have an impact on population consumption levels. The intention of the ban was to remove price-based incentives that would encourage consumers to purchase more alcohol than they may otherwise have bought thereby reducing overall consumption and, in turn, risk of alcohol-related harm.

The short-term impact of the Alcohol Act on population consumption levels in Scotland was evaluated in a previous MESAS study. Using retail sales data –

[i] The Alcohol Act included other provisions related to licensing policy statements and chief constables' reporting. These are described in more detail elsewhere.[1]

considered the most accurate data for estimating population consumption[2] – it was found that the Alcohol Act was associated with a 2.6% decrease in the total volume of alcohol sold off-trade per adult in Scotland in the one-year period after its implementation.[3] This was mainly driven by a 4.0% fall in wine sales, but there was also an 8.5% fall in sales of pre-mixed drinks (e.g. vodka mixed with lemonade) although these account for a very small market share. Importantly, the study took into account trends in England & Wales, as well as other factors that might have affected changes in consumption. It was therefore concluded that the introduction of the Alcohol Act was associated with a decrease in total off-trade alcohol sales in Scotland.

Reductions in population alcohol consumption levels have been shown to translate into effects on alcohol-related harms, with some effects happening immediately.[4] The aim of this study was therefore to investigate whether the Alcohol Act had any short-term impact on rates of alcohol-related deaths and hospital admissions in Scotland.

2. Methods

2.1. General approach

Descriptive analysis was carried out to describe trends and patterns in rates of alcohol-related deaths and hospital admissions in Scotland. Time series analysis using regression models was then performed to assess the impact of the Alcohol Act on these outcomes. Data for England & Wales and England were used as the main comparator areas for the deaths and admission analysis, respectively.

2.2 Data

Alcohol-related deaths

The number of alcohol-related deaths occurring in 4-weekly periods in Scotland between January 2001 and December 2013 were calculated by sex, age group and Carstairs deprivation decile (an area-based measure of socio-economic deprivation). This was done using a dataset provided by National Records for Scotland (NRS). Alcohol-related deaths were defined as those coded with a condition that is wholly attributable to alcohol as the underlying cause (Appendix Table S1). The 4-weekly periods were defined to coincide with the introduction of the Alcohol Act on 1st October 2011. Equivalent data for England & Wales (combined) were obtained by submitting a data request to the Office for National Statistics.

Alcohol-related hospital admissions

Data on the number of patients admitted to acute National Health Service (NHS) hospitals in Scotland (excluding psychiatric hospitals) with an alcohol-related condition in 4-weekly periods between January 2001 and December 2014 were obtained from NHS National Services Scotland (NSS). Attendances at Accident and Emergency that did not result in an admission are not included. As with the data on deaths, hospital admission data were obtained by sex, age group and Carstairs deprivation decile. Alcohol-related hospital admissions were defined using the same International Classification of Diseases (ICD-10) code set used by NSS who are responsible for publishing national statistics on alcohol-related hospital admissions in Scotland (Appendix Table S2). This includes only those conditions wholly attributable to alcohol. Data on patients with an alcohol-related condition coded in the primary diagnostic position only were included. Patients were counted only once in each 4-weekly period, even if they had multiple admissions. Equivalent data for England were obtained by submitting a request to the NHS Health and Social Care Information Centre.

The use of hospital admission data at the patient level and the inclusion of admissions with an alcohol-related condition coded as the primary diagnosis only ensured data for Scotland and England were as comparable as possible. However, it is important to note that the method used to define alcohol-related hospital

admissions in this report is different to the method used routinely for reporting alcohol-related hospital statistics in Scotland[5] and England[6]; the alcohol-related hospital admission rates in this report are lower.

Box B: 'Alcohol-related' health harms

The use of the term 'alcohol-related' in this report refers to those conditions that are **wholly attributable** to alcohol. This is consistent with the terminology used by NHS National Services Scotland and the Office for National Statistics.

2.3 Descriptive analysis

The rate of alcohol-related deaths and hospital admissions during each 4-weekly period in each population subgroup was calculated using population data derived from the 2001 and 2011 censuses. The crude rate in both of these outcomes over the study time period was plotted in charts. In addition, the overall trend in the crude rate of outcomes was further broken down to enable the underlying trend and seasonality to be shown more clearly. To show the pattern of alcohol-related deaths and hospital admissions across the different population subgroups, the average 4-weekly rate in the study time period before and after the Alcohol Act was introduced was calculated for presentation in tables.

2.4 Statistical analysis

Main analysis

A multivariable regression framework was used to analyse data in this study. To assess whether or not the introduction of the Alcohol Act was associated with a change in alcohol-related deaths or hospital admissions a binary intervention variable was included in the regression models, with the value of one assigned to deaths or hospital admissions occurring after the ban was introduced (1st October 2011 onwards) and the value of zero before. In order to isolate the effect of the Alcohol Act, the models took into account the existing underlying trend, seasonality and were also adjusted for sex, age group and area deprivation.

It was originally planned to combine data for Scotland and data for comparator areas in the same regression models. This would have enabled the 'net effect' of the legislation to be established. However, this was not possible because the pre-

intervention trends in Scotland and control groups were so different. Instead, separate models were applied to the deaths and hospital admissions data for comparator areas. In these models, the 'Alcohol Act' variable was included as a pseudo-intervention variable.

The extent to which the final regression models fitted the original data was assessed by plotting predicted versus measured values and by calculating other goodness of fit statistics. These are provided in the Appendix (Figures S1-S4).

Additional analyses

Fitting an appropriate model to the hospital admissions data in Scotland was difficult due to numerous inflection points (i.e. changes in the direction of the trend) in the pre-intervention period. The regression models applied to hospital admission data in Scotland and comparator areas were therefore rerun with a shorter pre-intervention time period starting in November 2008, which marked the beginning of a downward trend.

In another sensitivity check of the main results, the final, best-fitting regression models were also refitted using false legislation dates.[7] In these analyses, the Alcohol Act variable was moved to coincide with the date 6 and 12 months before and after the actual implementation date.

It has been suggested that Northern England is a more appropriate control group for Scotland than England or England & Wales.[8] As such, the main analyses were replicated using data on alcohol-related deaths and hospital admissions occurring in North East and North West England combined (NE/NW England).[9] These data were a subset of the main comparator data.

The differential impact of the Alcohol Act on deaths and admissions among population subgroups was explored by replicating the main analysis after data had been stratified by sex, age group and Carstairs deprivation. In other words, separate regression models were fitted for males, females, each age group and each Carstairs deprivation quintiles within each dataset (i.e. deaths and admissions data in Scotland, England & Wales and NE/NW England). Subgroup analyses should

generally be treated with caution, particularly when hypotheses are not explicitly specified at the start of the study.[10-13] This was the case in this study so results from these models are presented in the Appendix (Tables S3-S5) with limited description here.

