Lockdown drinking: The sobering effect of price controls in a pandemic

Farasat A.S. Bokhari [a], Ratula Chakraborty [b],
Paul W. Dobson [b] and Marcello Morciano [c]

[a] *School of Economics, Centre for Competition Policy, University of East Anglia*

[b] *Norwich Business School, Centre for Competition Policy, University of East Anglia*

[c] *Health Organisation, Policy and Economics Group, University of Manchester*

February 14, 2022

Abstract

Lockdown restrictions reduce the spread of COVID-19 but disrupt livelihoods and lifestyles that can induce harmful behavior changes, including problematic lockdown drinking fueled by cheap alcohol. Exploiting differences amongst the four constituent countries of the United Kingdom, we use triple difference analysis on alcohol retail sales to examine the efficacy of minimum unit pricing as a price control device to help curb excessive consumption in a pandemic setting. We find the policy is remarkably effective and well-targeted in reducing demand for cheap alcohol, with minimal spillover effects, and consumers overall buying and spending less.

Key words: pandemic, lockdown, price control, minimum unit pricing, alcohol, excessive consumption

JEL Classification: C54, D04, H23, I12, I18, L81

Lockdown drinking: The sobering effect of price controls in a pandemic

Abstract

Lockdown restrictions reduce the spread of COVID-19 but disrupt livelihoods and lifestyles that can induce harmful behavior changes, including problematic lockdown drinking fueled by cheap alcohol. Exploiting differences amongst the four constituent countries of the United Kingdom, we use triple difference analysis on alcohol retail sales to examine the efficacy of minimum unit pricing as a price control device to help curb excessive consumption in a pandemic setting. We find the policy is remarkably effective and well-targeted in reducing demand for cheap alcohol, with minimal spillover effects, and consumers overall buying and spending less.

Key words: pandemic, lockdown, price control, minimum unit pricing, alcohol, excessive consumption

JEL Classification: C54, D04, H23, I12, I18, L81

1. Introduction

Price controls can have good intentions but often poor outcomes in competitive markets (The Economist, 2020, Aparicio and Cavallo, 2021). At the outset of a pandemic, surging consumer demand for medical supplies, storable food and essential goods may drive up prices, tempting governments to introduce price ceilings to stem price gouging. Despite good intentions to protect consumers, such price caps might simply exacerbate supply shortages by encouraging hoarding (Cabral and Xu, 2021, Chakraborti and Roberts, 2021). Shortages and high prices may, though, be a short-term phenomenon in a pandemic, if supply can increase to meet demand. Instead, this paper considers price controls for the opposite problem – abundant supply and low prices – which could drive harmful excessive consumption in lockdowns and become habitual beyond the pandemic.

Any form of price regulation is controversial, by interfering with the market mechanism, but mandating a price floor that deliberately raises prices for consumers and stymies price competition may be especially so. Even a carefully targeted price floor, aimed only at raising the prices of products associated with harmful excessive consumption, risks distorting prices and demand more widely across the market. Nevertheless, our empirical analysis shows that such an intervention can be remarkably effective and well-targeted with minimal spillover effects in respect of alcohol consumption, with potential application to other products with harmful or addictive effects arising from excessive consumption in a pandemic.

Our context is the COVID-19 pandemic with concerns about the affordability of cheap alcohol fueling problematic lockdown drinking (Anderson et al., 2020, Daly and Robinson, 2020, Finlay and Gilmore, 2020). In particular, while lockdown restrictions might be necessary to reduce the spread of COVID-19, they can have an emotional and economic toll impacting mental health, leading to increased use of alcohol, drugs, gambling and overeating, as maladaptive coping mechanisms to alleviate stress or boredom (Avena et al., 2021). A carefully targeted alcohol policy might then be vital to curb harmful consumption, with encouragement instead for drinking in moderation or abstinence for health benefits.

Alcohol policy to counter harmful consumption generally relies on taxation along with restrictions on availability and marketing, but with varying success (Marcus and Siedler, 2015, Hinnosaar, 2016, Carpenter and Dobkin, 2017, Griffith et al., 2019, Kueng and Yakovlev, 2021). Such measures can help dampen general demand for alcohol and regulate consumption at licensed premises but may be less effective in restricting consumption at home when consumers can liberally buy heavily discounted cheap alcohol from supermarkets and other stores.[1] This policy shortcoming is magnified in a pandemic when lockdowns entail the suspension of more expensive on-premises consumption, resulting in more home consumption and heightened demand for cheap alcohol.

The concern about cheap alcohol is that the concentration of harm from excessive consumption, and so the bulk of negative externalities, rest with a small number of heavy drinkers who mostly buy cheaper and stronger varieties of alcoholic beverages than lighter drinkers (Griffith et al., 2019). Increasing excise taxes may seem the obvious way to ensure higher prices of such products, but vendors are under no obligation to pass on taxes fully or evenly, with evidence of tax under-shifting in highly competitive markets and for cheap alcohol

[1] In contrast, in highly regulated markets, state control of liquor stores or strict licensing can help ensure high prices (e.g., Miravete et al., 2018, 2020, Conlon and Rao, 2019, 2020, Avdic and von Hinke, 2021).

(Ally et al., 2014, Hindriks and Serse, 2019, Wilson et al., 2021). Instead, mandating a price floor with a set minimum price provides an assured way to reduce the affordability of cheap alcohol, with the benefit of having limited impact on light drinkers buying more expensive alcohol above the price floor (Griffith et al., 2022). Moreover, if expressed in the form of minimum unit pricing then the price floor can be easy to apply with a simple and universal pricing formula based on alcohol content (Calcott, 2019).[2]

Scotland and Wales were the first two countries in the world to implement a minimum unit price (MUP) policy, and the Republic of Ireland is set to follow in 2022, while other countries continue to evaluate the policy.[3] There may be general merits in such a policy for normal (non-pandemic) times, as evidenced by prior studies focused on Scotland's pre-pandemic MUP introduction (e.g., Xhurxhi, 2020, Griffith et al., 2022). For instance, Griffith et al. (2022) used household level data from Scotland and England to estimate the net impact of the MUP policy in a difference-in-differences (DD) setup. They found that on average, prices increased by 5% and consumption decreased by 11%. Further, by estimating a demand model on pre-MUP period, they report that while a tax policy outperforms a price floor in terms of welfare effects when externality is constant, a MUP policy is preferable when a small proportion of drinkers are responsible for the majority of problems associated with excessive alcohol consumption.

[2]For instance, Scotland and Wales apply the formula M $\times$ S $\times$ V, where M is the minimum unit price (£0.50 per 10ml ethanol), S is the percentage strength of the alcohol (ABV expressed as a cardinal number), and V is the volume of the container in liters.

[3]Other forms of minimum pricing are by liquid volume (e.g. parts of Australia and Canada) and/or product-specific (like high-strength spirits in several former Soviet countries) (WHO, 2020).

We differ from these papers in two important aspects. First, rather than focus on the the merits of optimal tax versus relatively simpler price floor policies, our focus is on the policy's effects in the context of a pandemic with heightened demand for cheap alcohol as consumers increase drinking at home in response to lockdowns and the suspension of more expensive on-premises consumption. However, the introduction of MUP in Wales was almost concomitant with the COVID-19 national lockdown which gave a large positive shock to off-sale purchases for alcohol (Anderson et al., 2020). If the impact of this demand shock differs across countries and product groups (e.g., cheap vs expensive alcoholic products), we face a significant identification challenge. Accordingly, our empirical method has to deal with the dynamic situation of surging demand but is also distinguished by the manner in which we assess the extent of spillover effects across different price tiers of products. In these circumstances, we examine how minimum pricing affects take-home alcohol volumes, the cost to consumers from raised prices, and shifts in demand from cheap to more expensive alcohol products.

Second, we note that at the time when MUP was introduced in Scotland, there was already a restrictive promotion policy for alcohol vis-à-vis a ban on non-linear pricing via volume discounts (Nakamura et al., 2014, Robinson et al., 2014). Thus, retailers in Scotland could not offer 'two for one' or other similar multi-buys while in England there was no such ban. As we note below, products that fall below the minimum unit price are sometimes below the price line because of temporary promotions including volume discounts, and the two policies may interact. Since in Scotland such a promotion was not possible, we primarily use data from Wales and England neither of which has a ban on multibuy, as it is likely that other jurisdictions considering a MUP policy also do not ban volume discounts.

Despite the policy's attractions in being targeted and easy to implement, critics of MUP question its efficacy, suggesting it will be ineffective because of heavy drinkers' inelastic demand, while distorting competition, being regressive in hitting the poorest hardest, conferring windfall profits at consumers' expense, and losing tax revenue (Snowdon, 2015, The Economist, 2018). Our paper is limited to considering efficacy rather than equity matters, but we find the policy is highly effective in reducing demand for cheap alcohol, with little demand spillover towards more expensive products, and consumers overall buying and spending less as desired, and so indicates that the policy is very well-targeted.

Specifically, our study uses a natural experiment relating to the four constituent countries of the United Kingdom (U.K.). Two of the countries – Scotland and Wales – have used their devolved powers to introduce a common minimum unit price at fifty pence per unit (50ppu), i.e., £0.50 (roughly \$0.70 or €0.58) per alcohol unit (10ml pure ethanol), applicable to all beverages, while the other two – England and Northern Ireland – have not adopted such a policy, yet all four countries operate with the same U.K. taxation rates. Scotland introduced its MUP before the pandemic in May 2018. However, Wales launched its MUP in March 2020, in the same month the WHO declared COVID-19 a global pandemic and all four U.K. countries simultaneously commenced lockdowns. The timing was a coincidence for Wales but presents an opportunity to compare the effects from MUP being introduced at the pandemic outset.

We have two potential controls for a classic difference-in-differences (DD) study design, either contrasting treated products ($<$ 50ppu) with untreated products ($\geq$ 50ppu) or the treated country (Wales) with a control country (initially England) for matched products. However, both have complications because demand spillovers in the former would violate the stable unit treatment value assumption (SUTVA), while country lockdown demand differences in the latter would break parallel trends. The latter is a real prospect since the lockdowns closed the entire on-trade (accounting for 30% of total alcohol consumption), so the scale of the take-home sales uplift could substantially magnify different population responses to the lockdowns (which each country separately controls under devolved powers, with restrictions gradually eased in the last two months of our study period).

For the former, treatment is not binary as the price floor can alter two types of prices – regular prices and promotional prices – suggesting a three-way classification based on the amount of time the products were previously priced below the price floor: never below (untreated), intermittently below (mildly treated), or consistently below (severely treated). Crucially, we find very limited demand spillover to the untreated product group. Specifically, we find that demand spillover from bottom-tier to mid-tier may arise, but mid-tier promotion depth restrictions seem to curb existing purchases rather than induce consumers to upscale to the top-tier. With this key feature, we use triple difference (DDD) analysis with temporal/country/group comparisons to isolate the price floor impact from differential country lockdown effects, while using other cross-country comparisons for validity testing.

Our data cover weekly retail sales from the market leading retailer, which accounts for over a quarter of all retail alcohol sales across the four countries, spanning 104 weeks with very wide product coverage.[4] In total, we have a perfect match on over 2,500 alcohol products

[4]The retailer is Tesco which held a consistent national market share of 27% over the study period for both alcohol and total grocery retail spending (based on Kantar Worldpanel FMCG data). Further details are available upon request.

sold in all four countries, allowing us to analyze in detail the impact of MUP and lockdown drinking on beers, ciders, spirits, wines, and other product types.

Our results are striking. The introduction of MUP ensured higher prices for over a third of the products but which accounted for nearly three quarters of all alcohol quantity sold. While take-home alcohol sales surged across most of the U.K., Wales saw a substantial fall in sales of the cheapest alcohol, curbing the overall volume of alcohol sold, with minimal impact on more expensive (untreated) products. On this basis, the policy looks to have been more effective than anticipated in normal (pre-pandemic) conditions, such as Scotland experienced in 2018. Moreover, the reduced quantity offsets the higher prices to leave average customer expenditure little changed, suggesting no discernible windfall profits.

