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Discussion Paper

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Estimation of own and cross price elasticities of alcohol demand in the UK – a pseudo-panel approach using the Living Costing and Food Survey 2001 to 2009

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Abstract:

Background: The estimation of own- and cross-price elasticities of alcohol demand for different beverages and trade types (off-trade vs. on-trade) is valuable for the appraisal of price-based policy interventions such as minimum unit pricing and taxation. A few studies have attempted to estimate cross-price elasticities using either national aggregate time series or cross-sectional data, while the ideal dataset would be longitudinal panel data which are normally unavailable. A pseudo-panel approach offers the opportunity to apply panel models using repeated cross-sectional data. This paper aims to apply this approach to the UK Living Cost and Food Survey (LCF) 2001/2-2009 to estimate the own- and cross-price elasticities of off- and on-trade beer, cider, wine, spirits and ready-to-drinks (RTDs) in the UK.

Methods: A pseudo-panel with 72 subgroups defined by birth year, gender and socioeconomic status are constructed. Elasticities are estimated using fixed effects, random effects and standard ordinary least squares models with purchase quantity as the dependent, and price of alcohol and income as main independent variables. Additional independent variables are tested such as rates of unemployment and marriage and smoking status. Extensive sensitivity analyses are performed to test the robustness of model results.

Results: All estimated own-price elasticities are negative and 8 out of 10 are statically significant ($p<0.05$). Off-trade cider and beer are most elastic (-1.27 and -0.98) and off-trade spirits and on-trade RTDs are least elastic (-0.08 and -0.19). Estimated cross-price elasticities are smaller in magnitude with a mix of positive and negative signs. Model estimates are reasonably robust to different modelling methods and selection criteria for the pseudo-panel subgroups. Fixed effects models appear to be more theoretically plausible than random effects models.

Conclusions: The pseudo-panel approach offers a method to estimating price elasticities of alcohol demand using repeated cross-sectional data. Resulting estimates of own- and cross-price elasticities appear theoretically plausible and robust and could be used for appraising price-based interventions in the UK.

Keywords: Alcohol demand, Elasticities, Cross price elasticities, Pseudo-panel

Introduction

The consumption of alcohol and alcohol-related health and social harms continue to be an issue of extensive policy debate in the UK and many other countries. Price-based policy interventions such as minimum unit pricing (MUP) and increases in taxation have been actively considered by the UK and Scottish governments who aim to reduce alcohol consumption and consequently various alcohol related harms among the population [1]. The estimation of price elasticities of alcohol demand is essential for the appraisal of such price-based policy interventions, because they link the prices of alcohol, which these interventions directly affect, and the demand for alcohol, which such interventions aim to reduce.

Price elasticities of alcohol demand represent the percentage change in alcohol demand due to a 1% change in alcohol price. When different beverages are considered (e.g., beer, wine, sprits), the elasticities can be classified as own- and cross-price elasticities, with own-price elasticities indicating the percentage change in the demand for one type of alcohol due to a 1% change in the price of this type of alcohol, and cross-price elasticities indicating the percentage change in demand for one type of alcohol due to a 1% change in the price of another type of alcohol. The sign of cross-price elasticities indicates whether the two types of alcohol of interest are substitutes (i.e., positive sign) or complements (i.e., negative sign). It is important to estimate elasticities for different beverage types (e.g. beer versus wine) and different trade sectors (off-trade versus on-trade) for policy appraisals as differential consumer preferences mean elasticities may vary across these categories. In the UK, off-trade refers to venues where alcohol can be sold but not consumed (e.g. supermarkets) and on-trade refers to venues where alcohol can be sold and consumed (e.g. pubs).

Meta-analyses of international evidence have focused on differential elasticities by beverage type and demonstrate that beer, wine and spirits have different own-price elasticities, with beer appearing to be less elastic than wine and spirits [2-4]. Cross-price elasticities, especially between off- and on-trade, are less widely studied. Previous studies suggested that different beverage types can be either substitutes or complements [5-7]; whilst off-trade purchasing and on-trade-purchasing were typically substitutes, albeit with some exceptions [7-9]. Few UK studies were identified which investigated cross-price elasticities between off- and on-trade alcohol. Huang et al examined own- and cross-price elasticities for off-trade beer, on-trade beer, wine and spirits using aggregate time series data in the UK from 1970 to 2002 [7]. Collis et al used a Tobit approach to model own- and cross-price elasticities for off- and on-trade beer, cider, wine, spirits and ready-to-drinks (RTDs) using household-level repeated cross-sectional data (the Living Cost and Food Survey, or LCF) in the UK from 2001/2 to 2006 [8]. Purshouse et al used the same data source when modelling minimum price policies, using estimated own- and cross-price elasticities for off- and on-trade beer, wine, spirits and RTDs, further split by high- and low-priced using an iterative three-stage least squares regression on a system of 17 simultaneous equations [9]. The key methodological limitation of these studies is the use of either national aggregate time series data or cross-sectional data; whereas the ideal data source is longitudinal/panel data where individuals or households have repeated observations over time. Such individual-level panel data is superior because panel models applied on such data use individuals themselves as controls to account for unobserved heterogeneity between individuals and causal relationships may be derived from such data.

However, individual-level panel data is generally more difficult and costly to obtain than cross-sectional or aggregate time series data. A solution to this problem is to use repeat cross-sectional data to construct a pseudo-panel and this approach takes advantage of the series of independent repeated cross-sectional surveys in many countries, such as the LCF in the UK. Compared to true panel data, repeated cross-sectional data does not have the issue of attrition and generally suffer much less from non-response, and are normally much larger in terms of both sample size and number of years of data [10]. A pseudo-panel approach constructs a panel where the unit of analysis is constructed population subgroups rather than individuals in the original cross-sectional data. Subgroups are defined by a set of characteristics (e.g. birth year, gender, ethnicity) which do not change or remain broadly constant over time. It is assumed that although the individuals within groups change between waves of cross-sectional surveys, the group itself can be viewed as a consistent panel member over time. Standard techniques for analysing panel data are then applied [10-13]. The pseudo-panel approach has been applied in many empirical studies estimating elasticities of demand for various goods (e.g. [14]), however, it has not been used to estimate elasticities of alcohol demand.

This study aims to apply the approach using the LCF data from 2001/2 to 2009 to estimate the own- and cross-price elasticities of off- and on-trade beer, cider, wine, spirits and RTDs in the UK. The key research questions are 1) What are the own- and cross- price elasticities for different types of alcohol in the UK? 2) How do the estimates compare with previous estimates from the literature? 3) How robust are these estimates to different model specifications and alternative constructions of the pseudo-panel.

Method

Data

The LCF, previously known as the Expenditure and Food Survey, is a national UK survey sponsored by the Office for National Statistics (ONS) and the Department for Environment, Food and Rural Affairs (DEFRA). The LCF is a cross-sectional survey of private households, collecting information on purchasing at both the household and individual level. Data on the purchasing of non-durable goods including alcohol is collected via a confidential two-week personal diary for individuals aged 16 and over. In the UK, around 12 000 households per year are selected and the response rate is typically just over 50%. At the time of the analysis, LCF data was available for the 9 years from 2001 to 2009 (financial years were used for LCF 2001/2 to 2005/6 and this changed to calendar years from 2006 to 2009) covering 107,763 individuals in 57,646 households in the UK. We obtained the datasets from the UK Data Archive at the University of Essex and detailed data sources are listed in Appendix 1.

Individual-level quantities of alcohol purchased are not available in the standard version of the dataset held by the UK Data Archive. However, via a special data request to DEFRA, anonymised individual-level diary data on 25 categories of alcohol (e.g., off-trade beers, see Appendix 2 for a complete list of the 25 categories) in terms of both expenditure (in pence) and quantity (in millilitres of product, e.g., 330ml of beer) was made available to the authors. The 25 categories of alcohol are grouped into 10 categories (off- and on-trade separated for beer, cider, wine, spirits and RTDs) and the spending and purchase level of the 10 types of alcohol (measured in units, where1 unit is defined as 10ml of ethanol in the UK) during the diary period were derived for each individual. Alcohol units were calculated by multiplying the recorded volume of product (e.g., 330ml of beer) and the alcohol by volume (ABV) for each beverage type (see Appendix 2 the ABV assumptions). For each individual, pence per unit (PPU) was calculated for each beverage type by dividing the total spending by total units purchased. Outliers were defined as individuals who pay extremely high or low PPU for any of the 10 types of alcohol (above 99.5th or below 0.5th percentile of the distributions) and were excluded from the analysis.