A more detailed description of the methods used in this study is provided in the Appendix.

3. Results

3.1. Descriptive analysis of alcohol-related deaths

The crude rate of 4-weekly alcohol-related deaths in Scotland increased from January 2001 to a peak in January 2005 (Figure 1). This was followed by a fluctuating downward trend to the end of the study time period in December 2013. Visual inspection of the trend component of alcohol-related deaths in Scotland does not indicate a clear change in the level or trend after implementation of the Alcohol Act.

Alcohol-related death rates in England & Wales were approximately 61% lower than in Scotland at the start of the study time period. Rates increased to a peak in October 2006, stabilised to December 2010 and then declined slightly to December 2013 when rates were approximately 42% lower than in Scotland. The downward trend in alcohol-related death rates in England & Wales in the 12-month period before the ban was introduced in Scotland continued in the post-implementation period.

In both Scotland and England & Wales, there was clear seasonality in alcohol-related deaths with sharp peaks over the Christmas and New Year period (which was particularly marked in Scotland) with lower rates over summer months. Most deaths across the entire period of analysis occurred among men, adults aged 55-64 years and those living in the most deprived areas (Table 1).

3.2 Descriptive analysis of alcohol-related hospital admissions

Rates of alcohol-related hospital admissions in Scotland were broadly stable between January 2001 and December 2004 (Figure 2). This was followed by a sharp increase to a peak in January 2008. Rates then declined gradually to January 2010 and stabilised to October 2011. After the legislation was implemented there was an apparent decline in the rate of alcohol-related admissions in Scotland followed by a fluctuating trend that initially increased but began to fall most recently.

In England, rates of alcohol-related hospital admissions increased from June 2002 to November 2009 and remained stable thereafter. Although there have been consistently higher alcohol-related hospital admission rates in Scotland, the difference between countries has decreased over time.

Seasonal patterns are different to those for deaths with the peak rate of admissions occurring over the summer months (Figure 2). In both countries, alcohol-related hospital admission rates were highest throughout the period of analysis among men, adults aged 45-54 years and those living in the most deprived areas (Table 2).

Figure 1 Trends in crude alcohol-related death rates in Scotland and England & Wales (a) and the decomposed seasonal (b) and trend (c) components, January 2001 and December 2013

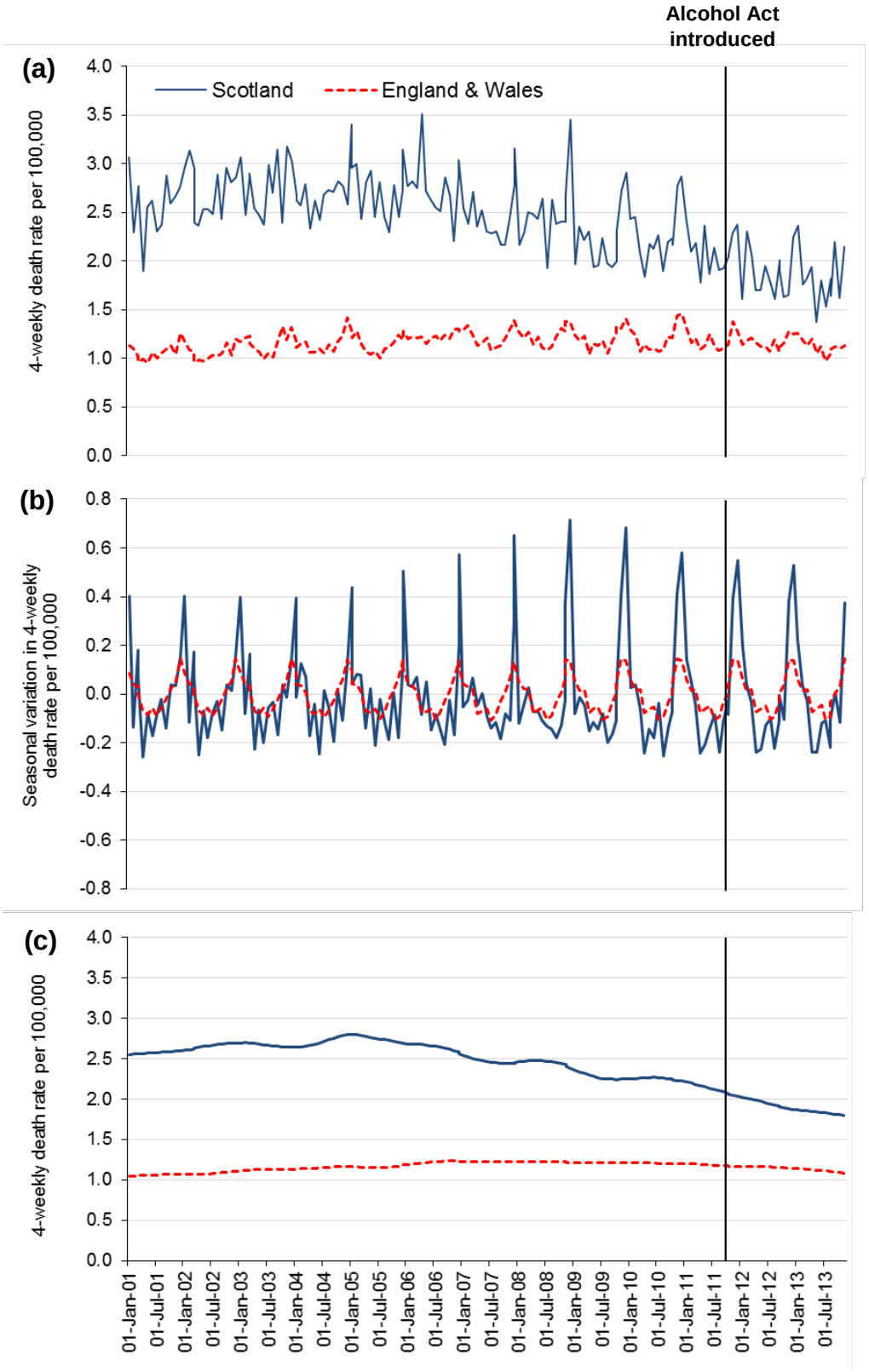

Table 1 Sociodemographic patterning of alcohol-related death rates in Scotland and England & Wales in the study time periods before and after the Alcohol Act was introduced in Scotland