Our approach, findings and intended contribution relate to two broader fields. First, a number of studies examine how risky health behaviors, like harmful drinking, adjust to changing economic conditions, such as over business cycles (Ruhm and Black, 2002, Dávalos et al., 2012, Stevens et al., 2015) or following economic shocks (Currie and Tekin, 2015, Adda and Fawaz, 2020). Our paper adds new insights on changes arising with the onset of a pandemic situation, which is foremost a health crisis but with immense personal and economic ramifications, as lockdowns and stay-at-home orders disrupt livelihoods and lifestyles that may induce harmful behavior changes, e.g., increased domestic violence linked to lockdown drinking (Chalfin et al., 2021).

The second broader field relates to policy evaluations using DD and DDD analysis. The range of applications using DD analysis is extremely wide, especially for public health policies (Wing et al., 2018), and with growing use of DDD analysis for policy assessment more generally (Olden and Møen, 2020). The COVID-19 pandemic has led to an upsurge in studies using these methods, either from an epidemiological perspective (Goodman-Bacon and Marcus, 2020) or in respect of evaluating economic outcomes arising from COVID-19 policy responses (Callaway and Li, 2021). Our focus is different in not being primarily about the impact of lockdowns, *per se*, but assessing how policy works to curb a harmful behavior (here, problematic drinking) when lockdowns contribute to exacerbating such behavior. In this regard, our study design may have relevance to the assessment of other policy interventions which require isolating policy effects from the pandemic. We contribute to the policy evaluation literature by highlighting under which conditions a triple differencing setup can help with the identification when there are concomitant events, i.e., MUP legislation and COVID-19 lockdowns.

The paper proceeds as follows. The next section details the data, methodology and econometric specification. Section 3 reports results of the DD and DDD analyses. Section 4 concludes. Online appendices provide additional analysis and testing details.

2. Data and Methods

We begin by outlining the data and variables, descriptive statistics, methodology and identifying assumptions, and the econometric specification.

2.1. **Data and Variables.** Our data are drawn from records of alcohol sales from the market leading retail chain Tesco which provides information at the stock keeping unit (SKU) level by country and week. An SKU example would be "COORS LIGHT 6X330ML". For each SKU, we obtained total expenditures and quantity sold (number of pack/bottles, etc.). The data series spans 104 weeks with 78 weeks before MUP implementation and the remaining

26 weeks starting the week of MUP implementation (March/2/2020). We supplemented this with information on alcohol by volume (ABV), measured as the percentage of ethanol for each SKU using internet searches. This allowed us to compute weekly quantities, measured in standard "units" of alcohol (per 10ml ethanol). Similarly, we obtained price per unit of alcohol for each SKU.

The MUP regulation specifies that no product should be sold at a price below 50ppu. However, prices change from week to week, and so a given product may be sold above the MUP threshold in one week, and below it in another week, but chiefly distinguished by regular prices as opposed to occasional or promotional prices below 50ppu. Accordingly, we classified all products into three groups based on cutoffs in the frequency of weeks each item was sold below the MUP price in Wales in the initial 78 weeks. These are:

- MUP1: never below 50ppu (0% weeks) – 1,576 items (share 28.6%);
- MUP2: intermittently below 50ppu (1-79% weeks) – 703 items (share 37.6%);
- MUP3: consistently below 50ppu ($\geq$ 80% weeks) – 276 items (share 33.8%).[5]

For the above classification, we used all 78 weeks rather than a smaller initial period since there is no reason to believe that retailers would start changing prices in anticipation before MUP implementation, and indeed our data confirm this. Importantly, we kept the same classification of the products in other U.K. constituent countries. To be clear, the classification of a product is based on its price in Wales and not in other countries, and hence if "COORS LIGHT 6X330ML" is classified as MUP1 based on Welsh prices and frequencies, it retains the same classification in other countries. This allows us to be able to compare

[5]The 80% cutoff represents the clearest break in the distribution of products by the proportion of weeks with prices below 50ppu, see Appendix A.

the before/after changes in prices and quantities for the same products. Our final sample consists of 2,555 SKUs (see Appendix A for details on data cleaning). While there are relatively fewer items classified as MUP2 and MUP3, which are the direct target of the price floor, they in fact represent 71.4% of alcohol purchase by quantity.

We aggregated SKU level data to MUP/country/week level and created four different outcomes of interest in log form. These are: (Y1) quantity in units (per 10ml ethanol), (Y2) quantity per customer, (Y3) total expenditure per customer, and (Y4) price per unit of alcohol. Here, 'per customer' refers to total customers visiting the retailer during that week for the given country, as a gauge of changes in individual shopping activity.

Table 1. Statistics by Country, MUP Group and Before/After Implementation

Wales	MUP3 Group				MUP2 Group				MUP1 Group			
	Before		After		Before		After		Before		After	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Y1	14.62	0.182	14.19	0.091	14.68	0.315	14.85	0.097	14.38	0.390	14.56	0.163
Y2	1.587	0.129	1.478	0.161	1.646	0.242	2.020	0.164	1.413	0.294	1.768	0.167
Y3	0.916	0.083	0.994	0.132	1.145	0.183	1.528	0.150	1.205	0.268	1.542	0.159
Y4	-0.954	0.037	-0.689	0.002	-0.672	0.044	-0.597	0.009	-0.288	0.028	-0.281	0.014
England												
Y1	16.98	0.155	17.10	0.099	17.19	0.296	17.31	0.131	16.94	0.372	17.07	0.154
Y2	1.432	0.108	1.728	0.153	1.602	0.230	1.903	0.177	1.414	0.282	1.702	0.155
Y3	0.817	0.069	1.063	0.119	1.111	0.172	1.379	0.146	1.211	0.260	1.486	0.146
Y4	-0.925	0.028	-0.897	0.012	-0.668	0.042	-0.654	0.027	-0.279	0.028	-0.273	0.021

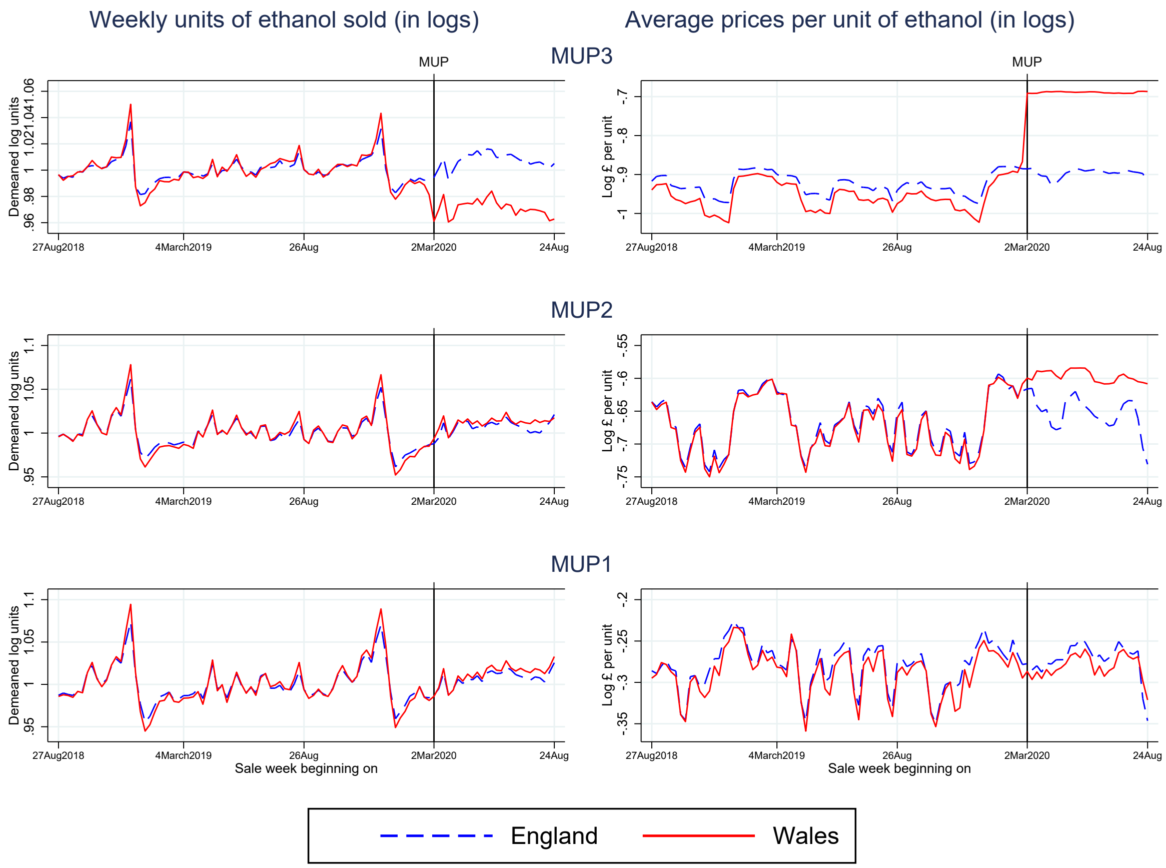
Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. Means and standard deviations are over the first 78 weeks (before) and following 26 weeks (after).

2.2. **Descriptive Statistics.** Table 1 gives descriptive statistics by country, product groups, and before/after periods for the main outcome measures. In percentage terms, mean alcohol quantity for MUP3 products decreased in Wales by 34.9% ($= 100(exp(14.19 - 14.62) - 1)$), while it increased for both MUP2 and MUP1 products by 18.5% and 19.7%, respectively. By comparison, the mean quantity increased for all three product groups in England. Quantity per customer (Y2) increased in England for all three MUP categories and also increased in Wales for MUP1 and MUP2 products, but declined for MUP3 products. Nonetheless, expenditures per customer (Y3) increased for all three MUP categories in both countries, albeit least for MUP3 in Wales. This increase in expenditures per customer is driven primarily by the decline in the absolute number of customers for the retailer in all countries during the pandemic (reflecting less shopping around and more one-stop shopping) (see Figure A-2). The largest and most obvious change was in the price of MUP3 products in Wales where the mean increased by 30.3%, followed by a smaller increase in the prices of MUP2 products (up 7.8%) with very little change in the prices of MUP1 products. There was also a small increase in prices in England but not as large as observed in Wales (e.g., up 2.9% for MUP3 products).

To highlight these changes, we plot the values of log quantity and log price overtime in Figure 1 (a similar comparison for England and Scotland is shown in Figure A-3 in Appendix A). The left panel shows the trends of log quantity for each of the MUP categories, where they have been demeaned over their own pre-ban averages.[6] Until March/2/2020, the quantity lines were remarkably parallel. Importantly, in the top left panel, we can see a deviation in the paths following MUP implementation in Wales, particularly for MUP3 products (consistently sold below 50ppu).

[6]The adult (18+) populations are Wales 3.1m, England 56.0m, Scotland 5.4m, and Northern Ireland 1.9m. Because of large differences in adult population, in the figures we have demeaned the log quantity over the pre-ban period, i.e., from each log quantity at time t, we subtract the mean value for the specific product group and country in the pre-ban period.

Figure 1. Average Quantity and Price per Week by MUP Group and Country



The right hand side panel in Figure 1 shows trends in log prices. The sharp rise in the prices of MUP3 products in Wales is in contrast to the stable trend of MUP3 products observed for England (top right panel). Similarly, there is a clear deviation in time paths for the prices of MUP2 products after MUP implementation in Wales. In contrast, the prices of MUP1 products follow similar paths in the two countries even after MUP implementation. Moreover, it appears that MUP1 products in both prices and quantities do not seem to be affected much by the MUP implementation, lending some credence to the notion that the spillover effect to MUP1 products is either not present or is very small. Finally, note that quantity paths changed for products sold in England too, presumably due to the lockdown, and especially the price of MUP2 products decreased significantly in England during the lockdown but in keeping with the seasonal pattern.

2.3. **Methodology (Identifying Assumptions).** A standard method of identifying the impact of policy change is to use a difference-in-differences (DD) design. Providing a 'parallel trend' assumption holds in the pre-policy period, we can then compare change on the outcome of the products affected by the MUP policy with the before/after change observed in a control group not affected by the policy (we test for it in Section 3.3). Two types of control groups are available: same products in another country, or an unaffected set of products in the same country.

For either of the two types of controls, the treatment groups are MUP3 (affecting regular prices) and MUP2 (affecting occasional/promotional prices), while the regulation has no direct impact on MUP1 products.