Constructing the pseudo-panel

In using pseudo-panel methods, it is important that the created subgroups are defined in terms of characteristics that are time-invariant such as the year of birth, gender and ethnicity [10] .A trade-off also needs to be considered when deciding the number of subgroups in a pseudo-panel (denoted by C): a larger C increases the heterogeneity of the pseudo-panel by increasing the variations between subgroups, but also decreases the average number of individuals per subgroup over time (denoted by n_c) resulting in less precise estimates of the subgroup means. Given a fixed total number N of individuals in the repeated cross-sectional dataset over a number of time periods T, then by definition, $N = C * n_c * T$ (for a balanced panel where every panel member has observation for every time period) or $N = C * n_c * T^*$ (for an unbalanced panel where some panel members have missing observations for some time periods), where T^* represents the mean number of repeated observations per subgroups. A large n_c is important for the necessary asymptotic theory to be applicable to the pseudo-panel approach[12, 13] and previous empirical applications of the pseudo-panel approach normally have n_c over 100 [10].

In the base case, a pseudo-panel with 72 subgroups was defined by 12 birth cohorts (born between year 1930-1934, and subsequent 5 year intervals, until 1985-1989), gender and 3 socioeconomic groups - higher, middle and lower (see Appendix 3 for definitions). The resulting average number of individuals per subgroup, or n_c, is 140 with *N=90,652, C=72* and *T=9*. Table 1 summarises the characteristics of the subgroups. Subgroups with less than 30 individuals were excluded from the analysis to ensure more robust estimates of subgroup mean statistics.

Table 1: Characteristics of the 72 subgroups in the pseudo-panel in the base case

		Higher socioeconomic group		Middle socioeconomic group		Lower socioeconomic group	
Birth year	Gender	Number of repeated observations[1]	Mean number of individuals per year[2] (Min, Max)	Number of repeated observations[1]	Number of individuals per year[2] (Min, Max)	Number of repeated observations[1]	Number of individuals per year[2] (Min, Max)
1930-1934	Male	8 (0)	3.0 (1, 5)	9 (9)	254.6 (227, 295)	9 (0)	8.7 (5, 14)
1935-1939	Male	9 (0)	9.4 (6, 21)	9 (9)	279.0 (255, 306)	9 (3)	23.8 (9, 47)
1940-1944	Male	9 (4)	26.1 (7, 42)	9 (9)	273.9 (199, 322)	9 (8)	59.0 (27, 104)
1945-1949	Male	9 (9)	55.7 (39, 68)	9 (9)	309.2 (242, 337)	9 (9)	89.3 (75, 108)
1950-1954	Male	9 (9)	69.4 (54, 88)	9 (9)	279.0 (260, 308)	9 (9)	82.9 (69, 100)
1955-1959	Male	9 (9)	88.3 (74, 109)	9 (9)	279.2 (250, 313)	9 (9)	84.3 (73, 95)
1960-1964	Male	9 (9)	91.0 (70, 105)	9 (9)	328.4 (291, 353)	9 (9)	98.2 (75, 132)
1965-1969	Male	9 (9)	96.3 (86, 111)	9 (9)	311.8 (288, 365)	9 (9)	97.9 (76, 113)
1970-1974	Male	9 (9)	86.1 (63, 107)	9 (9)	270.6 (243, 292)	9 (9)	89.8 (73, 104)
1975-1979	Male	9 (9)	58.7 (42, 91)	9 (9)	225.6 (196, 260)	9 (9)	75.3 (59, 91)
1980-1984	Male	9 (9)	39.7 (31, 50)	9 (9)	226.1 (203, 275)	9 (9)	85.8 (66, 108)
1985-1989	Male	9 (6)	34.4 (9, 51)	9 (9)	209.1 (72, 281)	9 (8)	86.2 (15, 111)
1930-1934	Female	9 (0)	2.8 (1, 4)	9 (9)	290.9 (217, 354)	9 (0)	9.7 (5, 16)
1935-1939	Female	9 (0)	7.2 (3, 14)	9 (9)	324.1 (274, 373)	9 (1)	17.1 (7, 30)
1940-1944	Female	9 (0)	18.4 (10, 28)	9 (9)	311.1 (265, 391)	9 (7)	44.1 (16, 96)
1945-1949	Female	9 (8)	43.3 (28, 67)	9 (9)	361.9 (291, 424)	9 (9)	91.2 (57, 128)
1950-1954	Female	9 (9)	63.0 (56, 71)	9 (9)	296.1 (265, 330)	9 (9)	96.0 (87, 109)
1955-1959	Female	9 (9)	83.0 (61, 99)	9 (9)	303.9 (291, 333)	9 (9)	95.0 (79, 119)
1960-1964	Female	9 (9)	94.7 (84, 116)	9 (9)	357.1 (301, 408)	9 (9)	113.3 (85, 136)
1965-1969	Female	9 (9)	97.1 (82, 110)	9 (9)	366.1 (326, 419)	9 (9)	114.4 (100, 149)
1970-1974	Female	9 (9)	88.1 (71, 113)	9 (9)	316.1 (295, 339)	9 (9)	109.9 (88, 144)
1975-1979	Female	9 (9)	66.9 (47, 96)	9 (9)	274.2 (241, 306)	9 (9)	88.0 (72, 106)
1980-1984	Female	9 (9)	43.1 (31, 60)	9 (9)	264.6 (229, 284)	9 (9)	103.7 (82, 134)
1985-1989	Female	9 (4)	32.1 (12, 51)	9 (9)	208.3 (58, 325)	9 (8)	90.2 (25, 115)
Summary		9.0 (6.5)	54.1	9.0 (9.0)	288.4	9.0 (7.5)	77.2

Remarks 1: value in bracket is the number of repeated observations where the number of individuals within a subgroup at a year equals or bigger than 30; 2: values in bracket are the minimum and maximum number of individuals within a subgroup over the 9 years.

Three alternative ways to construct subgroups were tested to examine the robustness of the estimated elasticities. These include 96 subgroups defined by birth cohorts, gender and 4 socioeconomic groups, 48 subgroups defined by birth cohorts, gender and 2 regions in the UK (England and rest of UK), and 96 subgroups defined by birth cohorts, gender and 4 regions in the UK (Southern England including London, Scotland, Northern Ireland and rest of UK).

Adjustment to prices, income and consumption

The monthly retail price index (RPI) in the UK was used to derive real term prices of alcohol and income, with December 2009 chosen as the base period [15]. The income variable used in this study is the household gross weekly income which has been consistently collected in the LCF during the period from 2001/2 to 2009.

Alcohol consumption or purchasing estimated from self-reported survey data generally suffers from underreporting relative to more accurate sales or taxation data [16]. Compared to the sales clearance data collected by the Her Majesty's Revenue and Customs (HMRC), the coverage of the LCF ranges from 55% to 66% over the period 2001 to 2009 [17]. We estimated beverage specific coverage rates for each year and applied these factors to adjust the alcohol purchase quantities for each individual in the LCF (see Appendix 4 for the adjustment factors and details of how they were applied).

Dependent and independent variables

For each observation of each subgroup (e.g., high income male born 1960-1964in the year 2009), the mean units purchased of the 10 types of alcohol, denoted by C_{ijt}, was calculated as the dependent variable, where *i* and *j* represent the subgroup and the type of alcohol respectively, and *t* represents the year.

The main independent variables are the mean PPUs for the 10 beverage types, denoted by P_{ijt}, and subgroup's mean income, denoted $Income_{it}$. Four other time-variant independent variables were also tested, namely the proportion of individuals having children, being married, being unemployed, and smoking, denoted by $KID_{it}, MRD_{it}, UNE_{it},\ and\ SMK_{it}$ respectively. Year dummies were included as independent variables to control for the annual trend on the purchase level and any potentially omitted independent variables that change linearly over time (e.g., mean age of the subgroup). The square of the mean age of subgroup was also tested to account for a potentially non-linear relationship between alcohol purchase and age.

Model specification and testing

Three commonly used models for analysing panel data were tested: fixed effects models (FEMs), random effects models (REMs) and standard ordinary least squares (OLS) models [18]. REMs assume no correlation between individual effect and independent variables and FEMs allow for arbitrary correlation between the individual effect and independent variables. In this study, the individual effect refers to the specific effect, or the regression intercept a_i, for each defined subgroup (see Equation 1 for more details). It has been argued that FEM can be a natural choice for pseudo-panel data when subgroup averages are based on a large number of individuals [13]. The Hausman tests were used to test the appropriateness of using REMs compared with corresponding FEMs. OLS models do not account for the longitudinal nature of the data and were tested for comparative purposes. Models were fitted separately for each type of alcohol.