Rate per 100,000 population (4-weekly)	Scotland		England & Wales	
	Jan 2001 - Sep 2011	Oct 2011 - Dec 2013	Jan 2001 - Sep 2011	Oct 2011 - Dec 2013
Overall	2.5	1.9	1.2	1.2
Sex				
Men	3.6	2.7	1.6	1.6
Women	1.5	1.2	0.8	0.8
Age group (years)				
15-24	0.04	0.03	0.02	0.01
25-34	0.5	0.4	0.2	0.2
35-44	2.0	1.3	1.0	0.9
45-54	4.1	2.7	1.9	1.8
55-64	5.5	3.8	2.3	2.2
65-74	4.2	3.4	1.8	2.0
75+	1.8	1.9	1.3	1.4
Area deprivation decile				
1 (most deprived)	5.9	4.0	2.1	1.9
2	3.9	3.0	1.8	1.7
3	2.8	2.2	1.6	1.5
4	2.2	2.0	1.3	1.3
5	1.9	1.8	1.2	1.2
6	1.6	1.4	1.0	1.0
7	1.3	1.1	0.9	1.0
8	1.0	0.8	0.8	0.8
9	0.9	1.0	0.7	0.7
10 (least deprived)	0.8	0.6	0.6	0.6

Figure 2 Trends in crude alcohol-related hospital admission rates in Scotland and England (a) and the decomposed seasonal (b) and trend (c) components, January 2001 and December 2014

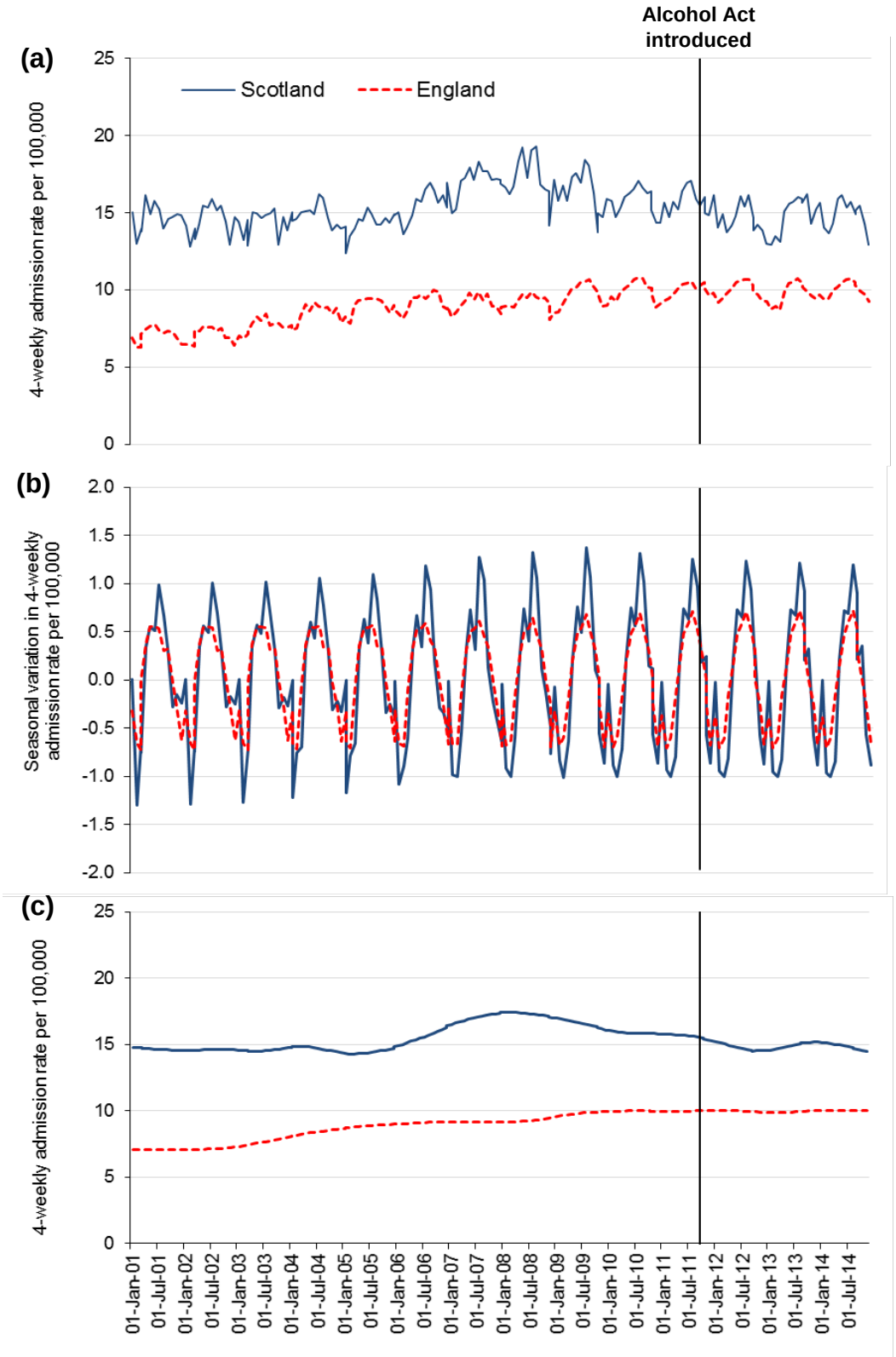

Table 2 Sociodemographic patterning of alcohol-related hospital admission rates in Scotland and England in the study time periods before and after the Alcohol Act was introduced in Scotland

Rate per 100,000 population (4-weekly)	Scotland		England	
	Jan 2001 - Sep 2011	Oct 2011 - Dec 2014	Jan 2001 - Sep 2011	Oct 2011 - Dec 2014
Overall	15.5	15.4	8.8	9.9
Sex				
Men	23.6	22.4	12.5	14.0
Women	8.1	8.4	5.2	6.0
Age group (years)				
15-24	6.8	5.1	5.0	4.0
25-34	9.6	11.2	6.7	7.9
35-44	19.1	19.3	13.6	14.0
45-54	25.3	23.5	14.1	17.2
55-64	23.0	19.8	10.6	12.3
65-74	14.5	14.5	5.6	7.8
75+	4.8	4.8	2.1	2.6
Area deprivation decile				
1 (most deprived)	24.4	30.7	18.6	18.8
2	16.8	17.3	15.5	17.6
3	15.2	16.2	12.5	14.6
4	14.8	13.6	10.2	11.5
5	16.1	14.2	8.3	9.9
6	16.1	14.6	6.7	8.1
7	13.9	11.3	5.6	6.7
8	12.2	9.4	4.8	5.5
9	10.7	10.1	4.3	4.8
10 (least deprived)	7.4	7.2	3.5	3.8

3.3 Estimated effect of the Alcohol Act

Box C: Interpreting the incidence rate ratio (IRR)

The estimated effect of the Alcohol Act on alcohol-related deaths and hospital admissions is expressed as an incidence rate ratio (IRR). The IRR provides a relative measure of the difference between two rates, in this case the rate in alcohol-related deaths or hospital admissions before and after the Alcohol Act legislation being implemented. To illustrate, an IRR of 0.99 (95% CI 0.91 to 1.07) can be interpreted as a best estimate of a 1% decline in rates associated with the legislation, but with the uncertainty around this best estimate ranging from a 9% decline to a 7% increase (95 times out of 100 it would be expected to be within this range).