For DD comparisons within Wales, we allow MUP1 products to form the control group. However, spillover effects are an evident possibility, as MUP1 products are potential substitutes for MUP2 and MUP3 products. For instance, with price competition and upward sloping best-response curves (strategic complementarity) amongst vertically (quality) differentiated products, the raised prices for treated products (previously below the price floor) could prompt an increase in the price of the control group prices as well, and that in turn would affect their demand. Even if prices of non-treated products do not change, the relative change in price for one set of products can affect the demand for products in the control group, unless the cross-price elasticity is almost zero. Thus, we could violate SUTVA.

Alternatively, we can obtain DD estimates by comparing before/after sales of products directly affected by the price floor in Wales with the before/after sales of the same products in England. Since England (neighboring Wales) did not apply MUP, the same products from England may provide a better control as they would not violate the above-mentioned SUTVA. The condition holds as long as there is no (strong) linkage in retail prices across the two countries and there is no significant cross-border purchases of alcohol, i.e., if the markets are segmented at national level.

While the second DD estimator sounds more plausible, a potential problem is that the U.K.-wide lockdown was initiated almost immediately following MUP implementation in Wales. So while we expect consumption to decrease due to the price floor introduction, this is countered by evidence of a strong surge in retail store alcohol purchases during the lockdown (Anderson et al., 2020). Furthermore, we do not know if the lockdown effect outcomes was the same across the countries. The cross-country DD estimator would not be valid if the effects of lockdown-induced sales on the treated products differ by countries, as it would imply that the sales in the two countries would follow different trajectories even if there was no policy change in minimum unit price. This could happen, for instance, if the lockdown induces a 30% increases in sales of MUP3 products in Wales but 50% increase in England. In fact, even the first DD estimator above (i.e., a within Wales cross-product DD estimator) would not be valid even if there were no spillover effects if the lockdown induced different trajectories for control (MUP1) and treated products (MUP2 and MUP3).

To account for the possibility of differential country lockdown effects, we use a triple difference (difference-in-differences-in-differences, DDD) estimator to identify the effect of MUP implementation on the MUP2 and MUP3 product groups. Essentially, from the cross-country

DD estimator for MUP2 and MUP3, we can subtract the cross-country DD estimator for MUP1, which would give us a DDD estimate. This DDD approach is valid under the alternative assumption that the effect of the lockdown on MUP1 versus the treated products is the same across countries. Under this setup, the identifying assumption is as follows. Suppose the lockdown effect on sales in Wales on MUP1 and MUP3 products is 10% and 30% respectively, so that the differential effect in Wales is 20%. Suppose further that the lockdown effect in England on MUP1 and MUP3 products is 30% and 50% respectively. Thus, the differential effect of lockdown between the treated and untreated products is again 20%, i.e., it is the same across the two countries (we thank an anonymous referee for this example). If this assumption holds, we can isolate the effect on outcomes of the price floor regulation from the effect induced by the country lockdowns. In a later section, we provide some corroborating evidence for such an assumption.

The intuition behind the DDD estimator is as follows. If there are no country differentials arising from the lockdowns and only within-country spillover effects, then the DD estimators by product groups across countries are sufficient for identification. If, though, there is no spillover effect on to MUP1 products, but there is a differential country lockdown effect that is the same the same across product groups (as given in the example above), then subtracting the DD estimator for MUP1 products from the DD estimators for MUP2 and MUP3 products would identify the net impact of the policy on affected products. Moreover, under these assumptions, the DD estimate for MUP1 captures the country lockdown differential between Wales and England for the control group. Appendix A illustrates the relationship between the DD and the DDD estimators using only mean values for total quantity before/after by country and MUP groups.

2.4. **Econometric Specification.** Both the DD and the DDD estimators can be obtained from a single reduced form regression that controls for seasonality and time trends. Let Y be the outcome variable of interest. Then we can estimate

$$\begin{aligned} Y_{it} &= \alpha_1 + \alpha_2 X_{it} + \beta_1 W_{it} + \beta_2 P_{it} + \beta_3 M2_{it} + \beta_4 M3_{it} \\ &\quad + \beta_5(W_{it}P_{it}) + \beta_6(W_{it}M2_{it}) + \beta_7(W_{it}M3_{it}) + \beta_8(P_{it}M2_{it}) + \beta_9(P_{it}M3_{it}) \\ &\quad + \beta_{10}(W_{it}P_{it}M2_{it}) + \beta_{11}(W_{it}P_{it}M3_{it}) + u_{it}. \end{aligned} \tag{1}$$

In the equation above, P, W, $M2$ and $M3$ are 1/0 indicator variables equal to 1 if the observation refers to a post MUP legislation period ($t \geq 79$), from Wales, for MUP2, or MUP3 category products, respectively. The variable X consists of time trends and seasonal dummies, a polynomial in time up to power four and dummies for each calendar month. As robustness check, we also allow the polynomial and monthly fixed effects to be country-specific by including additional interactions terms (see section 3.3). The DDD estimates of the effect of legislation for MUP2 and MUP3 products are β_{10} and β_{11} respectively, and if by assumption there is no spillover effect on MUP1, then the effect of the MUP enforcement is zero on these products (as mentioned above, the identifying assumption requires that the differential effect of the lockdown across the treated and control groups is the same across countries). The coefficient β_5 in this case represents the differential country lockdown effect on MUP1 products. Under the alternative (stronger) assumption that the lockdown effect is the same for a given product group across countries, but allowing for policy spillover effects on MUP1 products, we can obtain the DD estimates as β_5, $\beta_{10} + \beta_5$ and $\beta_{11} + \beta_5$ for MUP1, MUP2 and MUP3 products, respectively.

For any given outcome variable Y, equation (1) is essentially a comparison of six time series, consisting of three MUP categories in two countries each. Equivalently, it is a long panel of 104 weeks with six cross-sectional units, and hence the usual panel methods that rely on large number of cross sections for asymptotic inference are not appropriate here. Given the scale difference across the MUP categories and countries, our imposed error structure allows for country-MUP group level heteroskedasticity. We also allow for errors across the six series to be contemporaneously correlated and hence we specify a heteroskedastic error structure with cross-sectional correlation. Inspection of residuals from initial pooled OLS estimates indicates that error terms are correlated over time, and each time series exhibits an autoregressive process of order one ($u_{it} = \rho_i u_{i,t-1} + \epsilon_{it}$) (see Figure B-1 in Appendix B). Consequently, we estimate the models via Feasible-GLS (F-GLS) allowing additionally for separate AR(1) process for each of the time series (see Greene, 2003, p.320).

3. Results

We start with the main results by comparing Wales and England in section 3.1. Section 3.2 provides tests which i) uses data from England and Northern Ireland as a falsification, and ii) tests the presence of differentiated lockdown effects within MUP1 products only. We then describe the results of further robustness checks and parallel trends assumptions in section 3.3. Next, section 3.4 summarizes the main findings from analysis by product categories (beers, ciders, spirits, wines). Details/sub-analysis are confined in appendices. Finally, section 3.5 shows results of comparisons between England and Scotland, the first country in the world to implement a minimum unit price policy. In discussing the outcome effects, we express statistically significant coefficients in percentage change terms (to 1dp) (applying $exp(\beta_j) - 1$ from the estimated log-value coefficients).

3.1. **Minimum Unit Price in Wales.** Table 2 provides estimates of selected coefficients β_5, β_{10} and β_{11}, as well as of their sums $\beta_5 + \beta_{10}$ and $\beta_5 + \beta_{11}$ for all outcome measures. (See Table C-1 for all full set of regression coefficients). Additionally, for both DDD and DD estimates, the table provides the overall combined effect on MUP2 and MUP3 alcohol products and all alcohol products (MUP1, 2 and 3) combined.

Starting with Y1 (log of total quantity in alcohol units) and MUP3 products (consistently $<$ 50ppu), quantity sold in Wales declined by 44.4% due to the price floor. Surprisingly, there was no significant change in MUP2 products (intermittently $<$ 50ppu) sales. Note that these are both DDD estimates, which assumes that there is no spillover effect on MUP1 products (never $<$ 50ppu). Therefore, β_5, the coefficient for MUP1 products, measures the lockdown country differential between England and Wales that is not attributable to the MUP regulation, indicating 4.6% higher quantity. The combined effect on MUP2 and MUP3 products is an overall net reduction of 21.4% in quantity sold.[7] Under the alternative assumption of a lockdown country differential present between England and Wales, the β_5 estimate represents the DD estimate with a 4.6% increase in MUP1 products due to the spillover effects. Under this assumption, the effect of MUP implementation on MUP3 and

[7]The combined effect was computed using ancillary regressions similar to equation (1), but where MUP2 and MUP3 were combined into a single category. Appendix C, section C.2 provides details and regression outputs. An alternative is to compute the combined effect by multiplying coefficients with pre-MUP means for MUP2 and MUP3 to compute the implied change and convert back to percentages. However such computations rely on first-order Taylor series expansions and the approximation becomes worse when estimated coefficients are far away from zero (above 0.1 in magnitude), as is the case for our estimates of β_{10} and β_{11}.

Table 2. Effect of MUP Implementation in Wales (selected coefficients only)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP3: β_{11}	-0.587^a	-0.459^a	-0.218^a	0.225^a
	(0.014)	(0.012)	(0.010)	(0.005)
MUP2: β_{10}	0.00381	0.00972	0.0531^a	0.0553^a
	(0.011)	(0.009)	(0.007)	(0.005)
MUP1: β_5	0.0453^a	0.0612^a	0.0592^a	0.00200
	(0.012)	(0.008)	(0.008)	(0.003)
	DD estimates			
MUP3: $\beta_5 + \beta_{11}$	-0.542^a	-0.398^a	-0.158^a	0.227^a
	(0.013)	(0.011)	(0.009)	(0.005)
MUP2: $\beta_5 + \beta_{10}$	0.0491^a	0.0709^a	0.112^a	0.0573^a
	(0.012)	(0.009)	(0.006)	(0.004)
	Combined effect			
Combined	-0.241^a	-0.208^a	-0.0648^a	0.139^a
(MUP2 and 3)	(0.009)	(0.008)	(0.006)	(0.005)
Combined	-0.195^a	-0.145^a	-0.00449	0.139^a
(MUP1,2 and 3)	(0.009)	(0.008)	(0.007)	(0.005)
Observations	624	624	624	624
chi2	347661.8	3290.7	2511.0	34781.6
df	26	26	26	26

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups (robust S.E. in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. Full set of coefficients given in Table C-1.

MUP2 products are -41.8% and +5.0% respectively, and the combined effect on all three product groups is a decrease of 17.7%.

In terms of quantity per customer (Y2) and expenditure per customer (Y3), the DDD estimates indicate a reduction for MUP3 products of 36.8% and 19.6%, respectively (bearing in mind that these measure standardize on total number of customers for this retailer, and not the total number of customers that purchased alcohol products). These reductions are driven by a 25.2% increase in the price of MUP3 products. Under the DDD estimate, neither total quantity nor quantity per customer increases for MUP2 products, hence the 5.4% increase in expenditure per customer is driven by the 5.7% increase in price of MUP2 products. Thus, once again, we found no evidence of substitution effects from MUP3 to MUP2 products. The assumption of no spillover effect on MUP1 products is corroborated by no change in the price of MUP1 products ($\beta_{11} = 0.002$ and not significant at conventional levels). Overall, the combined effect of the introduction of MUP in Wales is a 14.9% increase in prices, 18.7% decrease in quantity per customer, and a 6.3% decline in expenditure per customer.

Under the alternative assumption of spillover effects on MUP1 products, the DD estimator shows that both the quantity and expenditure per customer still decrease for MUP3 products ($\beta_5 + \beta_{10} = -0.398$ and $\beta_5 + \beta_{11} = -0.158$). However, quantity and expenditure per customer for MUP2 products increased (coefficients are 0.071 and 0.112, respectively). Overall, the estimated combined effect of the legislation in Wales is broadly consistent with the DDD estimates, with a 14.9% increase in prices and slightly lower decreases in quantity sold and expenditure per customer (-13.5% and -0.4%, respectively).