In this study, it was assumed that the adjustment to alcohol demand to changes in prices does not take time longer than one year. Models tested in this study are static without the inclusion of lagged dependent variables. It was also assumed that habit persistence and any long-term changes in the preference of alcohol would be captured by the year dummies and birth cohort dummies (for REMs and OLS models).

The standard log-log functional form for the dependent variable and independent variables of PPU and income was applied. Other independent variables were tested as levels (i.e., in its original measurement and not logged). t-tests and F-tests were used to test the inclusion/exclusion of non-PPU/income independent variables.

All models were fitted using the STATA/SE 12.1 software (StataCorp, College Station, TX). To account for the different size of the subgroups, weighted FEMs and OLS models were applied using the mean number of individuals within a subgroup, or n_c, as weights.

As an illustration, the unrestricted FEM for off-trade beer (i.e., *j*=off-trade beer) is presented in Equation 1. Regarding the models for the other 9 types of alcohol, the independent variables are identical to those in Equation 1, with the dependent variable changing to the type of alcohol of interest (e.g., $lnC(offcider)_{it}$).

$$lnC(offbeer)_{it} = \beta_1 lnP(offbeer)_{it} + \beta_2 lnP(offcider)_{it} + \beta_3 lnP(offwine)_{it} + \beta_4 lnP(offspirit)_{it} + \beta_5 lnP(offRTD)_{it} + \beta_6 lnP(onbeer)_{it} + \beta_7 lnP(oncider)_{it} + \beta_8 lnP(onwine)_{it} + \beta_9 lnP(onspirit)_{it} + \beta_{10} lnP(onRTD)_{it} + \beta_{11} LnIncome_{it} + \beta_{12} KID_{it} + \beta_{13} MRD_{it} + \beta_{14} UNE_{it} + \beta_{15} SMK_{it} + \beta_{16} {Age^2}_{it} + \gamma YearDummies + a_i + u_{it} \qquad \textbf{Equation 1}$$

where, a_i is the unobserved fixed effects specific to subgroup i; u_{it} is the usual error term; and β_1 to β_{10} represent the own- and cross-price elasticities for the beverage type of interest (e.g., in Equation 1, β_1 represents own-price elasticity for off-trade beer, while β_2 to β_{10} represent cross-price elasticities for off-trade beer).

Results

Model selection

Tables 2 and 3 summarise the estimated coefficients, t-values, goodness-of-fit, and statistical tests for model selection for the demand for off- and on-trade beer. Detailed results for other 8 types of alcohol are presented in Appendix 5.

The results suggest that different model specifications give broadly similar estimates for own- and cross-price elasticities, both in terms of the positive/negative signs of the estimated elasticities and their statistical significance. For example, the estimated own-price elasticities for off-trade beer range from -0.980 to -1.105 for the three model specifications with all estimates statistically significant.

FEMs appear to be the more appropriate than REMs with the Hausman tests rejecting for off-trade beer and wine, and all five on-trade beverages at the 0.05 significance level. Compared to REMs which assume individual effects (a_i) are not correlated with the independent variables, FEMs do allow for arbitrary correlation between a_i and the independent variables also appear more plausible.

F-tests suggested that non-PPU/income independent variables are jointly significant for majority of models tested. The final chosen base case models were FEMs controlling for year dummies, age squared, and the proportions of individuals having children, married, unemployed and smoking.

Estimated own- and cross-price elasticities

Estimated own- and cross-price elasticities for the 10 types of alcohol are presented in Table 4 using the base case models. The estimated own-price elasticities using the base case models are all negative and 8 out of the 10 are statistically significant (except for off-trade spirits and on-trade RTDs). The estimates range from -0.08 (off-trade spirits) to -1.27 (off-trade cider). In the off-trade a wide range of elasticities was seen with, apart from cider, beer being most elastic (-0.98), followed by RTDs (-0.59), wine (-0.38) and spirits (-0.08). In the on-trade elasticities are generally more similar across beverages, with spirits appearing to be most elastic (-0.89), followed by wine (-0.87), beer (-0.79), cider (-0.59)

Table 2: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of off-trade beer

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	-0.980* (0.18)	-1.024* (0.17)	-1.105* (0.17)
lnP(off-cider)	0.065 (0.09)	0.124 (0.07)	0.153* (0.07)
lnP(off-wine)	-0.040 (0.18)	-0.068 (0.12)	0.008 (0.18)
lnP(off-spirits)	0.113 (0.11)	0.089 (0.11)	0.179 (0.13)
lnP(off-RTDs)	-0.047 (0.05)	-0.020 (0.06)	-0.012 (0.04)
lnP(on-beer)	0.148 (0.20)	0.180 (0.22)	0.046 (0.23)
lnP(on-cider)	-0.100 (0.09)	-0.079 (0.09)	-0.123 (0.11)
lnP(on-wine)	-0.197 (0.12)	-0.129 (0.11)	-0.103 (0.13)
lnP(on-spirits)	0.019 (0.12)	0.027 (0.11)	0.079 (0.13)
lnP(on-RTDs)	0.079 (0.08)	0.120 (0.09)	0.084 (0.07)
lnIncome	-0.074 (0.24)	0.217 (0.19)	0.210 (0.18)
Age x Age	-0.001* (0.00)	-0.001* (0.00)	-0.001* (0.00)
% Have children	-0.565* (0.23)	-0.402* (0.17)	-0.383* (0.18)
% Married	0.938* (0.33)	0.520 (0.29)	0.339 (0.26)
% Unemployed	0.638 (0.79)	0.645 (0.69)	1.594* (0.73)
% Smoker	1.351* (0.45)	1.544* (0.39)	1.065* (0.43)
Female[1]		-0.228* (0.05)	-0.225* (0.04)
Higher socioeconomic[2]		-0.060 (0.12)	-0.076 (0.11)
Lower socioeconomic		-0.045 (0.08)	-0.059 (0.07)
1930-1934[3]		2.208* (0.82)	1.936* (0.77)
1935-1939		1.683* (0.64)	1.405* (0.60)
1940-1944		1.133* (0.47)	1.001* (0.42)
1945-1949		0.612 (0.32)	0.545 (0.28)
1950-1954		0.225 (0.18)	0.234 (0.14)
1960-1964		-0.316 (0.17)	-0.252 (0.14)
1965-1969		-0.651* (0.27)	-0.628* (0.24)
1970-1974		-1.215* (0.36)	-1.134* (0.34)
1975-1979		-1.726* (0.47)	-1.634* (0.45)
1980-1984		-2.185* (0.57)	-2.137* (0.54)
1985-1989		-3.069* (0.67)	-3.111* (0.67)
F-test1 (p-value) [4]	1.06 (0.41)		1.59 (0.11)
F-test2 (p-value) [5]	6.43* (0.00)		4.79* (0.00)
SSE[6]	45.57		56.14
Log-likelihood	-96.79		-153.71
REM: Hausman-test (p-value)		37.46* (0.03)	

Remarks: *: p-value <=0.05; 1: reference group - male; 2: reference group - middle socioeconomic group; 3: reference group – born between 1960-1965; 4: F-test for cross-price effects; 5: F-test for age, % have children, married, unemployed and smoker; 6: SSE - Residual sum of squares.

Table 3: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of on-trade beer

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	-0.016 (0.20)	0.113 (0.18)	-0.070 (0.23)
lnP(off-cider)	-0.053 (0.06)	-0.065 (0.07)	-0.161* (0.08)
lnP(off-wine)	-0.245 (0.14)	-0.177 (0.13)	-0.214 (0.18)
lnP(off-spirits)	0.167 (0.10)	0.141 (0.11)	0.071 (0.13)
lnP(off-RTDs)	-0.061 (0.04)	-0.071 (0.06)	-0.041 (0.06)
lnP(on-beer)	-0.786* (0.28)	-0.921* (0.23)	-0.533 (0.38)
lnP(on-cider)	0.035 (0.13)	-0.025 (0.10)	0.104 (0.12)
lnP(on-wine)	-0.276 (0.18)	-0.232* (0.11)	-0.311 (0.18)
lnP(on-spirits)	-0.002 (0.11)	0.103 (0.11)	-0.014 (0.16)
lnP(on-RTDs)	0.121 (0.09)	0.140 (0.10)	0.013 (0.10)
lnIncome	0.409 (0.31)	0.598* (0.21)	0.538* (0.21)
Age x Age	0.000 (0.00)	0.000 (0.00)	0.001* (0.00)
% Have children	-1.118* (0.19)	-1.160* (0.18)	-1.039* (0.20)
% Married	-0.412 (0.35)	0.366 (0.33)	2.044* (0.31)
% Unemployed	1.455 (1.14)	1.229 (0.73)	0.454 (1.01)
% Smoker	1.066* (0.42)	1.313* (0.41)	2.027* (0.55)
Female[1]		-1.996* (0.07)	-1.984* (0.05)
Higher socioeconomic[2]		-0.225 (0.15)	-0.278* (0.12)
Lower socioeconomic		-0.128 (0.10)	-0.163 (0.10)
1930-1934[3]		-0.963 (0.87)	-2.973* (0.97)
1935-1939		-0.628 (0.69)	-2.428* (0.76)
1940-1944		-0.647 (0.51)	-1.802* (0.54)
1945-1949		-0.629 (0.36)	-1.351* (0.36)
1950-1954		-0.372 (0.23)	-0.729* (0.19)
1960-1964		0.314 (0.21)	0.657* (0.16)
1965-1969		0.427 (0.31)	1.122* (0.29)
1970-1974		0.452 (0.41)	1.561* (0.41)
1975-1979		0.455 (0.51)	2.156* (0.52)
1980-1984		0.553 (0.63)	2.742* (0.64)
1985-1989		0.301 (0.73)	2.899* (0.76)
F-test1 (p-value) [4]	1.99 (0.06)		1.48 (0.15)
F-test2 (p-value) [5]	12.24* (0.00)		11.44* (0.00)
SSE[6]	50.26		84.79
Log-likelihood	-121.86		-266.19
REM: Hausman-test (p-value)		50.54* (0.00)	