Table 3 shows the estimated effect of the Alcohol Act on alcohol-related deaths and hospital admissions in Scotland and England & Wales based on the regression analysis. There was no evidence to suggest that the Alcohol Act was associated with changes in the overall rate of alcohol-related deaths in Scotland (IRR 0.99, 95% confidence interval (CI) 0.91 to 1.07). In England & Wales, there was no overall change in alcohol-related death rates after the implementation of the legislation in Scotland (IRR 0.99, 95% CI 0.95 to 1.02)).

For alcohol-related hospital admissions, the implementation of the Alcohol Act was not associated with a change in the overall rate in Scotland (IRR 0.98, 95% CI 0.95 to 1.02). In England, the dummy Act variable was associated with an increase in alcohol-related hospital admission rates (IRR 1.05, 95% CI 1.03 to 1.07). This increase in admissions in England in the period after the Alcohol Act was introduced in Scotland was observed across most population subgroups (Appendix, Table S4).

Additional analysis

Restricting the time period analysed for the hospital admissions data to November 2008 onwards did not have a notable impact on the estimated effect of the Alcohol Act on the overall rate of admissions in Scotland or England (Table 3). However, the estimated impact of the Alcohol Act variable on alcohol-related outcomes was sensitive to the use of false legislation dates, with both magnitude and direction of the best estimate changing depending on the date used (Table 3). This was particularly the case for the estimated effect of the dummy Alcohol Act variable on hospital admissions in England; the IRR of 1.05 in the main analysis generally reduced in magnitude and moved closer to or below the null value of 1 as the legislation date was moved forwards or backwards in time. When analyses were repeated using data for NE/NW England, similar results were produced for alcohol-related deaths and hospital admissions as seen for England & Wales and England, respectively (Table 3).

Table 3 **Incidence rate ratios (IRRs) for the association between alcohol-related death and hospital admission rates and the implementation of the Alcohol Act legislation in Scotland and comparator areas. An IRR below 1 indicates a reduction in rates associated with the Alcohol Act (see Box C)).**

	Scotland		England & Wales / England[a]		NE/NW England[b]	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Main analysis						
Deaths	0.99	0.91 to 1.07	0.99	0.95 to 1.02	1.00	0.92 to 1.10
Admissions	0.98	0.95 to 1.02	1.05	1.03 to 1.07	1.03	0.99 to 1.07
Sensitivity analysis: shorter pre-intervention trend						
Admissions	0.99	0.94 to 1.04	1.08	1.05 to 1.11	1.07	1.03 to 1.11
Sensitivity analysis: false legislation dates						
Deaths						
12m pre	1.08	1.00 to 1.18	1.03	1.00 to 1.07	1.07	0.99 to 1.15
6m pre	1.00	0.92 to 1.08	1.00	0.97 to 1.04	1.06	0.98 to 1.15
6m post	0.99	0.92 to 1.07	0.99	0.96 to 1.02	1.07	0.97 to 1.18
12m post	1.00	0.93 to 1.08	0.98	0.95 to 1.01	0.96	0.87 to 1.05
Admissions						
12m pre	1.02	0.99 to 1.06	0.98	0.96 to 1.00	0.97	0.94 to 1.01
6m pre	1.01	0.98 to 1.05	1.03	1.00 to 1.05	1.03	0.99 to 1.07
6m post	0.95	0.92 to 0.99	0.99	0.97 to 1.00	0.99	0.96 to 1.02
12m post	0.97	0.93 to 1.01	0.97	0.95 to 0.99	0.96	0.93 to 0.99

Notes: [a] Models with hospital admissions as the outcome included data for England only. [b] Supplementary analysis. All models were adjusted for seasonality, underlying trends, sex, age group and area deprivation quintile.

4. Discussion

This study investigated the impact of a ban on multi-buy promotions on alcohol-related health harms. The main finding from the study is that the Alcohol Act was not associated with any measurable changes in overall rates of alcohol-related deaths or hospital admissions in Scotland within the first 2-3 years of its implementation.

4.1 Strengths and limitations

The data used in this study have complete national coverage and are likely to estimate accurately the true number of alcohol-related deaths and hospital admissions in Scotland and comparator areas. The use of data at patient level and the inclusion of alcohol-related ICD-10 codes that were wholly attributable to alcohol in the primary diagnostic position only ensured data were as comparable as possible and less likely to be affected by differences and/or changes in coding practices, a particular issue in terms of partially attributable conditions.[14] As data were broken down by age group, sex and area-based deprivation, statistical models could be adjusted for these sociodemographic characteristics. In addition, seasonality and temporal trends were also adjusted for, which is important when analysing time-series data. Reassuringly, most models, particularly for the population level analyses, had a good model fit.

In principle, other key strengths of this study were the long pre-intervention time period and the inclusion of concurrent geographic control groups, both of which typically strengthen the evaluation of natural experiments.[10,15,16] However, in practice, these features of the study design presented challenges to both the analytical methods and the interpretation of results. This was particularly the case for statistical models with alcohol-related hospital admissions as the outcome variable. For example, over the 10 year pre-intervention time period there were multiple changes in the direction of the trend. Although models with acceptable fit were obtained for overall admission rates, models for other subgroups were less robust. This was apparent when additional analyses were performed with a shorter pre-intervention time period that began at the start of the downward trend in admission

rates in Scotland; estimates of the intervention effect were similar overall, but results in some subgroups were sensitive to the change in period length.