Estimates obtained under the alternative error structure assumptions, i.e., that errors are independent across the six time series (see Table B-1 in Appendix B) lead to similar conclusions.

In the foregoing discussion, the two sets of estimators give bounds to the effect of the price floor under alternative assumptions, and differ by the estimate of β_5, which could be positive or negative. Just to be clear, under the DDD estimation, β_5 measures size of the country lockdown differential, while under the DD estimation it is interpreted as the size of the spillover effect with no country lockdown differentials. Thus if β_5 is significantly different from zero, it is due to (1) a spillover effect on MUP1 products in Wales, and/or (2) a country lockdown differential (or both). We next explore these issues.

3.2. **Falsification and differential lockdown effects tests.** We undertake two analyses in this section. First, we re-estimate the model above using data from England and Northern Ireland. Second, we check if the lockdown affected subgroups of the control MUP1 group equally. The rational for these tests and the results are discussed below.

England vs Northern Ireland. We use data from England and Northern Ireland – both countries without minimum pricing. This eliminates the possibility of any spillover effects. Thus, if the England/Northern Ireland before/after differential for MUP1 is similar to one observed for Wales/England, it indicates the presence of country lockdown differentials, which, in turn, supports the use of DDD estimator. If, though, this differential does not exist between England and Northern Ireland then it suggests that lockdown effects are similar across countries, and we can use the DD estimates from the initial model. Note also that had there been no lockdown, comparison of England and Northern Ireland data would give coefficients of interest that would not be significant different from zero, as there is no MUP regulation in either country. Given the lockdown however, these coefficients can be different from zero, but should be significantly smaller in magnitude compared to those from England/Wales comparison.

Table 3 shows selected coefficients in DDD estimation as before but using data from England and Norther Ireland. The DDD coefficient for Y1 for MUP1 is 0.0369, statistically significant, and in fact of similar magnitude as that for Wales vs England (0.0453). The coefficients for

TABLE 3. Northern Ireland vs England (Selected regression coefficients)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP3: β_{11}	-0.0811^a	-0.0683^a	-0.0593^a	-0.00976
	(0.027)	(0.022)	(0.018)	(0.006)
MUP2: β_{10}	-0.0882^a	-0.0690^a	-0.0569^a	-0.00689
	(0.028)	(0.023)	(0.020)	(0.008)
MUP1: β_5	0.0369^c	0.0132	0.0289^c	0.0199^a
	(0.022)	(0.016)	(0.016)	(0.005)
	DD estimates			
MUP3: $\beta_5 + \beta_{11}$	-0.0442^c	-0.0551^a	-0.0304^c	0.0101^a
	(0.025)	(0.021)	(0.016)	(0.003)
MUP2: $\beta_5 + \beta_{10}$	-0.0513^b	-0.0558^b	-0.0280	0.0130
	(0.024)	(0.024)	(0.017)	(0.008)
	Combined effect			
Combined (DDD)	-0.0906^a	-0.0830^a	-0.0739^a	-0.00918^c
(MUP2 and 3)	(0.020)	(0.017)	(0.014)	(0.005)
Combined (DD)	-0.0538^a	-0.0705^a	-0.0453^a	0.0104^a
(MUP1,2 and 3)	(0.015)	(0.015)	(0.013)	(0.003)
Observations	624	624	624	624
chi2	167482.1	1902.0	1830.6	23229.2
df	26	26	26	26

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups (robust S.E. in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. Only selected regression coefficients shown.

MUP2 and MUP3 are also statistically significant but considerably different in magnitude from those obtained in the Wales vs England case: the DDD and DD estimates for MUP3 are now -0.081 and -0.044, and sharply compare to previous estimates of -0.587 and -0.542. These large differences for MUP3 coefficients relative to the previous case provide a falsification test of our comparison between Wales and England: if the estimated effect on MUP3 products was not due to legislation, we would have expected a similar sized differential between England and Northern Ireland. Similarly, the combined effect on MUP2 and MUP3, or of all three combined, is in the range of 5.2% (DD) and 8.7% (DDD), and much smaller than what we got for Wales/England case, which were 21.4% (DD) and 17.7% (DDD). These results lend support for the country differential hypothesis, and preference for DDD estimates.

Nonetheless, when ignoring cross-series correlations, the Northern Ireland and England differences are no longer statistically different (see Table B-2 in Appendix B), and provide support for a DD estimate. We therefore consider the DDD and DD estimates as the lower and upper bounds for the net impact of the MUP introduction in Wales under alternative assumptions.

Differential effects of lockdown. Next, we test if our assumption for DDD might hold i.e., the differential effect of the lockdown across the treated and control product groups is the same across Wales and England. We cannot directly check this assumption. Instead, we check if the lockdown affected Wales and England similarly in other dimensions. To this end, we divide MUP1 products into two groups, MUP1A and MUP1B depending on if they are below or above the mean price for this group in Wales. Next, for each of these subgroups, we can estimate a DD model comparing England/Wales and before/after. If the DD estimates are β_{1A} and β_{1B}, we can test if these are equal or not. If they are, it shows that the lockdown effect is the same in two subgroups, and lends indirect support to our assumption above. The test is most directly implemented via a three way interaction term in joint estimation for MUP1A and MUP1B products. Specifically, we estimate

$$Y_{it} = \gamma_1 + \gamma_2 X_{it} + \theta_1 W_{it} + \theta_2 P_{it} + \theta_3 M1_{Bit} + \theta_4 (W_{it} M1_{Bit}) + \theta_5 (P_{it} M1_{Bit}) + \theta_6 (W_{it} P_{it}) + \theta_7 (W_{it} P_{it} M1_{Bit}) + u_{it}, \tag{2}$$

where $M1_{Bit}$ is a 1/0 dummy variable equal to one if the observation refers to MUP1B product, $\beta_{1A} = \theta_6$ and $\beta_{1B} = \theta_6 + \theta_7$, and the equality is tested by significance of θ_7.

Table 4 provides estimate of the triple interaction term as described above. The first row of the table shows the effect on MUP1A products. Note that these coefficients are very similar to MUP1 coefficients listed as β_5 in Table 2. The second row for θ_7 tests if $\theta_A = \theta_B$. Since we do not reject the null, it shows that England/Wales before/after DD estimate for MUP1A products is same as that for MUP1B products. In turn it lends support to our identification assumption for DDD estimates provided earlier.

TABLE 4. Falsification test (among MUP1 products only) - Imposing an hypothetical MUP for MUP1 products below (MUP1a) vs. above (MUP1b) the MUP1 median price in Wales (selected coefficients only)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP1a: θ_6	0.0393^{a}	0.0453^{a}	0.0404^{a}	0.000498
$(\beta_A = \theta_6)$	(0.012)	(0.008)	(0.006)	(0.002)
MUP1b: θ_7	0.0165	0.0135	0.0129	-0.00208
$(\beta_B = \theta_7 + \beta_A)$	(0.018)	(0.012)	(0.010)	(0.005)
Observations	416	416	416	416
chi2	302238.1	197.7	204.8	1256.0
df	22	22	22	22

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups (robust S.E. in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively.

3.3. **Robustness and Parallel trends.** We already noted earlier that our results in Table 2 and Table 3 hold when we allow for independence of errors across the six time series (which are given in Tables B-1 and B-2 in Appendix B). So far our specifications are parsimonious and account for common time trends (a polynomial in time to the power four) and common monthly fixed effects. Thus, we next check if the forgoing analysis holds up if allow for country-specific time trends and country-specific monthly fixed effects via additional interaction terms included in the main specification. The results are are given in Table B-3 and Table B-4 and are qualitatively similar but show slightly larger magnitudes for MUP1 products.

Critical to our identification setup is the 'parallel trends' assumption. While Figure 1 shows that the parallel trends assumption holds for log quantity and log price in the pre-MUP period, we conduct two closely related formal tests for parallel trends, with results reported for all outcome variables in Appendix B.4. The first test uses data from the pre-MUP period ($T \leq 78$) to estimate a variant of Equation 1 where the indicator variable P_{it} for pre-post period is replaced by a linear time-trend. We then test for the joint significance of β_5, β_{10} and β_{11} and do not reject the null that these parameters are equal to zero (see Table B-5. This supports the hypothesis of parallel trends in the pre-MUP period. In a second test, we run a placebo test. We again use only the pre-MUP period data but this time keep P_{it} as an indicator variable which is set to one after $T/2$. We then test for the significance levels of key parameters, and in all but one case, they are not statistically significant.[8] The test results are given in Table B-6.

[8] The one exception is for $Y1$ for MUP3 parameter β_{11} in which case the parameter is significantly different from zero at the 10% level. But even here, the magnitude is only -0.0204 in this placebo test, and compares sharply with the non-placebo variant reported in Table 2 where the same parameter was -0.587 and significant at 1% level.

3.4. **DDD Estimates by Product categories.** We also estimated the impact of the MUP regulation in Wales by segmenting alcohol products by the following types: (i) Beers (includes ales, stouts and lagers); (ii) Ciders (including perries); (iii) Spirits; and (iv) Wines (including all wine-based drinks). Estimation details and results are described in Appendix C.3. Briefly, they show a large reduction in quantity sold of MUP3 products for beers and ciders but with considerably less reduction for wines.

3.5. **Lockdown Impact for Existing MUP Regulation.** We next compare the effect of lockdown drinking across Scotland and England, where the former already had its price floor in place before the beginning of our time series, while the latter has no price floor. For this analysis, we employed a DD estimator as there are no changes in MUP policy in either country during the study period. We kept the same MUP classification (based on prices observed in England) even though there were no products priced under the MUP floor in Scotland.

The movement over time in (log) quantity and prices is shown in Appendix A. Mean (log) quantity increased in England for all three MUP categories after week 79, by 13.7%, 12.7% and 13.2% for MUP1, MUP2 and MUP3 products, respectively. In contrast, the corresponding increases in quantity in Scotland were 15.8%, 7.6% and 3.5%. Prices also increased in England slightly for all three categories (0.7%, 1.5% and 2.9% for MUP1, MUP2 and MUP3, respectively) while they showed no systematic pattern in Scotland (decreasing by 1.1% for MUP1 products and increasing slightly for MUP2 and MUP3 products by 0.3% and 0.5%, respectively).

TABLE 5. Scotland vs England (DD Estimates)

	(Y1)	(Y2)	(Y3)	(Y4)
MUP1: β_5	-0.0134	-0.00895	-0.0179	-0.0108
	(0.047)	(0.038)	(0.032)	(0.011)
MUP3: $\beta_5 + \beta_{11}$	-0.100^a	-0.104^a	-0.0896^a	-0.00831
	(0.025)	(0.024)	(0.015)	(0.010)
MUP2: $\beta_5 + \beta_{10}$	-0.0533	-0.0439	-0.0380^c	-0.00198
	(0.037)	(0.031)	(0.019)	(0.014)
	Combined effect			
Combined (DD)	-0.0646^a	-0.0684^a	-0.0676^a	-0.00737
(MUP1,2 and 3)	(0.023)	(0.022)	(0.016)	(0.009)

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, group level heteroscedasticity and correlation across groups (robust se in parenthesis). Only selected regression coefficients shown. Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively.

We estimated a -9.5% difference in MUP3 products sales in Scotland compared to England, and the effect is statistically significant. The -5.2% difference estimated for MUP2 products is not statistically significant. Similarly, no significant difference in sales of MUP1 products were found between these two countries. The estimated net combined reduction for all products sold in Scotland was -6.3% and was statistically significant. Similarly, there is a large 21%-35% unadjusted increase in quantity per customer across MUP categories in both countries post lockdown commencing. This is because of fewer customers with shoppers reducing store visits (see Figure A-2). However the DD estimates show that while there was no statistically significant difference in quantity per customer for MUP1 and MUP2 products, sales per customer of MUP3 products declined by 9.9% in Scotland. The combined net reduction on quantity per customer for Scotland was 6.6%. A similar story emerged for expenditure per customer. There was no statistically significant difference between the two countries for prices.

Overall, these results imply that while consumption increased with the lockdowns, the relatively lower increase in total quantity, as well as quantity and expenditure per customer, in Scotland was mainly driven by the considerably smaller increases in demand for MUP2 and MUP3 products, which already had a 50ppu floor in place.