Remarks: as for Table 2-1.

Table 4: Estimated own- and cross-price elasticities of off- and –on trade beer, cider, wine, spirits and RTDs in the UK

		Purchase									
		Off-beer	Off-cider	Off-wine	Off-spirits	Off-RTDs	On-beer	On-cider	On-wine	On-spirits	On-RTDs
Price	Off-beer	-0.980*	-0.189	0.096	-0.368	-1.092	-0.016	-0.050	0.253	0.030	0.503
	Off-cider	0.065	-1.268*	0.118	-0.122	-0.239	-0.053	0.093	0.067	-0.108	-0.194
	Off-wine	-0.040	0.736*	-0.384*	0.363	0.039	-0.245	-0.155	0.043	-0.186	0.110
	Off-spirits	0.113	-0.024	0.163	-0.082	-0.042	0.167	0.406	0.005	0.084	0.233
	Off-RTDs	-0.047	-0.159	-0.006	0.079	-0.585*	-0.061	0.067	0.068	-0.179*	0.093
	On-beer	0.148	-0.285	0.115	-0.028	0.803	-0.786*	0.867	1.042*	1.169*	-0.117
	On-cider	-0.100	0.071	0.043	0.021	0.365	0.035	-0.591*	0.072	0.237*	0.241
	On-wine	-0.197	0.094	-0.154	-0.031	-0.093	-0.276	-0.031	-0.871*	-0.021	-0.363
	On-spirits	0.019	-0.117	-0.027	-0.280	-0.145	-0.002	-0.284	0.109	-0.890*	0.809*
	On-RTDs	0.079	0.005	-0.085	-0.047	0.369	0.121	-0.394	-0.027	-0.071	-0.187

Remarks *: p-value <0.05

and RTDs (-0.19). For wine and spirits, the estimated own-price elasticities in the off-trade are smaller than in the on-trade. The opposite is observed for beer, cider and RTDs.

The estimated cross-price elasticities were a mix of positive and negative signs (46 and 44 respectively) and only 6 out of 90 were statistically significant, among which 5 out of 6 have positive signs. F-tests showed cross-price effects are jointly significant for the demand for on-trade wine and spirits, using a significance level of 0.05, and for on-trade beer, using a significance level of 0.1. The magnitude of the estimated cross-price elasticities was much smaller than that of the own-price elasticities. If we only focus on central estimates, most of the estimated cross-price elasticities of on-trade demand with respect to off-trade prices are positive (15 out of 25 in the top right corner of Table 3), which appears to indicate some level of overall substitution effect.

Using the base case models, three alternative methods for creating subgroups were tested. Appendix 6 compares the estimated own-price elasticities using these methods and shows these are broadly similar. For example, the own-price elasticity for off-trade beer was -0.98 for the 72 subgroups used in the base case, -1.03 for the 96 subgroups defined by 4 social groups, -1.12 for the 48 subgroups defined by 2 regions, and -1.11 for the 96 subgroups defined by 4 regions. This suggests that the estimated elasticities are reasonably robust with respect to different ways to define subgroups.

Discussion

This is the first study to utilise a pseudo-panel approach on repeated cross-sectional data to estimate price elasticities of demand for alcohol in the UK. The final base case model, which uses FEMs to control for unobserved and unaccounted time-invariant subgroup characteristics, enables estimation of own- and cross-price elasticities for 10 different beverage categories. This granularity is essential for detailed analysis of pricing policies which can affect the various beverage categories differentially. The estimated elasticities are not directly comparable with most previous estimates in the literature because the data used is from fairly recent (2001 to 2009) UK population survey, and because the beverage categories included are more detailed than most previous studies which tend not to separate cider and RTDs, or consider off- vs. on-trade differences. Nevertheless, the estimated own-price elasticities from this study are broadly in line with earlier estimates. Three recent meta-analyses estimated that the simple means of reported elasticities are −0.45 to -0.83 for beer, −0.65 to -1.11 for wine and −0.73 to -1.09 for spirits [2-4], while one meta-analysis reported the standard deviations and ranges of individual estimates for the 3 beverage types as 0.46 (-3 to 1.28), 0.51 (-3 to 0.82) and 0.37 (-4.65 to 0.37) for beer, wine and spirits respectively [3] which demonstrated significant variations in estimates. The simple average of beer, wine and spirits own-price elasticities estimated from this study (e.g., average of off- and on-trade beer for beer estimate) are -0.88, -0.63 and -0.49 which are all within one standard deviation (as reported by Fogarty et al[3]) of any of the three mean estimates from meta-analysis. In the on-trade, a similar pattern is observed in this study as in previous meta-analyses that beer appears to be less elastic than wine or spirits. However, this pattern is not observed in the off-trade, where it was found that beer is more elastic than wine and spirits. Overall, the estimated own-price elasticities are broadly in line with historical estimates, and most modelled beverage types are found to have significant negative elasticities suggesting the pseudo-panel approach is a valid technique for deriving alcohol elasticities.

It is more challenging to compare the estimated cross-price elasticities with previous estimates, especially when the beverages are separated by off- and on-trade, because there are actually very few existing studies for comparison. Out of our 90 estimated cross-price elasticities, only 6 are statistically significant. However, the estimation of cross-price elasticities is still useful and important for two reasons: 1) the estimation of own-price elasticities is improved by controlling for cross-price effects, and 2) they may be jointly statistically significant as has been found in our study for on-trade wine and spirits. The estimated cross-price elasticities appear plausible regarding the expected signs and magnitude, and they could be used for quantifying estimates of cross-price effects when appraising policy interventions.

The main limitations of this study relates to the data available. The ideal data for the estimation of price elasticities of alcohol demand would be individual-level longitudinal data over a long period of time with price, purchasing and consumption information incorporated. The main advantage of longitudinal/panel data, compared to cross-sectional data, is that unobserved heterogeneity of subjects can be controlled by exploiting the time dimension of data and causality could be investigated. More detailed analysis can be performed if purchasing and consumption information can be collected separately because the issues of inventory behaviour (i.e., consumers may purchase large quantities and consume over a longer period of time which is common for certain beverage type and when consumers face heavy discounting) and the issue of purchasing for others (e.g., the main shopper in the family frequently buy alcohol for other family members). However, such panel data is currently not available in the UK and in most other countries. Therefore, we used repeated individual-level cross-sectional data for this analysis.

The pseudo-panel approached used in this study is designed to “longitudinise” repeated individual-level cross-sectional data into panel data to have the advantages of panel analysis. Most previous analyses utilised cross-sectional models on individual-level cross-sectional data (for example [8]) and such analyses may potentially have substantial endogeneity problem. The main reason is that, even many variables can be used either as independent variable, there is still possibility that important independent variables may be omitted from the model (either by ignorance or by availability) which will cause endogeneity. The FEM used in our base case can substantially reduce the endogeneity problem because all time-invariant independent variables, observed or not, are controlled for on the defined subgroup level (genuine individual-level panel data, if exists, will allow control on the individual level). The pseudo-panel approach also solve the problem caused by inventory behaviour by using subgroup average purchase quantities rather than individual purchase quantities.