It is recommended in quasi-experimental designs that intervention and control groups have similar pre-intervention trends and that the outcomes would be expected to respond in a similar way in the absence of the intervention.[15] For both outcomes in this study – alcohol-related deaths and hospital admissions – pre-intervention trends in Scotland and comparator populations were distinctly different. Multiple approaches were explored to combine data for the intervention and control groups into a single regression model but it was not possible to fit a model that was suitably robust. Furthermore, results from both the main and additional analyses support the finding that the dummy Alcohol Act variable entered into models for our control groups was associated with increased rates of alcohol-related hospital admissions. As the control groups were not affected by the legislation, unmeasured factors offer the best explanation for this seemingly spurious effect. The validity of results from the evaluation of non-randomised interventions are particularly vulnerable to the presence of residual confounding.[15] Other factors, such as changes in alcohol policies and the wider socioeconomic context, can influence alcohol-related harms. However, such confounding would only be likely if the factor had a different effect over time in the intervention and control groups.

Other limitations to this study include the relatively short post-intervention time period for both health outcomes enabling only the short-term impact of the legislation could be assessed. Nonetheless, assessing longer-term impacts is also challenging because of the increased likelihood of confounding. The use of wholly attributable alcohol conditions meant that it was not possible to assess the impact of the Alcohol Act on the wider range of deaths and hospital admissions that are partially attributable to alcohol. In addition, including only those admissions with an alcohol-related condition coded as the primary diagnosis, while enhancing comparability between intervention and control groups (which was priority at the outset of the study), meant that admissions where an alcohol-related condition was coded as a secondary diagnoses in a patient's admission were excluded. Finally, the small number of deaths and, to a lesser extent, hospital admissions in Scotland in each 4-

week period meant that there was large uncertainty around the best estimates of the intervention effect, particularly in sub-group analyses.

4.2 Interpretation

In light of the above limitations, the following interpretation is focused on the results observed in Scotland for overall rates of alcohol-related deaths and hospital admissions.

There is good evidence to show that changes in population consumption levels are associated with changes in alcohol-related harms.[4] It was therefore hypothesised that overall rates of alcohol-related health harms in Scotland would decline. However, the results suggested that it was unlikely that the Alcohol Act was associated with any substantial reduction in overall rates of alcohol-related deaths or hospital admissions. There are a number of potential reasons for this:

- **The study was not able to detect the intervention effect.** Only small reductions in alcohol-related health harms would be expected, particularly in the short term, from a 2.6% reduction in off-trade consumption levels.[17] The study found a best estimate of the effect of the Alcohol Act was for a 1-2% reduction in alcohol-related deaths and hospital admissions. However, the uncertainty around this estimate was too wide to enable definitive conclusions to be drawn.

- **The study was concerned with a short-term effect on harms**. Although immediate effects are expected for a number of alcohol-related conditions, the full effect of changes in population consumption on changes in alcohol-related harms (both wholly and partially alcohol-attributable) would not be expected within the study time-period.[4] It remains plausible that the reduced population consumption associated with the Alcohol Act in Scotland, if sustained, will translate into reduced levels of alcohol-related harm in Scotland over a longer time period.

- **Wine was the drink type most affected by the Alcohol Act.** Those at highest risk of an alcohol-related hospital admission or death – men, those living in more deprived areas and very heavy drinkers – are least likely to consume wine.[18-20] Wine is most likely to be consumed by population subgroups that have a relatively low incidence of alcohol-related harms: women and those living in less deprived areas.[18,19] Thus, reduced consumption among these subgroups is unlikely to have had a measurable impact on alcohol-related harms.

- **The study focused only on 'alcohol-related' deaths and hospitalisations.** Alcohol-related deaths and hospital admissions refer to those conditions wholly attributable to alcohol. It is possible that the reduced population consumption levels translated into reductions in the wider range of alcohol-attributable causes (i.e. including those for which alcohol is only a partially attributable cause, such as ischaemic heart disease). However, this was not examined in the study. In addition, as only those admissions with an alcohol-related condition coded as a primary diagnosis were included in the study, it is possible that the impact of the Alcohol Act using a broader definition of alcohol-related hospital admissions could differ from that estimated in this study.

4.3 Implications

The results of this study do not suggest that implementation of the Alcohol Act has had a substantial impact on short-term alcohol-related deaths or hospital admissions in Scotland (i.e. those wholly attributable to alcohol). Nonetheless, a restriction on promotions is an important aspect of creating an environment in which alcohol is sold responsibly.[21] Furthermore, the Alcohol Act was associated with reduced off-trade alcohol sales in Scotland.[3] Indeed, in combination with policies that raise the price of alcohol (thereby reducing its affordability), particularly the types of alcohol consumed by the heaviest drinkers, a more substantive immediate impact on alcohol-related harms may have been observed.[17]

The analytical challenges that emerged during the course of this study have implications for future evaluations of Scottish alcohol policy (and beyond). Fluctuating pre-intervention trends are problematic if attempting to maximise the use of time-series data by accounting for underlying secular and seasonal trends. However, such approaches are more powerful than simple pre- post study designs.[10] Inadequate control groups may serve to hinder rather than help interpretation and preliminary analysis should be set out before the start of the study with criteria for deciding whether a control group is appropriate or not. Future evaluation studies should explore methods such as synthetic control and propensity score-based weighting, which may offer the potential to strengthen causal inference by enabling better control for unexposed geographical comparators.[22,23]

4.4 Conclusion

In conclusion, this study suggests that the introduction of the Alcohol Act legislation in Scotland in October 2011, which was associated with reduced population consumption levels in the year after its implementation, has not had a measurable short-term effect on alcohol-related deaths or hospital admissions (those wholly attributable to alcohol). The longer term impact of the Alcohol Act, and its impact on deaths and hospital admissions partially attributable to alcohol, remains unknown.

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Appendix

Further information on the methods

Table S1 ICD-10 codes included in the definition of alcohol-related deaths.

ICD-10 code	Description
F10	Mental and behavioural disorders due to use of alcohol
G31.2	Degeneration of nervous system due to alcohol
G62.1	Alcoholic polyneuropathy
I42.6	Alcoholic cardiomyopathy
K29.2	Alcoholic gastritis
K70	Alcoholic liver disease
K73	Chronic hepatitis, not elsewhere classified
K74	Hepatic fibrosis
K74.1	Hepatic sclerosis
K74.2	Hepatic fibrosis with hepatitic sclerosis
K74.6	Other and unspecified cirrhosis of liver
K86.0	Alcohol induced chronic pancreatitis
X45	Accidental poisoning by and exposure to alcohol
X65	Intentional self-poisoning by and exposure to alcohol
Y15	Poisoning by and exposure to alcohol, undetermined intent

Table S2 ICD-10 codes included in the definition of alcohol-related hospital admissions.