4. Conclusion

We find that minimum unit pricing as a price control can be highly effective in reducing demand for cheap alcohol with an overall net reduction in take-home alcohol as a measure to counter harmful drinking which lockdown restrictions could exacerbate. There is the risk that this could be only a short-term effect, where the sudden jump in the cheapest alcohol prices initially put off consumers faced with "sticker shock", but who might later adjust their expectations and start buying the products again. However, as Figure 1 clearly shows, this is not the pattern we observe over the full six months after the MUP introduction in Wales. Similarly, as evident from the comparison involving Scotland, MUP appears to have a persistent demand dampening effect on cheap alcohol.

Perhaps the most striking aspect is how well targeted is the intervention with very limited spillover effects on sales or prices for more expensive (untreated) alcohol products. Our intuition is that the sharp price hike for the very cheapest alcohol cut its demand sharply but with some spillover as these consumers switched to buying more from the next quality tier up, whose prices had been hovering around the price floor, but in turn whose existing consumers bought less due to the depth restrictions on promotional prices. If so, then these opposing demand effects essentially cancelled out each other for this mid-tier, yet with little further spillover to the top tier.

Our focus is limited to efficacy rather than equity matters, but we find that MUP dampened rather than increased shopper spending, with consumers opting to buy and spend less when confronted with higher prices. Accordingly, demand for cheap alcohol looks surprisingly elastic, which appears to have substantially lessened any regressive impact of the policy and without entailing a discernible profit windfall for industry (with higher margins offset by lower volumes). Nevertheless, we recognize our study's shortcomings in not providing a complete picture for full policy evaluation since we only cover an early part of the pandemic and not the full retail sector, and we only study aggregate customer behavior rather than the decisions of individual households, all of which may be important avenues for future research.

References

Adda, Jérôme and Yarine Fawaz (2020) "The health toll of import competition," *The Economic Journal*, 130 (630), 1501–1540, 10.1093/ej/ueaa058.

Ally, Abdallah K., Yang Meng, Ratula Chakraborty, Paul W Dobson, Jonathan S. Seaton, John Holmes, Colin Angus, Yelan Guo, Daniel Hill-McManus, Alan Brennan, and Petra S. Meier (2014) "Alcohol tax pass-through across the product and price range: do retailers treat cheap alcohol differently?" *Addiction*, 109 (12), 1994–2002, 10.1111/add.12590.

Anderson, Peter, Eva Jané-Llopis, Amy O'Donnell, and Eileen Kaner (2020) "Impact of COVID-19 Confinement on Alcohol Purchases in Great Britain: Controlled Interrupted Time-Series Analysis During the First Half of 2020 Compared With 2015–2018," *Alcohol and Alcoholism*, 56 (3), 307–316, 10.1093/alcalc/agaa128.

Aparicio, Diego and Alberto Cavallo (2021) "Targeted price controls on supermarket products," *The Review of Economics and Statistics*, 103 (1), 60–71, 10.1162/rest_a_00880.

Avdic, Daniel and Stephanie von Hinke (2021) "Extending alcohol retailers' opening hours: Evidence from Sweden," *European Economic Review*, 138 (103830), 1–22, 10.1016/j.euroecorev.2021.103830.

Avena, Nicole M., Julia Simkus, Anne Lewandowski, Mark S. Gold, and Marc N. Potenza (2021) "Substance use disorders and behavioral addictions during the COVID-19 pandemic and COVID-19-related restrictions," *Frontiers in Psychiatry*, 12 (653674), 1–7, 10.3389/fpsyt.2021.653674.

Cabral, Luís and Lei Xu (2021) "Seller reputation and price gouging: Evidence from the COVID-19 pandemic," *Economic Inquiry*, 59 (3), 867–879, 10.1111/ecin.12993.

Calcott, Paul (2019) "Minimum unit prices for alcohol," *Journal of Health Economics*, 66, 18–26, 10.1016/j.jhealeco.2019.04.007.

Callaway, Brantly and Tong Li (2021) "Policy evaluation during a pandemic," Posted at arXiv.org, `https://arxiv.org/abs/2105.06927`, Last accessed on May 28, 2021.

Carpenter, Christopher and Carlos Dobkin (2017) "The minimum legal drinking age and morbidity in the United States," *The Review of Economics and Statistics*, 99 (1), 95–104, 10.1162/REST_a_00615.

Chakraborti, Rik and Gavin Roberts (2021) "Learning to hoard? – The effects of preexisting and surprise price-gouging regulation during the COVID-19 pandemic," *Journal of Consumer Policy*, 44 (4), 507–529, 10.1007/s10603-021-09493-1.

Chalfin, Aaron, Shooshan Danagoulian, and Monica Deza (2021) "COVID-19 has strengthened the relationship between alcohol consumption and domestic violence," NBER Working Paper 28523, National Bureau of Economic Research, 10.3386/w28523.

Conlon, Christopher T. and Nirupama L. Rao (2019) "The price of liquor is too damn high: alcohol taxation and market structure," NYU Wagner Research Paper 2610118, New York University, `https://chrisconlon.github.io/site/liquor.pdf`.

——— (2020) "Discrete prices and the incidence and efficiency of excise taxes," *American Economic Journal: Economic Policy*, 12 (4), 111–43, 10.1257/pol.20160391.

Currie, Janet and Erdal Tekin (2015) "Is there a link between foreclosure and health," *American Economic Journal: Economic Policy*, 7 (1), 63–94, 10.1257/pol.20120325.

Daly, Michael and Eric Robinson (2020) "Problem drinking before and during the COVID-19 crisis in US and UK adults: Evidence from two population-based longitudinal studies," medRxiv - The preprint server for health sciences, 10.1101/2020.06.25.20139022.

Dávalos, María E., Hai Fang, and Michael T. French (2012) "Easing the pain of an economic downturn: macroeconomic conditions and excessive alcohol consumption," *Health Economics*, 21 (11), 1318–1335, 10.1002/hec.1788.

Finlay, Ilora and Ian Gilmore (2020) "Covid-19 and alcohol – a dangerous cocktail," *British Medical Journal*, 369 (m1987), 1–2, 10.1136/bmj.m1987.

Goodman-Bacon, Andrew and Jan Marcus (2020) "Using difference-in-differences to identify causal effects of COVID-19 policies," *Survey Research Methods*, 14 (2), 153–158, 10.18148/srm/2020.v14i2.7723.

Greene, William H. (2003) *Econometric Analysis*, Upper Saddle River, New Jersey: Prentice-Hall, 5th edition.

Griffith, Rachel, Martin O'Connell, and Kate Smith (2019) "Tax design in the alcohol market," *Journal of Public Economics*, 172, 20–35, 10.1016/j.jpubeco.2018.12.005.

——— (2022) "Price floors and externality correction," *The Economic Journal*, forthcoming, 10.1093/ej/ueac011.

Hindriks, Jean and Valerio Serse (2019) "Heterogeneity in the tax pass-through to spirit retail prices: Evidence from Belgium," *Journal of Public Economics*, 176, 142–160, 10.1016/j.jpubeco.2019.06.009.

Hinnosaar, Marit (2016) "Time inconsistency and alcohol sales restrictions," *European Economic Review*, 87, 108–131, 10.1016/j.euroecorev.2016.04.012.

Kueng, Lorenz and Evgeny Yakovlev (2021) "The long-run effects of a public policy on alcohol tastes and mortality," *American Economic Journal: Economic Policy*, 13 (1), 294–328, 10.1257/pol.20180439.

Marcus, Jan and Thomas Siedler (2015) "Reducing binge drinking? the effect of a ban on late-night off-premise alcohol sales on alcohol-related hospital stays in Germany," *Journal of Public Economics*, 123, 55–77, 10.1016/j.jpubeco.2014.12.010.

Miravete, Eugenio J., Katja Seim, and Jeff Thurk (2018) "Market power and the Laffer curve," *Econometrica*, 85 (5), 1651–1687, 10.3982/ECTA12307.

——— (2020) "One markup to rule them all: taxation by liquor pricing regulation," *American Economic Journal: Microeconomics*, 12 (1), 1–41, 10.1257/mic.20180155.

Nakamura, Ryota, Marc Suhrcke, Rachel Pechey, Marcello Morciano, Martin Roland, and Theresa M. Marteau (2014) "Impact on alcohol purchasing of a ban on multi-buy promotions: a quasi-experimental evaluation comparing Scotland with England and Wales," *Addiction*, 109 (4), 558–567, 10.1111/add.12419.

Olden, Andreas and Jarle Møen (2020) "The triple difference estimator," Discussion Paper 2020/1, NHH Dept. of Business and Management Science, `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3582447`.

Robinson, Mark, Claudia Geue, James Lewsey, Daniel Mackay, Gerry McCartney, Esther Curnock, and Clare Beeston (2014) "Evaluating the impact of the alcohol act on off-trade alcohol sales: a natural experiment in Scotland," *Addiction*, 109 (12), 2035–2043, 10.1111/add.12701.

Ruhm, Christopher J. and William E. Black (2002) "Does drinking really decrease in bad times?" *Journal of Health Economics*, 21 (4), 659–678, 10.1016/S0167-6296(02)00033-4.

Snowdon, Christopher (2015) "Minimum unit pricing," in Coyne, Christopher and Rachel Coyne eds. *Flaws and ceilings: Price controls and the damage they cause*, Chap. 10, 177–197, London W1P 3LB: Institute of Economic Affairs, `https://papers.ssrn.com/sol3/`

papers.cfm?abstract_id=3123729.

Stevens, Ann H., Douglas L. Miller, Marianne E. Page, and Mateusz Filipski (2015) "The best of times, the worst of times: understanding pro-cyclical mortality," *American Economic Journal: Economic Policy*, 7 (4), 279–311, 10.1257/pol.20130057.

The Economist (2018) "Bottom's up: Scotland's minimum price for alcohol may have unintended consequences," *The Economist*.

——— (2020) "In a fix: Why price controls are so uncontrollably persistent," *The Economist*, https://www.economist.com/finance-and-economics/2020/01/09/why-price-controls-are-so-uncontrollably-persistent.

WHO (2020) "Alcohol pricing in the WHO European Region: Update report on the evidence and recommended policy actions,"Technical report, World Health Organization, Geneva, Switzerland, https://apps.who.int/iris/bitstream/handle/10665/336159/WHO-EURO-2020-1239-40989-55614-eng.pdf, Last accessed on May 17, 2021.

Wilson, Luke B. Robert Pryce, Colin Angus, Rosemary Hiscock, Alan Brennan, and Duncan Gillespie (2021) "The effect of alcohol tax changes on retail prices: how do on-trade alcohol retailers pass through tax changes to consumers?" *European Journal of Health Economics*, 22 (3), 381–392, 10.1007/s10198-020-01261-1.

Wing, Coady, Kosali Simon, and Ricardo A. Bello-Gomez (2018) "Designing difference in difference studies: best practices for public health policy research," *Annual Review of Public Health*, 39 (1), 453–469, 10.1146/annurev-publhealth-040617-013507.

Xhurxhi, Irena Palamani (2020) "The early impact of Scotland's minimum unit pricing policy on alcohol prices and sales," *Health Economics*, 29 (12), 1637–1656, 10.1002/hec.4156.

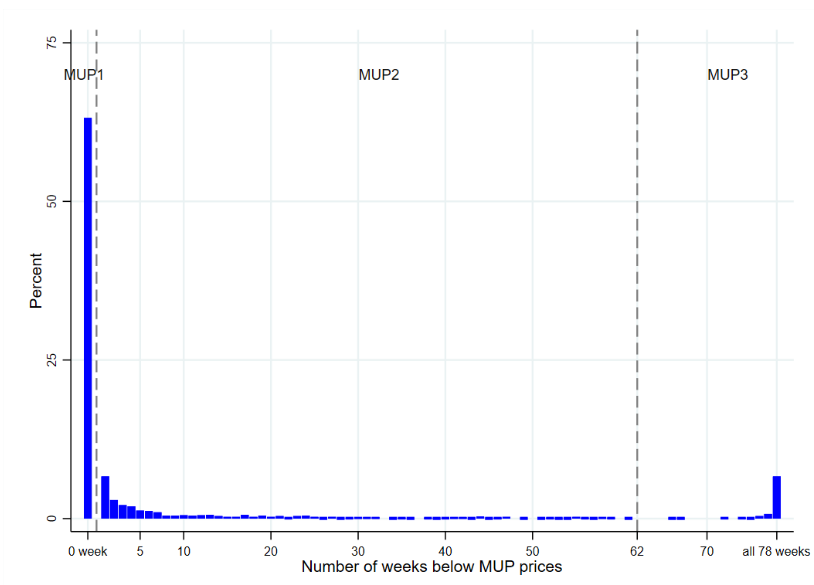
Appendices (online)

These appendices are for the paper titled, “Lockdown Drinking: The Sobering Effect of Price Controls in a Pandemic’ and optionally can be made available as online only.