Nevertheless, panel models cannot remove all endogeneity problems because potential time-variant independent variables which are correlated with price variables may be omitted and endogeneity can also be caused by simultaneity or measurement error [18]. Firstly, we used self-reported prices from within the LCF which is the price actually paid by individuals. A limitation of using self-reported prices of alcohol is that the observed price variables could be endogenous due to simultaneity because not only the purchase level (i.e., the dependent variable in the model) is dependent on the price paid, but also the price paid could potentially be dependent on the purchase level. It has been found that a heavy drinker who spends a bigger proportion of their income on alcohol tends to choose lower quality beverages with low PPU (e.g., cheaper brand, larger container which tends to result in lower PPU); while a lighter drinker with similar income tends to choose a higher quality beverage with a higher PPU for better taste or a more-convenient container size [19]. Secondly, since the LCF data does not provide brand or packaging data, the panel models used in the study have not controlled for the brand and packaging preferences which may change over time and affect the PPU independent variables. Thirdly, the self-reported prices may also suffer from measurement error which may also cause endogeneity. In theory, we would like to use price "faced" rather than price paid as the independent variable because the estimated price elasticities is defined as the change in demand due to a change in price where the price implicitly means price faced, rather than price paid, by the population of interest. We acknowledge that it is difficult to obtain primary data on price faced and, as far as we know, no survey has attempted to do this. Due to the above reasons, the estimated elasticities based on the pseudo-panel approach may still be biased due to endogeneity of price variables. However, in the absence of the ideal panel data, we think that the pseudo-panel approach is a better alternative to cross-sectional methods given current data and evidence.

When constructing subgroups in pseudo-panels, we assumed that the socioeconomic status (in the base case) and the region people live (in sensitivity analysis) do not generally change over time. While the validity of these assumptions may be questioned, we think they reasonably hold given the limited time period of the data (2001 to 2009) and the large size of the regions we used (2 or 4 regions in UK). Furthermore, the similarity of the results and conclusions obtained from the base case and sensitivity analyses where alternative subgroups are defined is reassuring in this regard.

Models tested in this study are static without the inclusion of lagged dependent variables. The inclusion of these variables as independent covariates would make the estimation of the model more complicated due to the correlation between the lagged dependent variable and the error terms. It has also been suggested that the inclusion of lagged dependent variable may compromise the explanatory power of other independent variables [20] and that a significant lagged effect of the dependent variable may be due to omitted variables or measurement error bias rather than true lagged effect [21].

The key implications of the study for decision makers, is that they can utilise these elasticities to examine the effects of price-based interventions in terms of estimates of the impact on alcohol demand in the UK. The practical advantage of applying the estimates in this study is the detailed beverage types considered, i.e., beer, cider, wine, spirits and RTDs for off- and on-trade. This allows detailed estimation of beverage-specific demand changes due to beverage specific price changes. This is appealing for appraising interventions which have differential price impact on different beverage types. For example, in the UK, off-trade PPUs are much lower than on-trade equivalents, thus a minimum unit pricing policy will have differential impacts in these two sectors. In the off-trade, cider will be most affected due to the high prevalence of very high strength and low priced products. The estimated cross-price elasticities can also be applied to estimate the changes in demand for one beverage type when the price of another beverage type changes. Caution needs to be taken when only the price of a single or a small number of beverages is affected, because the estimated individual cross-price effect is less robust than joint cross-price effects. Another note of caution is that the estimated changes in demand are less robust when changes in price are substantial (e.g., a more than 50% increase/decrease in price). This is because the data used for estimating these elasticities generally contain small price variations and the estimated elasticities may not hold for, or extrapolate to, for large price changes. The pseudo-panel approach used could be applied to a different setting where large repeated cross-sectional data is available; however the estimated elasticities are UK specific and may not apply to a different context.

Future research is suggested to test alternative model specifications and different ways to construct subgroups. The application of the approach to other countries would also be beneficial. Large scale and long-term individual-level longitudinal data as describe above would be hugely beneficial for better estimates of price elasticities. If possible, such potential data could also include information regarding the branding and packaging information so that the issue of price endogeneity could be properly dealt with. Future research to link price faced and price paid would also be valuable.

In conclusion, the pseudo-panel approach offers an approach to estimate price elasticities of alcohol demand using repeated cross-sectional data. Resulting estimates of own- and cross-price elasticities appear theoretically plausible and robust and can be used for appraising the estimated impact of price-based interventions in the UK. Our estimates suggest policies to increase the price of UK alcohol would lead to substantive reductions in alcohol consumption.

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Declaration of interest

None.

Appendix

Appendix 1: Data source

University of Essex. Institute for Social and Economic Research and National Centre for Social Research, Expenditure and Food Survey, 2001/2002 (EFS) [computer file]. Colchester, Essex: UK Data Archive [distributor], 6 September 2007, SN 4697.

EFS 2002/2003, [computer file]. Colchester, Essex: UK Data Archive [distributor], 6 September 2007, SN 5003.

EFS 2003/2004, [computer file]. Colchester, Essex: UK Data Archive [distributor] , 27 May 2008, SN 5210.

EFS 2004/2005, [computer file]. Colchester, Essex: UK Data Archive [distributor] , 27 May 2008, SN 5375.

EFS 2005/2006, [computer file]. Colchester, Essex: UK Data Archive [distributor] , 31 October 2007, SN 5688.

EFS 2006, [computer file]. Colchester, Essex: UK Data Archive [distributor] , 16 July 2009, SN 5986.

EFS 2007, [computer file]. Colchester, Essex: UK Data Archive [distributor] , 16 July 2009, SN 6118.

Living Cost and Food Survey (LCF) 2008, [computer file]. Colchester, Essex: UK Data Archive [distributor] , 2 June 2011, SN 6385.

LCF 2009, [computer file]. Colchester, Essex: UK Data Archive [distributor] , 27 July 2011, SN 6655.

Appendix 2: Mapping types of alcohol and conversion factors for each type

Maffcode in LCF	On/off trade in LCF	Description in LCF	Types of alcohol used for this analysis	Alcohol by volume (ABV)
38102	Off-trade	Beers	off-trade beer	4.0%
38202	Off-trade	Lagers and continental beers	off-trade beer	3.9%
38302	Off-trade	Ciders and perry	off-trade cider	4.8%
38402	Off-trade	Champagne, sparkling wines and wine with mixer	off-trade wine	11.4%
38403	Off-trade	Table wine	off-trade wine	12.8%
38501	Off-trade	Spirits with mixer	off-trade spirits	7.4%
38601	Off-trade	Fortified wines	off-trade wine	14.5%
38701	Off-trade	Spirits	off-trade spirits	40.2%
38801	Off-trade	Liqueurs and cocktails	off-trade spirits	33.8%
38901	Off-trade	Alcopops	off-trade RTDs	4.7%
270101	On-trade	Spirits	on-trade spirits	42.3%
270102	On-trade	Liqueurs	on-trade spirits	30.3%
270103	On-trade	Cocktails	on-trade spirits	13.4%
270104	On-trade	Spirits or liqueurs with mixer e.g. gin & tonic, Bacardi & coke	on-trade spirits	7.8%
270201	On-trade	Wine (not sparkling) including unspecified 'wine'	on-trade wine	11.3%
270202	On-trade	Sparkling wines (e.g. Champagne) and wine with mixer (e.g. Bucks Fizz)	on-trade wine	9.6%
270203	On-trade	Fortified wine e.g. sherry, port, vermouth	on-trade wine	17.5%
270204	On-trade	Cider or perry - half pint or bottle	on-trade cider	4.8%
270205	On-trade	Cider or perry - pint or can or size not specified	on-trade cider	4.8%
270206	On-trade	Alcoholic soft drinks (alcopops), and ready-mixed bottled drinks	on-trade RTDs	4.7%
270301	On-trade	Bitter - half pint or bottle	on-trade beer	4.3%
270302	On-trade	Bitter - pint or can or size not specified	on-trade beer	4.3%
270303	On-trade	Lager or other beers including unspecified 'beer' - half pint or bottle	on-trade beer	5.1%
270304	On-trade	Lager or other beers including unspecified 'beer' - pint or can or size not specified	on-trade beer	5.1%
270401	On-trade	Round of drinks, alcohol not otherwise specified	on-trade beer	4.9%