ICD-10 code	Description
F10	Mental and behavioural disorders due to use of alcohol
K70	Alcoholic liver disease
X45	Accidental poisoning by and exposure to alcohol
X65	Intentional self-poisoning by and exposure to alcohol
Y15	Poisoning by and exposure to alcohol, undetermined intent
Y90	Evidence of alcohol involvement determined by blood alcohol level
Y91	Evidence of alcohol involvement determined by level of intoxication
E24.4	Alcohol-induced pseudo-Cushing's syndrome
E51.2	Wernicke's encephalopathy
G31.2	Degeneration of nervous system due to alcohol
G62.1	Alcoholic polyneuropathy
G72.1	Alcoholic myopathy
I42.6	Alcoholic cardiomyopathy
K29.2	Alcoholic gastritis
K86.0	Alcohol-induced chronic pancreatitis
O35.4	Maternal care for (suspected) damage to fetus from alcohol
P0.43	Fetus and newborn affected by maternal use of alcohol
Q86.0	Fetal alcohol syndrome (dysmorphic)
T51.0	Ethanol
T51.1	Methanol
T51.9	Alcohol, unspecified
Y57.3	Alcohol deterrents
R78.0	Finding of alcohol in blood
Z50.2	Alcohol rehabilitation
Z71.4	Alcohol abuse counselling and surveillance
Z72.1	Alcohol use
K85.2	Alcohol induced acute pancreatitis

Note: K852 was added in 2014 - this code was introduced in Scotland from 1 April 2013.

Carstairs measure of area deprivation

Carstairs scores were originally developed in the 1980s using 1981 census data at postcode sector level. The scores were created from four census variables: car ownership, male unemployment, overcrowding and low social class. For the purposes of this study, Carstairs scores were created for merged 'datazones' in Scotland and Lower Super Output Areas in England and Wales. This enhanced comparability in the size of geographical units across Great Britain (GB). This was important because population-weighted deciles were calculated across the whole of Great Britain. In other words, the 10% of the Scottish population living in the most deprived decile in Scotland did not necessarily all live within the most deprived GB decile.

Decomposition of trends

To ease visual interpretation of trends, the time series for each outcome was decomposed into trend and seasonal components using the command *stl* (seasonal decomposition by loess) in R Studio 3.0.2 software (R Studio, Boston, USA).[24] This decomposition is not adjusted for sex, age or socio-demographic factors and uses a different approach to trends and seasonality than the regression analysis (described below) and is included for descriptive purposes only.

Regression approach

Separate models were fitted for deaths and admissions for each of the geographical areas under consideration (Scotland, England & Wales and NE/NW England for deaths; Scotland, England and NE/NW England for admissions). As data were count data (ie a number of deaths or admissions) and its variance greater than its mean (over-dispersion), negative binomial regression methods were used. A multivariable regression framework was applied and models were adjusted for sex, age group (15-34; 35-44; 45-54; 55-64; 65+ years) and Carstairs deprivation quintile ('1 most deprived' to '5 least deprived'), which were collapsed from deciles to avoid problems caused by very small counts. Population was accounted for as an offset variable. A random effects regression model was selected as this allowed the over-dispersion to vary by sex, age-group and deprivation sub-categories within each regression.

To analyse whether or not the introduction of the Alcohol Act was associated with a change in alcohol-related deaths or hospital admissions, a binary intervention variable was included in all models, with the value of one assigned to deaths or hospital admissions occurring after the ban was introduced (1st October 2011 onwards) and the value of zero before. This variable was included as a pseudo intervention variable in the comparator areas.

In order to isolate the effect of the Alcohol Act, seasonality and the underlying trend in deaths and admissions had to be accounted for. Seasonality was accounted for by including 13 pseudo month variables to represent 13 four week periods per annum. As the underlying trend in some of the datasets fluctuated, the approach adopted allowed the study period to be split into a number of distinct sections with the trend modelled differently in each section. This approach uses the *mkspline* command in Stata/SE 14 to create multiple cubic splines (where a spline is a curve joining two points).[25] The study period was split into three evenly sized sections, then in turn four to seven sections, and the regression analysis run. Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) statistics were recorded. These statistics measure how well the model fits the data but penalise a model which includes too many variables (overfits the data). The model with the lowest statistics was chosen. This exercise was undertaken separately for each dataset. The decision to test between 3 and 7 sections was based on the judgement that given a study period length of 172/180 periods to split the data into more than 7 sections would have been over-fitting.

Once the model had been selected, goodness of fit was assessed by comparing predicted values with observed values using the R^2 and root mean square error (RMSE) statistics. R^2 is a statistical measure of how close the data are to the fitted model (it is the amount of variance in the outcome variable that is explained by the model) which takes values between zero and one with one being a perfect fit. RMSE gives the mean of the squares of the differences between predicted and observed values and has the same units as the response variable; a low value is indicative of a good model fit. Plots of predicted versus observed values and the goodness of fit statistics for the main models are provided in Figures S1-S4.

The differential impact of the Alcohol Act on deaths and admissions among population subgroups was explored by stratifying the data by sex, age group and Carstairs deprivation quintile. Separate models for males, females, single age groups and Carstairs deprivation quintiles were fitted within each dataset (Scotland, England/Wales and North East/North West England, Deaths and Admissions). For consistency, when possible, the time period was split into the same number of sections in this analysis of subgroups as for the larger dataset. For some subsets of data due to low counts the model was unable to converge (to find a solution to the regression equation). In these cases, the next best number of sections was used (again as suggested by the AIC and BIC statistics). In some cases the model was not able to converge at all and this is noted in the appropriate table (see Tables S3-S5).

Regression analysis was undertaken using STATA/SE 14 software (STATA Corp, Texas, USA).

Table S3 Adjusted incidence rate ratios (IRRs) for the association between alcohol-related death rates and the implementation of the Alcohol Act legislation in Scotland and comparator areas for different population subgroups. An IRR below 1 indicates a reduction in rates associated with the Alcohol Act.

	Scotland		England & Wales		NE/NW England	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Sex						
Men	0.99	0.90 to 1.09	0.97	0.93 to 1.01	0.96	0.88 to 1.04
Women	0.98	0.85 to 1.13	1.02	0.97 to 1.08	1.07	0.96 to 1.20
Age group (years)						
<35	1.09	0.61 to 1.97	0.77*	0.64 to 0.91	0.78*	0.56 to 1.08
35-44	0.71	0.52 to 0.97	0.90	0.83 to 0.99	0.94*	0.80 to 1.12
45-54	0.86	0.69 to 1.07	0.99	0.93 to 1.06	1.08	0.95 to 1.22
55-64	0.97	0.80 to 1.19	0.96*	0.91 to 1.03	0.96*	0.85 to 1.10
65+	1.06	0.86 to 1.30	1.08*	1.01 to 1.15	1.01	0.88 to 1.20
Area deprivation quintile						
1 (most deprived)	1.06	0.94 to 1.20	0.97	0.91 to 1.04	1.02*	0.92 to 1.14
2	0.89	0.76 to 1.04	0.97*	0.90 to 1.03	0.93*	0.81 to 1.01
3	1.06	0.86 to 1.30	1.00*	0.93 to 1.08	0.98	0.82 to 1.20
4	0.82*	0.64 to 1.06	1.02*	0.94 to 1.12	0.98*	0.80 to 1.20
5 (least deprived)	0.88	0.64 to 1.23	0.98*	0.89 to 1.08	1.07*	0.85 to 1.35

Notes: *Convergence was not achieved in these models. Stratified models were adjusted for seasonality, underlying trends and all other sociodemographic characteristics (e.g. when modelling within age groups the models are adjusted for sex and deprivation, etc).