Appendix A. Further Descriptive Analysis

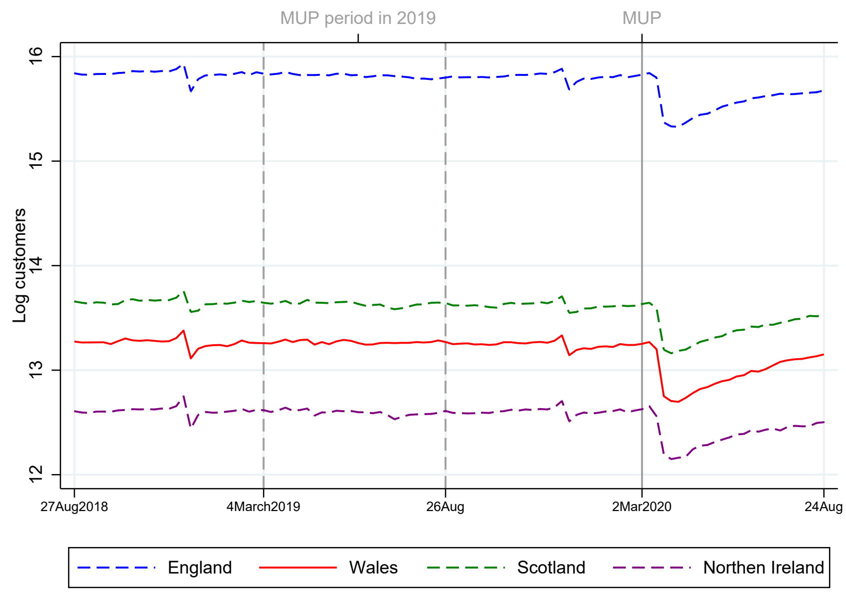
A.1. **Selection of SKUs.** There were 3,934 item (SKUs) in our data set with any alcohol content. We focused on 2,631 alcohol products with positive sales in Wales in the pre-MUP regulation (weeks 1-78). Of these, we further excluded 46 items that were speciality gift bundles (e.g. sets that include a glass or something else and primarily concentrated around the Christmas period) and another 30 products whose ABV content could not be retrieved with our internet search. This left us with a final sample of 2,555 alcohol products used in our analysis. Of these, 1,576 are classified as MUP1 (those that are never below 50p per unit), 703 as MUP2 (intermittently below 50p per unit) and only 276 items as MUP3 products (consistently below 50p per unit). The cutoff between 'intermittently' and 'consistently' (i.e. between MUP2 and MUP3 products) is if the price was less than 50p per unit 80% of the time or more (i.e. about 62 weeks out of 78) and is based the frequency plot in Figure A-1. As the figure shows, there is a clear break around value of 62 and classifications, and hence results, would not change by much if for instance we changed it to 60 weeks or 70 weeks. While there are relatively fewer items classified as MUP2 and MUP3, which would be the direct target of the regulation, they in fact represent 71.4% of alcohol purchase by quantity (the share by quantity is 28.6%, 37.6% and 33.8% for MUP1, MUP2 and MUP3 respectively).

Figure A-1. Frequency of Prices Below 50p Per Alcohol Unit – Sample 2,555 products



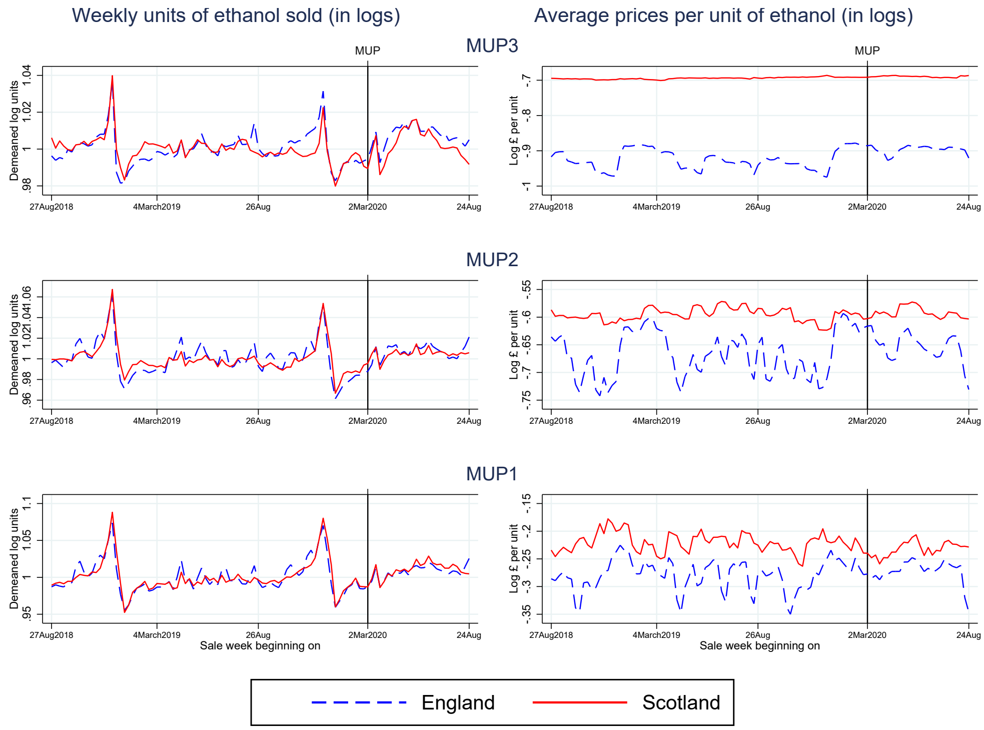
A.2. **Customers over time.** Figure A-2 plots the log of number of customers of the retailer by country. There is a parallel drop in the number of visits in all four countries at the time of the COVID-19 lockdown restrictions.

FIGURE A-2. Weekly Customer Numbers (log values) by Country



A.3. **Quantity and Price for England and Scotland.** Figure A-3 plots the log of quantity (left) and log of prices (right) for England and Scotland overtime and by product groups MUP1, MUP2 and MUP3.

FIGURE A-3. Weekly Average Quantity and Price by MUP Product Group and Country



A.4. **DD vs DDD estimator.** This appendix provides a comparison of DD and DDD estimators. We start by reporting the means for one outcome variable, total quantity (not logged) in a format that highlights our DD and DDD methodology. Table A-1 shows mean values by MUP category, country computed in comparable pre- and post-MUP implementation periods of 26 weeks, from March-August in 2019 and March-August 2020 (whereas in the regression analysis reported in the main paper, we use the full period since we can control for seasonal effects more easily).

TABLE A-1. Quantity (Units of Alcohol) per week

Quantity	Wales		England	
	pre	post	pre	post
MUP1 Products (never < 50ppu)	1.73	2.12	22.12	26.18
% increase	22.90%		18.35%	
DD MUP1:	4.54%			
MUP2 Products (intermittently < 50ppu)	2.49	2.84	30.10	33.21
% increase	14.21%		10.36%	
DD MUP2:	3.85%			
MUP3 Products (consistently < 50ppu)	2.30	1.46	24.19	26.87
% increase	-36.31%		11.12%	
DD MUP3:	-47.42%			
DDD-MUP3: (DD-MUP3 - DD-MUP1)	-51.97%			
DDD-MUP2: (DD-MUP2 - DD-MUP1)	-0.70%			
Overall sales	6.51	6.42	76.40	86.27
% increase	-1.31%		12.91%	
% DD (Combined effect)	-14.23%			

Mean value in millions of alcohol units over 26 weeks before and after March/02/2020.

For products classified as MUP1 (never < 50ppu), the mean value of quantity sold per week in Wales was 1.73 million units of alcohol, and this increased to 2.12 million units in the post period following MUP implementation in Wales, for a total change of 22.9% increase. By comparison, the same products increased by 18.35% in England. Thus, for MUP1 products, the net increase in sales relative to England was 4.54%. Similar calculations for MUP2 products (intermittently < 50ppu) show a relative net increase in Wales of 3.85%, i.e., sales increased by 14.21% in Wales and 10.36% in England. Additionally, looking at the MUP3 products (consistently < 50ppu), we find that quantity sold decreased by 36.31% in Wales and increased by 11.12% in England. Thus, relative to England, *there was a 47.42% reduction in weekly units of alcohol sold for MUP3 products* in Wales, which is equivalent to the DD estimate for MUP3, but without using all the data or controlling for seasonality. Under the alternative assumption that there was no spillover but there was a country lockdown differential of 4.54% in Wales relative to England, the triple difference estimates would be

-0.70% and -51.97% decrease in quantity sold of MUP2 and MUP3 products respectively due to the minimum unit price regulation.

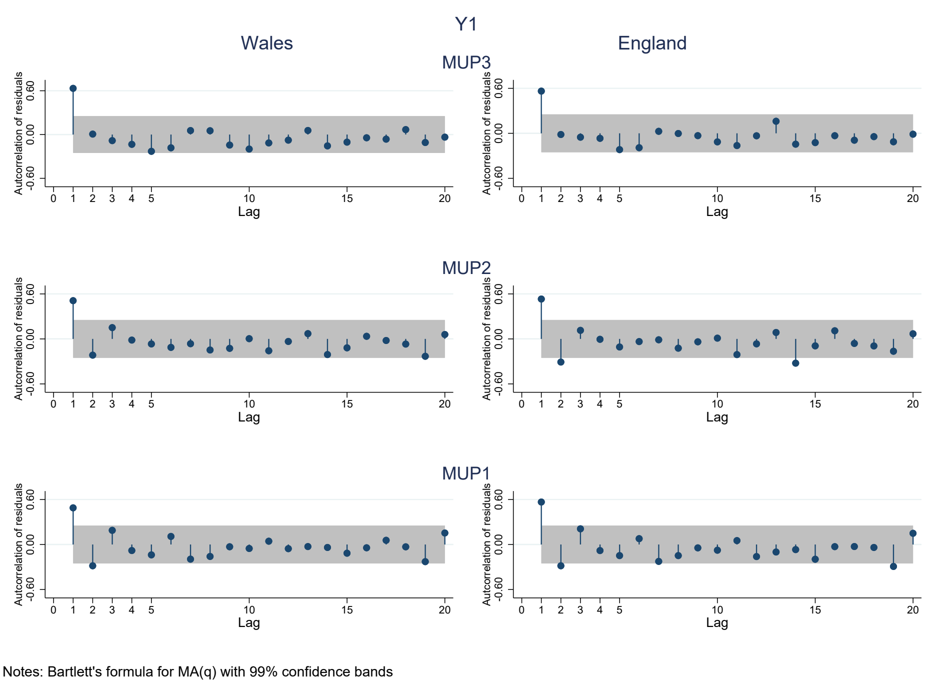
The bottom panel of the table indicates that there was an overall decrease in quantity of 1.31% in Wales, while over the same period, there was a 12.91% increase in England. Thus, the net difference is 14.23% decease in quantity sold in Wales relative to England. This is a DD estimate and inclusive of any spillover effects that may shift demand from MUP2 and MUP3 products to MUP1 products. For all the remaining outcomes, and to control for time trends and seasonality, we use regression analysis.

Appendix B. Robustness checks and Parallel Trends

The main model is estimated allowing for heteroskedastic error structure with cross-sectional correlation across six groups (three MUP categories and 2 countries). Additionally it allows for separate AR(1) process for each of the six time series. This appendix provides: (1) a graphical analysis of partial autocorrelation functions for log of quantity Y1 (Y2-Y4 available upon request); (2) estimates of results in Table 2 and Table 3 under alternative assumption that there is no cross-section correlation across the six series (it still allows for heteroskedastic error structure and separate AR(1) for each group); (3) re-estimate of the main model but with country-specific time trends and country specific monthly trends; (4) two tests for parallel trends, where the second on is via a placebo test.