Appendix 3: Definition of socioeconomic groups

Description	3 socioeconomic groups (base case)	4 socioeconomic groups (sensitivity analysis)
Employers in large organisations	Higher	Higher
Higher managerial	Higher	Higher
Higher professional (traditional) - employees	Higher	Higher
Higher professional (new) - employees	Higher	Higher
Higher professional (traditional) - self employed	Higher	Higher
Higher professional (new) - self-employ	Higher	Higher
Lower professional & higher technical (traditional) - employees	Medium	Medium
Lower professional & higher technical (new) - employees	Medium	Medium
Lower professional & higher technical (traditional) - self employed	Medium	Medium
Lower professional & higher technical (new) - self-employ	Medium	Medium
Lower managerial	Medium	Medium
Higher supervisory	Medium	Medium
Intermediate clerical and administrative	Medium	Medium
Intermediate sales and service	Medium	Medium
Intermediate technical and auxilary	Medium	Medium
Intermediate engineering	Medium	Medium
Employers (small organisations, non-prof	Medium	Medium
Employers (small - agricultural)	Medium	Medium
Own account workers (non-professional)	Medium	Medium
Own account workers (agriculture)	Medium	Medium
Lower supervisory	Medium	Medium
Lower technical craft	Medium	Medium
Lower technical process operative	Medium	Medium
Semi-routine sales	Lower	Lower
Semi-routine service	Lower	Lower
Semi-routine technical	Lower	Lower
Semi-routine operative	Lower	Lower
Semi-routine agricultural	Lower	Lower
Semi-routine clerical	Lower	Lower
Semi-routine childcare	Lower	Lower
Routine sales and service	Lower	Lower
Routine production	Lower	Lower
Routine technical	Lower	Lower
Routine operative	Lower	Lower
Routine agricultural	Lower	Lower
Never worked	Lower	Lower
Long-term unemployed	Lower	Lower
Full-time students	Medium	Student/other
Occupations not stated	Medium	Student/other
Not classifiable for other reasons	Medium	Student/other
Not recorded	Medium	Student/other

Appendix 4: Coverage rates of spirits, beer, wine and cider in the LCF compared with sales data from the HMRC between 2001 to 2009

	All	Spirits	Beer	Wine	Cider
2001	66.1%	67.0%	64.1%	73.3%	41.7%
2002	60.3%	51.4%	59.1%	72.9%	41.8%
2003	58.7%	51.0%	55.5%	73.4%	42.5%
2004	57.1%	50.0%	55.3%	68.8%	34.2%
2005	57.0%	46.2%	54.4%	71.9%	35.5%
2006	57.1%	52.4%	54.2%	69.7%	34.1%
2007	56.3%	51.2%	53.1%	67.0%	40.1%
2008	55.3%	51.5%	51.3%	67.5%	35.2%
2009	55.5%	50.0%	54.3%	65.9%	35.4%

Example of how coverage rate was estimated

For year 2001, the annual per capita purchase quantity measure by litres of ethanol for spirits using the EFS2001/2 is 1.3878 litres. For the same year, the HMRC estimated that the per capital consumption of spirits is 2.07 litres. Therefore, the calculated coverage rate for spirits in year 2001 is 67.0% (i.e., 1.3878 divided by 2.07).

Example of how coverage rate was applied to adjust the LCF purchase quantities

For year 2001, the purchase quantity of all spirits were adjusted by dividing the unadjusted value by the estimated coverage rate of 67.0%. For example, if the unadjusted purchase quantity for spirits is 5 units per week in year 2001/2, then the adjusted purchase quantity is around 7.46 units per week (i.e., 5 divided by 67.0%).

Appendix 5-1: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of off-trade cider

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	-0.189 (0.40)	-0.367 (0.35)	-0.301 (0.36)
lnP(off-cider)	-1.268* (0.23)	-1.275* (0.13)	-1.228* (0.19)
lnP(off-wine)	0.736* (0.35)	0.646* (0.28)	0.723* (0.32)
lnP(off-spirits)	-0.024 (0.30)	0.060 (0.24)	0.065 (0.28)
lnP(off-RTDs)	-0.159 (0.11)	-0.186 (0.12)	-0.144 (0.12)
lnP(on-beer)	-0.285 (0.43)	-0.349 (0.47)	-0.505 (0.46)
lnP(on-cider)	0.071 (0.15)	0.125 (0.19)	0.101 (0.17)
lnP(on-wine)	0.094 (0.22)	0.028 (0.22)	0.132 (0.21)
lnP(on-spirits)	-0.117 (0.23)	-0.289 (0.23)	-0.134 (0.21)
lnP(on-RTDs)	0.005 (0.16)	-0.003 (0.19)	0.019 (0.17)
lnIncome	-0.133 (0.52)	-0.200 (0.38)	-0.172 (0.43)
Age x Age	-0.002* (0.00)	-0.003* (0.00)	-0.003* (0.00)
% Have children	-0.109 (0.39)	0.046 (0.34)	0.192 (0.35)
% Married	0.863 (0.85)	-0.752 (0.57)	-0.589 (0.62)
% Unemployed	-2.114 (1.63)	-2.935* (1.39)	-1.928 (1.49)
% Smoker	1.511 (0.81)	0.806 (0.80)	0.827 (0.85)
Female[1]		0.109 (0.09)	0.113 (0.08)
Higher socioeconomic[2]		-0.062 (0.22)	-0.166 (0.23)
Lower socioeconomic		0.018 (0.15)	-0.021 (0.15)
1930-1934[3]		6.126* (1.65)	6.202* (1.45)
1935-1939		4.759* (1.29)	4.704* (1.12)
1940-1944		3.775* (0.95)	3.830* (0.85)
1945-1949		2.289* (0.63)	2.365* (0.57)
1950-1954		0.905* (0.34)	1.017* (0.30)
1960-1964		-1.096* (0.31)	-1.158* (0.29)
1965-1969		-2.280* (0.52)	-2.241* (0.49)
1970-1974		-3.638* (0.72)	-3.621* (0.67)
1975-1979		-4.966* (0.92)	-5.019* (0.87)
1980-1984		-5.886* (1.12)	-5.859* (1.04)
1985-1989		-7.310* (1.31)	-7.333* (1.23)
F-test1 (p-value) [4]	1.12 (0.36)		1.06 (0.39)
F-test2 (p-value) [5]	4.61* (0.00)		6.68* (0.00)
SSE[6]	171.29		196.17
Log-likelihood	-440.12		-473.75
REM: Hausman-test (p-value)		31.09 (0.12)	

Remarks: *: p-value <=0.05; 1: reference group - male; 2: reference group - middle socioeconomic group; 3: reference group – born between 1960-1965; 4: F-test for cross-price effects; 5: F-test for age, % have children, married, unemployed and smoker; 6: SSE - Residual sum of squares.

Appendix 5-2: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of off-trade wine

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	0.096 (0.17)	0.372 (0.20)	0.109 (0.20)
lnP(off-cider)	0.118 (0.07)	0.110 (0.08)	0.067 (0.08)
lnP(off-wine)	-0.384* (0.16)	-0.378* (0.14)	-0.229 (0.20)
lnP(off-spirits)	0.163 (0.10)	0.150 (0.13)	0.134 (0.13)
lnP(off-RTDs)	-0.006 (0.04)	0.032 (0.07)	0.014 (0.05)
lnP(on-beer)	0.115 (0.20)	0.240 (0.26)	0.316 (0.32)
lnP(on-cider)	0.043 (0.08)	-0.059 (0.11)	-0.031 (0.11)
lnP(on-wine)	-0.154 (0.14)	0.174 (0.12)	0.065 (0.17)
lnP(on-spirits)	-0.027 (0.10)	0.020 (0.13)	0.048 (0.13)
lnP(on-RTDs)	-0.085 (0.07)	-0.058 (0.11)	-0.086 (0.07)
lnIncome	-0.156 (0.24)	0.128 (0.21)	0.094 (0.20)
Age x Age	-0.001* (0.00)	-0.001* (0.00)	-0.001* (0.00)
% Have children	-1.273* (0.37)	-0.686* (0.18)	-0.964* (0.20)
% Married	0.692* (0.34)	1.095* (0.31)	1.384* (0.29)
% Unemployed	-0.044 (1.33)	-1.600* (0.77)	-1.566 (1.12)
% Smoker	1.149* (0.44)	1.361* (0.45)	1.433* (0.47)
Female[1]		0.580* (0.05)	0.587* (0.04)
Higher socioeconomic[2]		0.234 (0.12)	0.252* (0.11)
Lower socioeconomic		-0.601* (0.08)	-0.581* (0.09)
1930-1934[3]		2.860* (0.93)	2.538* (0.80)
1935-1939		2.157* (0.72)	1.893* (0.61)
1940-1944		1.756* (0.53)	1.364* (0.45)
1945-1949		1.025* (0.36)	0.816* (0.29)
1950-1954		0.402* (0.19)	0.299* (0.15)
1960-1964		-0.426* (0.18)	-0.311* (0.14)
1965-1969		-0.856* (0.30)	-0.733* (0.24)
1970-1974		-1.504* (0.41)	-1.336* (0.34)
1975-1979		-2.125* (0.52)	-1.946* (0.45)
1980-1984		-3.082* (0.63)	-2.762* (0.54)
1985-1989		-4.225* (0.74)	-3.853* (0.64)
F-test1 (p-value) [4]	1.03 (0.42)		0.67 (0.73)
F-test2 (p-value) [5]	5.60* (0.00)		14.12* (0.00)
SSE[6]	51.46		70.78
Log-likelihood	-129.72		-216.87
REM: Hausman-test (p-value)		126.91* (0.00)	

Remarks : same as Table in Appendix 5-1.