Table S4 **Adjusted incidence rate ratios (IRRs) for the association between alcohol-related hospital admission rates and the implementation of the Alcohol Act legislation in Scotland and comparator areas for different population subgroups. An IRR below 1 indicates a reduction in rates associated with the Alcohol Act.**

	Scotland		England		NE/NW England	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Sex						
Men	0.98	0.94 to 1.02	1.06	1.03 to 1.09	1.05	1.01 to 1.10
Women	0.99	0.93 to 1.06	1.03	0.99 to 1.07	0.99	0.93 to 1.06
Age group (years)						
<35	1.05	0.96 to 1.14	1.02	0.98 to 1.07	0.94	0.87 to 1.02
35-44	0.89	0.83 to 0.96	1.06	1.03 to 1.11	1.07	1.01 to 1.15
45-54	1.02	0.96 to 1.08	1.06	1.02 to 1.10	1.09	1.02 to 1.16
55-64	0.98	0.91 to 1.06	1.02	0.98 to 1.07	1.00	0.92 to 1.09
65+	0.99	0.91 to 1.08	1.09	1.02 to 1.15	0.99	0.88 to 1.12
Area deprivation quintile						
1 (most deprived)	0.94	0.89 to 0.99	1.06	1.03 to 1.11	1.06	1.01 to 1.13
2	1.04	0.97 to 1.11	1.06	1.01 to 1.10	1.00	0.93 to 1.07
3	0.98	0.91 to 1.06	1.02	0.97 to 1.07	0.99	0.90 to 1.09
4	1.07*	0.98 to 1.16	1.08	1.02 to 1.14	1.05	0.94 to 1.17
5 (least deprived)	0.91	0.81 to 1.02	0.99	0.93 to 1.06	1.02	0.89 to 1.16

Notes: *Convergence was not achieved in these models. Stratified models were adjusted for seasonality, underlying trends and all other sociodemographic characteristics (e.g. when modelling within age groups the models are adjusted for sex and deprivation, etc).

Table S5 Adjusted incidence rate ratios (IRRs) for the association between alcohol-related hospital admission rates and the implementation of the Alcohol Act legislation in Scotland and comparator areas for different population subgroups (sensitivity analysis with shorter pre-intervention trend beginning November 2008). An IRR below 1 indicates a reduction in rates associated with the Alcohol Act.

	Scotland		England		NE/NW England	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Sex						
Men	0.97	0.92 to 1.03	1.07	1.04 to 1.11	1.08	1.03 to 1.14
Women	1.04	0.94 to 1.14	1.08	1.03 to 1.34	1.04	0.98 to 1.11
Age group (years)						
<35	1.03	0.92 to 1.17	1.07	1.01 to 1.13	1.01*	0.93 to 1.09
35-44	0.83	0.74 to 0.92	1.09	1.04 to 1.15	1.12	1.04 to 1.20
45-54	1.02	0.93 to 1.12	1.07	1.02 to 1.12	1.11*	1.04 to 1.19
55-64	1.02*	0.91 to 1.14	1.07	1.01 to 1.13	1.02	0.93 to 1.12
65+	1.13	0.99 to 1.29	1.1	1.01 to 1.19	1.02	0.90 to 1.16
Area deprivation quintile						
1 (most deprived)	0.96	0.88 to 1.04	1.08	1.03 to 1.14	1.11	1.04 to 1.17
2	0.98	0.89 to 1.09	1.09	1.04 to 1.16	1.04	0.96 to 1.12
3	1.04	0.93 to 1.17	1.04	0.98 to 1.11	1.04	0.94 to 1.15
4	1.05	0.92 to 1.20	1.09	1.02 to 1.18	1.06	0.94 to 1.20
5 (least deprived)	0.95	0.80 to 1.12	1.05	0.97 to 1.14	1.03	0.90 to 1.19

Notes: *Convergence was not achieved in these models. Stratified models were adjusted for seasonality, underlying trends and all other sociodemographic characteristics (e.g. when modelling within age groups the models are adjusted for sex and deprivation, etc).

Figure S1 Plot of observed versus predicted rates of alcohol-related deaths in Scotland