B.1. **Partial autocorrelation functions.** This section provides partial correlograms for Y1 separated by MUP groups and country. Thus correlograms for six time series (MUP1, MUP2, MUP3 for England and Wales) and displayed for up to 20 lags of the outcome variable. These graphs lend support to using AR(1) process in the estimation. Similar correlograms for Y2 through Y4 also provide support for AR(1) error structure, but are omitted in interest of space (available from authors upon request).

Figure B-1. Y1: log quantity in units (i.e. 10ml of ethanol per unit of alcohol)



B.2. **Estimates under alternative error structure.** The main analysis given in Table 2 and Table 3 assumes the error terms in the six time series are AR(1) and correlated across the six series (MUP1, MUP2, MUP3 Groups for England and Wales). An alternative assumption is that while they are still AR(1), these series are independent of each other.

Results corresponding to Table 2 for the alternative assumption on the error structure are given below in Table B-1.

TABLE B-1. Effect of MUP regulation (non-correlated errors across groups)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP3: β_{11}	-0.588^{a} (0.127)	-0.458^{a} (0.098)	-0.218^{b} (0.096)	0.226^{a} (0.016)
MUP2: β_{10}	0.00339 (0.137)	0.00977 (0.107)	0.0531 (0.099)	0.0566^{a} (0.018)
MUP1: β_5	0.0478 (0.113)	0.0620 (0.085)	0.0586 (0.086)	0.00145 (0.013)
	DD estimates			
MUP3: $\beta_5 + \beta_{11}$	-0.540^{a} (0.057)	-0.396^{a} (0.049)	-0.159^{a} (0.044)	0.227^{a} (0.010)
MUP2: $\beta_5 + \beta_{10}$	0.0512 (0.078)	0.0718 (0.065)	0.112^{b} (0.050)	0.0580^{a} (0.014)
	Combined effect			
Combined (DDD) (MUP2 and 3)	-0.241^{b} (0.118)	-0.208^{b} (0.093)	-0.0648 (0.086)	0.138^{a} (0.014)
Combined (DD) (MUP1,2 and 3)	-0.193^{a} (0.059)	-0.145^{a} (0.054)	-0.00455 (0.048)	0.140^{a} (0.010)
Observations	624	624	624	624
chi2	347661.8	3290.7	2511.0	34781.6
df	26	26	26	26

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group and group level heteroscedasticity but no correlation across groups (robust se in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. The main text provides results when errors are also correlated across country-MUP groups in Table 2.

Similarly, results corresponding to Table 3 for the alternative assumption on the error structure are given below in Table B-2.

Table B-2. Falsification Test - Northern Ireland/England (non-correlated errors across groups)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP3: β_{11}	-0.0904	-0.0806	-0.0689	-0.00852
	(0.132)	(0.102)	(0.096)	(0.016)
MUP2: β_{10}	-0.0905	-0.0729	-0.0613	-0.00448
	(0.142)	(0.113)	(0.100)	(0.022)
MUP1: β_5	0.0375	0.0138	0.0304	0.0188
	(0.113)	(0.086)	(0.083)	(0.014)
	DD estimates			
MUP3: $\beta_5 + \beta_{11}$	-0.0529	-0.0668	-0.0384	0.0103
	(0.068)	(0.056)	(0.048)	(0.009)
MUP2: $\beta_5 + \beta_{10}$	-0.0531	-0.0592	-0.0309	0.0144
	(0.086)	(0.074)	(0.055)	(0.017)
	Combined effect			
Combined (DDD)	-0.0913	-0.0818	-0.0732	-0.00941
(MUP2 and 3)	(0.118)	(0.092)	(0.084)	(0.016)
Combined (DD)	-0.0532	-0.0684	-0.0429	0.0106
(MUP1,2 and 3)	(0.059)	(0.052)	(0.046)	(0.010)
Observations	624	624	624	624
chi2	20163.9	645.1	1128.1	29905.0
df	26	26	26	26

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group and group level heteroscedasticity but no correlation across groups (robust se in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. The main text provides results when errors are also correlated across country-MUP groups in Table 3.

B.3. **Estimates under country-specific trends and monthly fixed effects.** The main analysis given in Table 2 and Table 3 estimates the model with time trends (up to polynomial of degree four) and monthly time trends (dummies for each month) that are common to the countries in question (England and Wales in Table 2 or England and Northern Ireland in Table 3). In this appendix, we relax this assumption further and allow for country-specific time trends as well as country-specific monthly effects.

Results corresponding to Table 2 for country-specific trends and fixed effects is given below in Table B-3.

TABLE B-3. Effect of MUP Implementation in Wales (w/ country specific time trends and monthly effects)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP3: β_{11}	-0.586^a	-0.459^a	-0.217^a	0.228^a
	(0.014)	(0.012)	(0.010)	(0.005)
MUP2: β_{10}	0.00489	0.00958	0.0532^a	0.0552^a
	(0.011)	(0.009)	(0.007)	(0.005)
MUP1: β_5	0.0829^b	0.0940^a	0.0773^a	-0.00721
	(0.032)	(0.023)	(0.019)	(0.007)
	DD estimates			
MUP3: $\beta_5 + \beta_{11}$	-0.503^a	-0.365^a	-0.140^a	0.220^a
	(0.032)	(0.023)	(0.019)	(0.007)
MUP2: $\beta_5 + \beta_{10}$	0.0878^a	0.104^a	0.131^a	0.0480^a
	(0.032)	(0.023)	(0.018)	(0.008)
	Combined effect			
Combined (MUP2 and 3)	-0.240^a	-0.208^a	-0.0645^a	0.141^a
	(0.009)	(0.008)	(0.007)	(0.005)
Combined (MUP1,2 and 3)	0.0668^b	0.0841^a	0.0755^a	-0.00973
	(0.030)	(0.022)	(0.020)	(0.007)
Observations	624	624	624	624
chi2	537384.3	3953.1	3056.8	28424.9
df	41	41	41	41

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups (robust S.E. in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. The main text provides results when there is a common (across countries) time trend and common monthly fixed effects in Table 2. By comparison, this table allows for country-specific time trends and country-specific monthly fixed effects.

Similarly, results corresponding to Table 3 for the country specific trends and monthly effects is given in Table B-4.

Table B-4. Falsification Test - Northern Ireland/England (country specific trends and monthly effects)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP3: β_{11}	-0.0820^a	-0.0696^a	-0.0604^a	-0.00930
	(0.027)	(0.023)	(0.018)	(0.006)
MUP2: β_{10}	-0.0858^a	-0.0683^a	-0.0562^a	-0.00564
	(0.028)	(0.024)	(0.020)	(0.007)
MUP1: β_5	0.0350	0.0301	0.0449	0.00863
	(0.059)	(0.048)	(0.040)	(0.007)
	DD estimates			
MUP3: $\beta_5 + \beta_{11}$	-0.0470	-0.0395	-0.0156	-0.000666
	(0.059)	(0.049)	(0.039)	(0.007)
MUP2: $\beta_5 + \beta_{10}$	-0.0508	-0.0382	-0.0113	0.00299
	(0.059)	(0.050)	(0.040)	(0.008)
	Combined effect			
Combined (MUP2 and 3)	-0.0904^a	-0.0829^a	-0.0739^a	-0.00695
	(0.019)	(0.016)	(0.014)	(0.005)
Combined (MUP1,2 and 3)	-0.00472	0.00182	0.00288	0.00436
	(0.051)	(0.045)	(0.040)	(0.008)
Observations	624	624	624	624
chi2	182635.3	2030.4	2078.0	22133.4
df	41	41	41	41

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups (robust S.E. in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. The main text provides results when there is a common (across countries) time trend and common monthly fixed effects in Table 3. By comparison, this table allows for country-specific time trends and country-specific monthly fixed effects.

B.4. **Parallel Trend Assumption.** Critical to the difference-in-differences model is the 'parallel trends' assumption (e.g., as Wing et al. (2018) discuss in the context of public health policy analysis). That is, without the MUP policy, time trends across MUP groups would have been parallel in Wales and England. The graphical inspection of Figure 1 suggests similar trends in the period prior to the MUP implementation (weeks 1-78) and that the common trends is a reasonable assumption. We consider two tests here.

Test 1. We test whether the trends in Y1, Y2, Y3 and Y4 are parallel in the pre-MUP period ($t < T = 78$). We estimate a variant of Equation 1 with a linear time trend (t) interacted with the treatment group dummies ($M2$ and $M3$) and the country indicators (W) instead of the original P_{it} dummy variable. Thus, we estimate

$$\begin{aligned} Y_{it} = {} & \alpha_1 + \alpha_2 X_{it} + \beta_1 W_{it} + \beta_2 t + \beta_3 M2_{it} + \beta_4 M3_{it} \\ & + \beta_5 (W_{it} t) + \beta_6 (W_{it} M2_{it}) + \beta_7 (W_{it} M3_{it}) + \beta_8 (t M2_{it}) + \beta_9 (t M3_{it}) \\ & + \beta_{10} (W_{it} t M2_{it}) + \beta_{11} (W_{it} t M3_{it}) + u_{it}, \end{aligned} \tag{3}$$

and test whether β_5, β_{10}, and β_{11} are significantly different from zero. Note that X consists of quadratic, cubic and quartic time trends and monthly-dummies. The p-values of the F-test results are reported in Table B-5 for all outcomes. We do not reject the hypothesis that the these coefficients are equal to zero for all outcomes, with p-values always above 0.1. For log prices (Y4) p-values are lower than for other outcomes, notably for MUP3 products. However, the common trend assumption holds at 1% level or below for all outcomes and MUP groups.

Table B-5. Parallel trends test (in pre-MUP period), Wales vs. England

		Y1	Y2	Y3	Y4
MUP3	Chi2	2.111	1.503	0.599	0.946
	p-value	0.146	0.220	0.439	0.331
MUP2	Chi2	0.063	0.052	0.118	0.433
	p-value	0.802	0.819	0.732	0.511
MUP1	Chi2	1.830	0.720	0.243	1.137
	p-value	0.176	0.396	0.622	0.286

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups.

Test 2. Similar to above, we only use pre-MUP regulation observations ($t < T = 78$). Again we re-estimate equation (1), but place a placebo policy at $T/2$ at week 39 (T/2 is between week 38 and 39). Specifically, in equation (1) we redefine the indicator variable $P_{it} = 1$ if ≥ 39 and otherwise 0. Regression coefficients of interest β_5, β_{10} and β_{11} for all four outcomes are summarized in Table B-6. In all but one case, they are not statistically significant and we do not reject the null hypothesis of parallel trends. The one exception is for $Y1$ for MUP3 parameter β_{11} in which case the parameter is significantly different from zero at the 10% level. But even here, the magnitude is only -0.0204 and compares sharply with the non-placebo variant reported in Table 2 where the same parameter was -0.587 and significant at 1% level.

Table B-6. Falsification test - Imposing an hypothetical MUP in the middle of the pre-MUP period in Wales (selected coefficients only)

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillovers)			
MUP3: β_{11}	-0.0204^c	-0.0153	-0.0111	0.00213
	(0.011)	(0.010)	(0.009)	(0.004)
MUP2: β_{10}	0.00270	0.00258	0.00133	-0.0000374
	(0.009)	(0.006)	(0.006)	(0.003)
MUP1: β_5	0.0252^b	0.0110	0.00810	-0.00175
	(0.012)	(0.008)	(0.008)	(0.003)
Observations	462	462	462	462
chi2	472661.7	2489.6	1091.7	20060.6
df	26	26	26	26

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups (robust S.E. in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively.

Appendix C. Regression coefficients

C.1. **Coefficients in Table 2.** This appendix provides detailed regression coefficients reported Table 2 in the main text.