Appendix 5-3: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of off-trade spirits

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	-0.368 (0.21)	-0.231 (0.23)	-0.443* (0.22)
lnP(off-cider)	-0.122 (0.11)	-0.239* (0.09)	-0.098 (0.10)
lnP(off-wine)	0.363 (0.21)	0.339 (0.19)	0.428* (0.21)
lnP(off-spirits)	-0.082 (0.17)	-0.171 (0.15)	-0.070 (0.19)
lnP(off-RTDs)	0.079 (0.06)	0.098 (0.08)	0.112 (0.06)
lnP(on-beer)	-0.028 (0.23)	-0.356 (0.31)	-0.147 (0.26)
lnP(on-cider)	0.021 (0.14)	0.006 (0.12)	0.023 (0.13)
lnP(on-wine)	-0.031 (0.17)	0.137 (0.14)	0.038 (0.14)
lnP(on-spirits)	-0.280 (0.16)	-0.214 (0.15)	-0.243 (0.14)
lnP(on-RTDs)	-0.047 (0.09)	-0.082 (0.13)	-0.092 (0.09)
lnIncome	0.795* (0.32)	0.438 (0.24)	0.677* (0.26)
Age x Age	0.000 (0.00)	-0.001 (0.00)	0.000 (0.00)
% Have children	-0.475 (0.24)	-0.285 (0.22)	-0.391 (0.22)
% Married	0.161 (0.49)	0.179 (0.37)	0.472 (0.33)
% Unemployed	0.414 (1.07)	0.275 (0.92)	0.937 (0.99)
% Smoker	0.428 (0.66)	0.140 (0.52)	0.451 (0.54)
Female[1]		0.483* (0.06)	0.505* (0.05)
Higher socioeconomic[2]		-0.380* (0.14)	-0.514* (0.14)
Lower socioeconomic		-0.056 (0.09)	0.001 (0.10)
1930-1934[3]		2.323* (1.09)	1.220 (0.84)
1935-1939		1.704* (0.85)	0.889 (0.66)
1940-1944		1.171 (0.62)	0.592 (0.49)
1945-1949		0.817* (0.41)	0.407 (0.32)
1950-1954		0.386 (0.23)	0.219 (0.17)
1960-1964		-0.267 (0.20)	-0.001 (0.17)
1965-1969		-0.521 (0.34)	-0.090 (0.27)
1970-1974		-1.165* (0.47)	-0.560 (0.38)
1975-1979		-1.476* (0.61)	-0.728 (0.49)
1980-1984		-1.952* (0.74)	-1.094 (0.59)
1985-1989		-2.460* (0.87)	-1.314 (0.71)
F-test1 (p-value) [4]	1.16 (0.34)		1.93* (0.05)
F-test2 (p-value) [5]	2.54* (0.04)		1.56 (0.17)
SSE[6]	80.77		90.07
Log-likelihood	-253.39		-282.50
REM: Hausman-test (p-value)		24.22 (0.39)	

Remarks : same as Table in Appendix 5-1.

Appendix 5-4: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of off-trade RTDs

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	-1.092 (0.57)	-1.145* (0.50)	-1.108* (0.50)
lnP(off-cider)	-0.239 (0.24)	-0.243 (0.20)	-0.100 (0.22)
lnP(off-wine)	0.039 (0.32)	-0.256 (0.36)	-0.206 (0.41)
lnP(off-spirits)	-0.042 (0.29)	-0.120 (0.30)	0.001 (0.29)
lnP(off-RTDs)	-0.585* (0.27)	-0.429* (0.15)	-0.556* (0.26)
lnP(on-beer)	0.803 (0.52)	0.824 (0.60)	0.897 (0.51)
lnP(on-cider)	0.365 (0.21)	0.200 (0.25)	0.264 (0.24)
lnP(on-wine)	-0.093 (0.32)	0.037 (0.30)	0.076 (0.29)
lnP(on-spirits)	-0.145 (0.29)	0.259 (0.31)	-0.083 (0.35)
lnP(on-RTDs)	0.369 (0.28)	0.264 (0.26)	0.330 (0.28)
lnIncome	0.530 (0.63)	0.666 (0.52)	1.023 (0.56)
Age x Age	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)
% Have children	-0.843 (0.61)	-0.877 (0.46)	-0.756 (0.45)
% Married	1.498 (1.12)	0.723 (0.82)	1.170 (0.83)
% Unemployed	-0.410 (1.72)	-2.574 (1.91)	-1.327 (2.06)
% Smoker	1.096 (1.24)	0.310 (1.09)	0.855 (1.14)
Female[1]		0.582* (0.14)	0.803* (0.12)
Higher socioeconomic[2]		-0.081 (0.33)	-0.404 (0.34)
Lower socioeconomic		0.613* (0.22)	0.598* (0.21)
1930-1934[3]		0.200 (2.18)	-0.922 (2.11)
1935-1939		-0.264 (1.72)	-1.142 (1.68)
1940-1944		0.067 (1.26)	-0.954 (1.22)
1945-1949		-0.317 (0.84)	-0.986 (0.82)
1950-1954		-0.222 (0.49)	-0.370 (0.45)
1960-1964		0.598 (0.44)	0.644 (0.43)
1965-1969		0.081 (0.72)	0.374 (0.73)
1970-1974		0.150 (0.98)	0.571 (0.98)
1975-1979		-0.082 (1.26)	0.495 (1.25)
1980-1984		0.266 (1.54)	1.208 (1.54)
1985-1989		0.663 (1.79)	1.483 (1.81)
F-test1 (p-value) [4]	1.85 (0.08)		1.30 (0.23)
F-test2 (p-value) [5]	0.69 (0.63)		0.94 (0.45)
SSE[6]	248.03		293.91
Log-likelihood	-496.32		-533.41
REM: Hausman-test (p-value)		27.11 (0.25)	

Remarks : same as Table in Appendix 5-1.

Appendix 5-5: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of on-trade cider

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	-0.050 (0.48)	-0.330 (0.45)	-0.155 (0.52)
lnP(off-cider)	0.093 (0.21)	0.053 (0.18)	-0.104 (0.22)
lnP(off-wine)	-0.155 (0.36)	-0.187 (0.36)	0.172 (0.40)
lnP(off-spirits)	0.406 (0.23)	0.411 (0.28)	0.316 (0.29)
lnP(off-RTDs)	0.067 (0.14)	0.126 (0.16)	0.101 (0.15)
lnP(on-beer)	0.867 (0.68)	1.379* (0.63)	1.377 (0.82)
lnP(on-cider)	-0.591* (0.23)	-0.220 (0.23)	-0.399 (0.27)
lnP(on-wine)	-0.031 (0.26)	-0.061 (0.27)	0.074 (0.33)
lnP(on-spirits)	-0.284 (0.29)	-0.023 (0.28)	-0.255 (0.33)
lnP(on-RTDs)	-0.394 (0.30)	-0.149 (0.25)	-0.342 (0.28)
lnIncome	-0.165 (0.54)	-0.051 (0.48)	-0.006 (0.53)
Age x Age	-0.001 (0.00)	-0.001 (0.00)	-0.001 (0.00)
% Have children	-1.699* (0.53)	-0.714 (0.43)	-0.582 (0.42)
% Married	2.021* (0.84)	1.531* (0.76)	1.891* (0.75)
% Unemployed	0.502 (2.19)	-1.558 (1.80)	-1.650 (1.88)
% Smoker	0.130 (1.00)	0.381 (1.01)	0.975 (1.12)
Female[1]		-1.080* (0.12)	-1.155* (0.11)
Higher socioeconomic[2]		-0.537 (0.29)	-0.609* (0.31)
Lower socioeconomic		-0.015 (0.20)	-0.088 (0.24)
1930-1934[3]		0.594 (2.16)	0.406 (2.31)
1935-1939		0.207 (1.70)	-0.099 (1.81)
1940-1944		0.311 (1.25)	0.066 (1.42)
1945-1949		0.211 (0.84)	-0.095 (0.86)
1950-1954		0.122 (0.46)	-0.035 (0.46)
1960-1964		-0.299 (0.42)	-0.138 (0.42)
1965-1969		-0.417 (0.70)	-0.229 (0.72)
1970-1974		-0.432 (0.95)	-0.258 (1.01)
1975-1979		-0.564 (1.22)	-0.214 (1.30)
1980-1984		-0.322 (1.49)	0.220 (1.57)
1985-1989		-0.172 (1.75)	0.184 (1.82)
F-test1 (p-value) [4]	1.10 (0.37)		0.74 (0.67)
F-test2 (p-value) [5]	4.25* (0.00)		2.97* (0.01)
SSE[6]	283.67		356.49
Log-likelihood	-562.65		-618.86
REM: Hausman-test (p-value)		43.53* (0.00)	

Remarks : same as Table in Appendix 5-1.