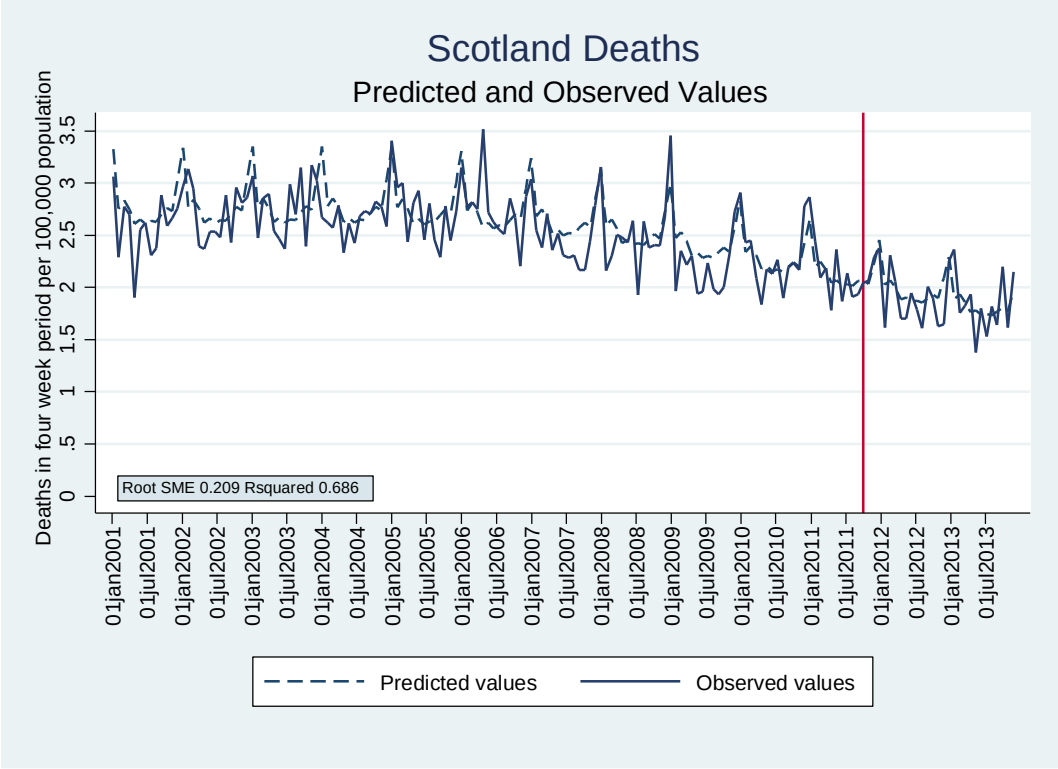

Figure S2 Plot of observed versus predicted rates of alcohol-related deaths in England & Wales

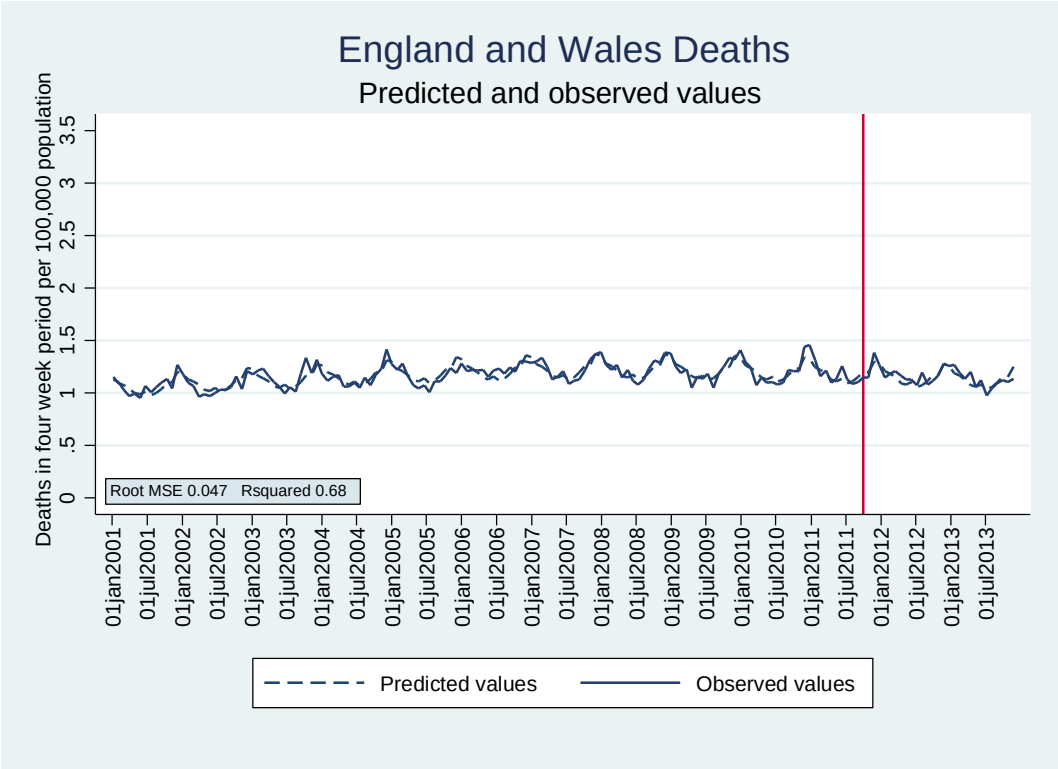

Figure S3 Plot of observed versus predicted rates of alcohol-related hospital admissions in Scotland

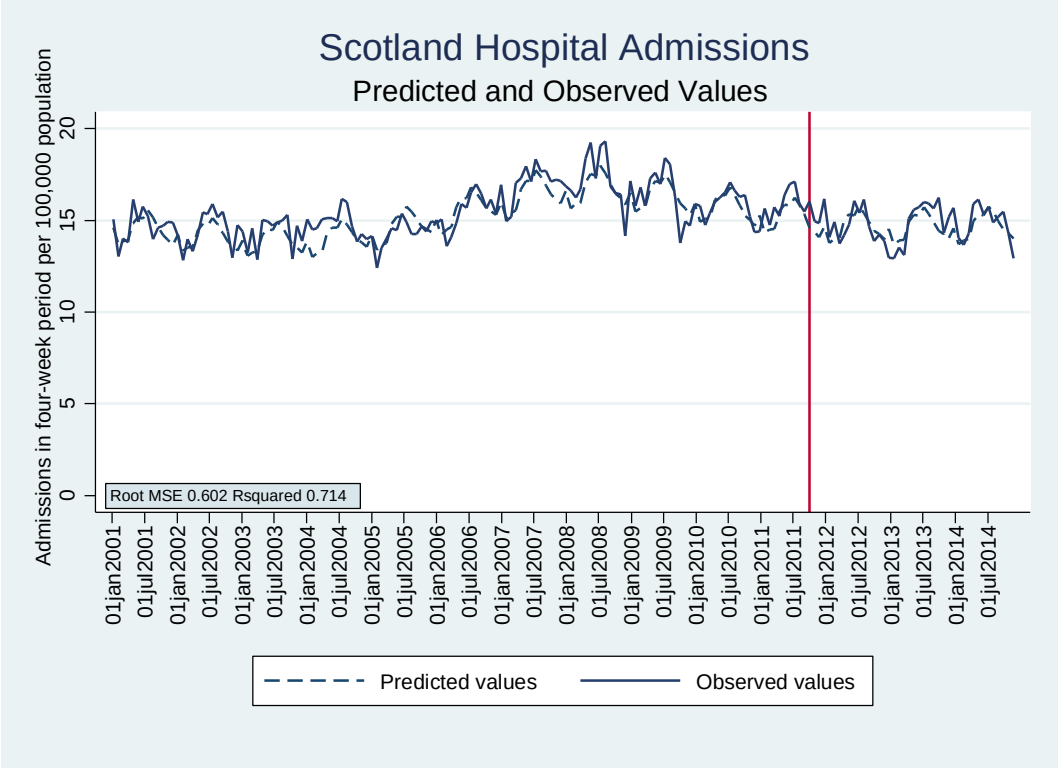

Figure S4 Plot of observed versus predicted rates of alcohol-related hospital admissions in England