Table C-1. Regression Coefficients - DDD Wales/England/MUP-Group

	Y1	Y2	Y3	Y4
β_1 (Wales)	-2.562[a]	0.000816	-0.00572	-0.00871[a]
	(0.006)	(0.004)	(0.004)	(0.002)
β_2 (Post)	0.134	0.165	0.170[c]	-0.0159
	(0.155)	(0.116)	(0.096)	(0.016)
β_3 (MUP2)	0.252[a]	0.190[a]	-0.0957[a]	-0.388[a]
	(0.019)	(0.014)	(0.017)	(0.005)
β_4 (MUP3)	0.0410	0.0224	-0.385[a]	-0.645[a]
	(0.031)	(0.024)	(0.027)	(0.005)
β_5 (Wales*Post)	0.0453[a]	0.0612[a]	0.0592[a]	0.00200
	(0.012)	(0.008)	(0.008)	(0.003)
β_6 (Wales*MUP2)	0.0545[a]	0.0429[a]	0.0397[a]	0.00599[b]
	(0.005)	(0.005)	(0.004)	(0.003)
β_7 (Wales*MUP3)	0.198[a]	0.152[a]	0.102[a]	-0.0173[a]
	(0.007)	(0.006)	(0.005)	(0.003)
β_8 (Post*MUP2)	-0.0169	0.00593	-0.0196	0.00587
	(0.037)	(0.027)	(0.032)	(0.010)
β_9 (Post*MUP3)	-0.0196	-0.00874	-0.0594	0.0200[b]
	(0.061)	(0.047)	(0.051)	(0.010)
β_{10} (Wales*Post*MUP2)	0.00381	0.00972	0.0531[a]	0.0553[a]
	(0.011)	(0.009)	(0.007)	(0.005)
β_{11} (Wales*Post*MUP3)	-0.587[a]	-0.459[a]	-0.218[a]	0.225[a]
	(0.014)	(0.012)	(0.010)	(0.005)
t: time/1000	15.66	19.77	17.56	2.926
	(20.441)	(15.583)	(12.336)	(2.163)
$t2$: t^2 (coeff/10)	-68.94	-93.12	-85.43[c]	-14.37
	(85.17)	(64.54)	(51.01)	(8.898)
$t3$: t^3 (coeff/100)	102.7	149.2	134.9[c]	22.16[c]
	(126.9)	(95.86)	(75.76)	(13.18)

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, group level heteroscedasticity and correlation across groups (robust se in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. Selected regression coefficients from this table appear in Table 2.

continued

Table C-1. Regression Coefficients - DDD Wales/England/MUP-Group

	Y1	Y2	Y3	Y4
$t4$: t^4	-49.79	-74.77	-66.05[c]	-10.42[c]
(coeff/1000)	(60.44)	(45.64)	(36.09)	(6.272)
month=2	0.0518	0.0338	0.0421	0.00394
	(0.067)	(0.050)	(0.038)	(0.007)
month=3	0.146	0.133[c]	0.108[b]	-0.00808
	(0.092)	(0.069)	(0.054)	(0.010)
month=4	0.235[a]	0.245[a]	0.198[a]	-0.0197[b]
	(0.088)	(0.067)	(0.053)	(0.009)
month=5	0.317[a]	0.301[a]	0.247[a]	-0.0151
	(0.089)	(0.068)	(0.054)	(0.009)
month=6	0.254[a]	0.240[a]	0.198[a]	-0.00883
	(0.090)	(0.069)	(0.055)	(0.010)
month=7	0.212[b]	0.199[a]	0.148[b]	-0.00995
	(0.100)	(0.076)	(0.060)	(0.010)
month=8	0.261[b]	0.250[a]	0.198[a]	-0.0160
	(0.117)	(0.088)	(0.069)	(0.012)
month=9	0.197[c]	0.173[b]	0.141[b]	-0.00484
	(0.107)	(0.081)	(0.063)	(0.011)
month=10	0.244[a]	0.224[a]	0.153[a]	-0.0271[a]
	(0.087)	(0.067)	(0.052)	(0.009)
month=11	0.250[a]	0.219[a]	0.140[a]	-0.0304[a]
	(0.076)	(0.058)	(0.046)	(0.008)
month=12	0.266[a]	0.202[a]	0.142[a]	-0.0313[a]
	(0.065)	(0.049)	(0.038)	(0.007)
Constant	16.68[a]	1.142[a]	1.010[a]	-0.274[a]
	(0.171)	(0.130)	(0.105)	(0.018)
Observations	624	624	624	624
chi2	347661.8	3290.7	2511.0	34781.6
df	26	26	26	26

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, group level heteroscedasticity and correlation across groups (robust se in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. Selected regression coefficients from this table appear in Table 2.

C.2. **Combined effects.** This appendix provides selected coefficients from ancillary regressions used to compute the combined effect of the regulation on MUP2 and MUP3 products. The combined effects were reported at the bottom of Table 2. The combined effect is computed by estimating a variant of the main model in equation (1) with $M23$ being a dummy variable that takes the value of 1 if $M2 = 1$ or $M3 = 1$ and 0 otherwise.

$$\begin{aligned} Y_{it} &= \alpha_1 + \alpha_2 X_{it} + \beta_1 W_{it} + \beta_2 P_{it} + \beta_{3,4} M23_{it} \\ &\quad + \beta_5 (W_{it} P_{it}) + \beta_{6,7} (W_{it} M23_{it}) + \beta_8 (P_{it} M23_{it}) \\ &\quad + \beta_{10,11} (W_{it} P_{it} M23_{it}) + u_{it} \end{aligned} \tag{4}$$

Table C-2 provides selected estimates of coefficients from the equation given above.

Table C-2. Effect of MUP regulation (MUP2 and MUP3 groups combined in a single group, selected regression coefficients), Wales vs. England

	(Y1)	(Y2)	(Y3)	(Y4)
	DDD estimates (No spillover)			
MUP2/3: $\beta_{10,11}$	-0.241^b	-0.208^b	-0.0648	0.138^a
	(0.118)	(0.093)	(0.086)	(0.014)
MUP1: β_5	0.0484	0.0634	0.0603	0.00152
	(0.102)	(0.075)	(0.071)	(0.010)
	DD estimates			
MUP2/3: $\beta_{10,11} + \beta_5$	-0.193^a	-0.145^a	-0.00455	0.140^a
	(0.059)	(0.054)	(0.048)	(0.010)
Observations	416	416	416	416
chi2	13695.0	1673.0	667.8	21654.7
df	22	22	22	22

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, and correlation across groups (robust se in parenthesis). Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively. Only selected regression coefficients shown.

C.3. **MUP Effect by Product Type - Details.** This appendix provides a summary of the effects from the MUP implementation on different types of alcoholic beverages.

Table C-3 provides a breakdown by how many products are classified as MUP1, MUP2 and MUP3 by five alcohol product types: (i) Beers (includes ales, stouts and lagers); (ii) Ciders (including perries); (iii) Spirits; (iv) Wines (including all wine-based drinks); and (v) Flavored alcohol beverages (FABs). MUP3 products (consistently < 50ppu) are more common in the ciders category (27%); MUP2 products (intermittently < 50ppu) occur mainly for wines (31%), spirits (28%), and beers (28%). Flavored alcoholic beverages (FABs) are rarely priced below 50ppu.

Table C-3. Number of Items and Alcohol Unit Shares by Product Type in Wales

MUP-types	Item Counts Beers	Ciders	Wines	Spirits	FABs	Total	Shares (Qnty)
MUP1 (never < 50ppu)	426	89	560	368	133	1,576	28.63%
MUP2 (intermittently < 50ppu)	189	35	305	164	10	703	37.55%
MUP3 (consistently < 50ppu)	64	45	114	53	0	276	33.82%
Total	679	169	979	585	143	2,555	100%

Counts of SKUs and quantity shares are based on pre-MUP regulation data from Wales.

We estimate equation (1) by product type using data from Wales and England. We omitted flavored alcoholic beverages as there were no items of that product type in the MUP3 product category and only 10 items in MUP2 category. Impact for each product type is estimated the same way, i.e., by first aggregating the sales data by MUP classification, week and country but including only sales for the appropriate product type (Beers, Ciders, etc.) and then estimating equation (1) for each of them separately.

The DDD estimates (to be interpreted as no spillover effects and coefficient on MUP1 products as due to lockdown differentials) are summarized in Table C-4. The impact of the price floor is not even across all product types. There is a decline in quantity of MUP3 products for all types, but the decline is much larger for beers and ciders than for spirits and wines. There is also an opposite negative and positive effect on MUP2 products for beers and ciders respectively, but no significant effect for spirits and wines groups. Similarly, beers and ciders also show that consumption of MUP1 products increased in Wales relative to England following MUP implementation and the lockdowns commencing ($\beta_5 = 0.120$ and 0.118 respectively, and statistically significant) while there is no similar increase for spirits and wines ($\beta_5 = 0.0391$ and 0.0129 respectively and not statistically significant).

Quantity per customer decreased for MUP3 products and increased for MUP1 products for all four alcohol types, and there are mixed results for MUP2 products: increasing by 2.03% and 2.35% for ciders and wines, but no change for beers or spirits. Expenditures per customer also follow a similar pattern, decreasing for MUP3 products (especially for beers, but less so for wines) and increasing in all MUP1 products in Wales relative to England.

In terms of prices, MUP3 prices increase for all four types (up 26.7% for beers, 53.1% for ciders, 20.2% for spirits and 13.4% for wines), and a similar but smaller increase in prices for MUP2 products, with increase of 11.3%, 2.7% and 6.6% for beers, ciders and spirits, respectively, but no significant change for wines. MUP1 products do not change much in prices, and where we do see a small but statistically significant change (+1.15% for wines and -0.82% for spirits), we associate these as due to country lockdown differentials.

TABLE C-4. DDD Estimates by Product Types (Selected regression coefficients)

	Y1	Y2	Y3	Y4
	Beers (Ales,Stout & Lager)			
MUP3: β_{11}	-1.104^a	-0.573^a	-0.284^a	0.237^a
	(0.024)	(0.016)	(0.009)	(0.008)
MUP2: β_{10}	-0.0392^c	-0.000919	0.0571^a	0.107^a
	(0.023)	(0.014)	(0.009)	(0.011)
MUP1: β_5	0.120^a	0.0727^a	0.0573^a	-0.000741
	(0.012)	(0.005)	(0.004)	(0.004)
	Ciders & Perries			
MUP3: β_{11}	-0.764^a	-0.243^a	-0.0524^a	0.426^a
	(0.037)	(0.013)	(0.005)	(0.010)
MUP2: β_{10}	0.0884^b	0.0201^a	0.00564	0.0266^b
	(0.044)	(0.005)	(0.005)	(0.010)
MUP1: β_5	0.118^a	0.0460^a	0.0349^a	-0.000736
	(0.036)	(0.006)	(0.006)	(0.005)
	Spirits			
MUP3: β_{11}	-0.392^a	-0.212^a	-0.0759^a	0.184^a
	(0.032)	(0.015)	(0.012)	(0.006)
MUP2: β_{10}	0.00265	0.00257	0.0300^a	0.0639^a
	(0.033)	(0.015)	(0.009)	(0.010)

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, group level heteroscedasticity and correlation across groups (robust se in parenthesis). Only selected regression coefficients shown. Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively.

continued

Table C-4. DDD Estimates by Product Types (Selected regression coefficients)

	Y1	Y2	Y3	Y4
MUP1: β_5	0.0391	0.0334^a	0.0257^a	-0.00827^c
	(0.025)	(0.008)	(0.007)	(0.005)
	Wines (including other wine-based drinks)			
MUP3: β_{11}	-0.172^a	-0.0905^a	-0.0292^a	0.126^a
	(0.018)	(0.011)	(0.009)	(0.005)
MUP2: β_{10}	0.0200	0.0232^b	0.0217^a	0.00461
	(0.014)	(0.009)	(0.008)	(0.004)
MUP1: β_5	0.0129	0.0245^a	0.0282^a	0.0115^a
	(0.014)	(0.008)	(0.008)	(0.004)

Y1 is log of quantity (in units of alcohol), Y2 log of quantity per customer, Y3 is log of expenditure per customer and Y4 is log of price per unit. F-GLS estimates with separate AR(1) process for each country-MUP group, group level heteroscedasticity and correlation across groups (robust se in parenthesis). Only selected regression coefficients shown. Superscripts a, b, c indicate significance at 1%, 5% and 10%, respectively.