Appendix 5-6: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of on-trade wine

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	0.253 (0.22)	0.298 (0.22)	0.211 (0.27)
lnP(off-cider)	0.067 (0.09)	0.094 (0.09)	-0.118 (0.11)
lnP(off-wine)	0.043 (0.15)	0.221 (0.16)	0.327 (0.20)
lnP(off-spirits)	0.005 (0.14)	-0.117 (0.14)	-0.114 (0.18)
lnP(off-RTDs)	0.068 (0.07)	0.092 (0.08)	0.041 (0.08)
lnP(on-beer)	1.042* (0.38)	1.281* (0.28)	1.481* (0.41)
lnP(on-cider)	0.072 (0.11)	0.142 (0.12)	0.175 (0.13)
lnP(on-wine)	-0.871* (0.15)	-0.963* (0.13)	-0.839* (0.23)
lnP(on-spirits)	0.109 (0.15)	0.115 (0.14)	0.129 (0.17)
lnP(on-RTDs)	-0.027 (0.10)	-0.068 (0.12)	-0.064 (0.11)
lnIncome	0.264 (0.26)	0.520* (0.26)	0.528* (0.26)
Age x Age	0.000 (0.00)	0.000 (0.00)	0.001 (0.00)
% Have children	-1.347* (0.28)	-1.077* (0.22)	-0.985* (0.25)
% Married	0.462 (0.54)	0.869* (0.41)	2.324* (0.38)
% Unemployed	1.196 (1.24)	0.161 (0.91)	-1.886 (1.09)
% Smoker	0.574 (0.50)	0.648 (0.50)	2.086* (0.58)
Female[1]		-0.044 (0.08)	-0.029 (0.06)
Higher socioeconomic[2]		0.135 (0.17)	0.112 (0.15)
Lower socioeconomic		-0.694* (0.12)	-0.655* (0.10)
1930-1934[3]		-0.891 (1.08)	-1.959 (1.09)
1935-1939		-0.553 (0.84)	-1.523 (0.86)
1940-1944		-0.294 (0.63)	-1.108 (0.63)
1945-1949		-0.226 (0.44)	-0.694 (0.41)
1950-1954		-0.199 (0.27)	-0.418* (0.20)
1960-1964		0.267 (0.25)	0.517* (0.20)
1965-1969		0.416 (0.38)	0.864* (0.33)
1970-1974		0.496 (0.50)	1.248* (0.46)
1975-1979		0.630 (0.63)	1.799* (0.61)
1980-1984		0.395 (0.77)	2.036* (0.74)
1985-1989		-0.174 (0.90)	1.881* (0.86)
F-test1 (p-value) [4]	2.16* (0.04)		2.81* (0.00)
F-test2 (p-value) [5]	7.11* (0.00)		8.66* (0.00)
SSE[6]	68.32		119.66
Log-likelihood	-207.32		-360.34
REM: Hausman-test (p-value)		62.73* (0.00)	

Remarks : same as Table in Appendix 5-1.

Appendix 5-7: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of on-trade spirits

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	0.030 (0.27)	-0.078 (0.25)	-0.009 (0.27)
lnP(off-cider)	-0.108 (0.10)	-0.113 (0.10)	-0.212 (0.12)
lnP(off-wine)	-0.186 (0.22)	-0.348 (0.18)	-0.104 (0.24)
lnP(off-spirits)	0.084 (0.15)	0.093 (0.16)	0.042 (0.18)
lnP(off-RTDs)	-0.179 (0.09)	-0.117 (0.09)	-0.147 (0.10)
lnP(on-beer)	1.169* (0.36)	1.029* (0.33)	1.548* (0.42)
lnP(on-cider)	0.237* (0.12)	0.260 (0.14)	0.386* (0.14)
lnP(on-wine)	-0.021 (0.16)	-0.021 (0.15)	-0.073 (0.20)
lnP(on-spirits)	-0.890* (0.19)	-1.036* (0.16)	-0.911* (0.23)
lnP(on-RTDs)	-0.071 (0.12)	-0.146 (0.14)	-0.160 (0.14)
lnIncome	0.592 (0.37)	0.950* (0.29)	0.899* (0.32)
Age x Age	-0.001 (0.00)	0.000 (0.00)	0.001 (0.00)
% Have children	-1.356* (0.28)	-1.237* (0.26)	-1.370* (0.26)
% Married	-0.819 (0.61)	-0.085 (0.46)	2.010* (0.53)
% Unemployed	-0.801 (0.94)	-0.789 (1.04)	-3.049* (1.20)
% Smoker	1.111 (0.60)	1.383* (0.58)	2.382* (0.62)
Female[1]		-0.434* (0.09)	-0.480* (0.07)
Higher socioeconomic[2]		-0.447* (0.20)	-0.627* (0.18)
Lower socioeconomic		-0.131 (0.14)	-0.044 (0.12)
1930-1934[3]		0.370 (1.24)	-2.660* (1.26)
1935-1939		0.698 (0.97)	-1.931* (0.94)
1940-1944		0.220 (0.72)	-1.639* (0.71)
1945-1949		-0.051 (0.50)	-1.228* (0.47)
1950-1954		-0.181 (0.30)	-0.718* (0.24)
1960-1964		0.142 (0.28)	0.761* (0.22)
1965-1969		0.248 (0.43)	1.322* (0.38)
1970-1974		0.247 (0.57)	1.861* (0.53)
1975-1979		0.344 (0.72)	2.687* (0.69)
1980-1984		0.597 (0.88)	3.727* (0.85)
1985-1989		0.637 (1.03)	4.337* (1.00)
F-test1 (p-value) [4]	2.16* (0.04)		3.17* (0.00)
F-test2 (p-value) [5]	9.27* (0.00)		9.63* (0.00)
SSE[6]	102.06		154.12
Log-likelihood	-317.30		-430.86
REM: Hausman-test (p-value)		54.09* (0.00)	

Remarks : same as Table in Appendix 5-1.

Appendix 5-8: Estimated coefficients, goodness-of-fit, and statistical tests for model selection for the demand of on-trade RTDs

Variables	Fixed Effects Model Coeff. (s.e.)	Random Effects Model Coeff. (s.e.)	OLS Coeff. (s.e.)
lnP(off-beer)	0.503 (0.43)	0.487 (0.38)	0.424 (0.41)
lnP(off-cider)	-0.194 (0.18)	-0.201 (0.17)	-0.265 (0.19)
lnP(off-wine)	0.110 (0.27)	0.116 (0.26)	0.007 (0.33)
lnP(off-spirits)	0.233 (0.29)	-0.050 (0.23)	0.123 (0.26)
lnP(off-RTDs)	0.093 (0.16)	-0.095 (0.15)	0.040 (0.18)
lnP(on-beer)	-0.117 (0.50)	0.060 (0.50)	0.497 (0.54)
lnP(on-cider)	0.241 (0.20)	0.386 (0.21)	0.401 (0.21)
lnP(on-wine)	-0.363 (0.20)	-0.458* (0.23)	-0.307 (0.21)
lnP(on-spirits)	0.809* (0.33)	0.778* (0.26)	0.666* (0.27)
lnP(on-RTDs)	-0.187 (0.27)	-0.070 (0.20)	-0.147 (0.26)
lnIncome	-0.418 (0.44)	-0.323 (0.43)	-0.346 (0.44)
Age x Age	0.001 (0.00)	0.001* (0.00)	0.001 (0.00)
% Have children	-1.526* (0.37)	-1.314* (0.35)	-1.282* (0.39)
% Married	-0.737 (1.03)	0.720 (0.67)	0.754 (0.73)
% Unemployed	-1.662 (1.51)	0.248 (1.48)	-1.690 (1.52)
% Smoker	1.694* (0.83)	1.909* (0.88)	2.416* (0.93)
Female[1]		-0.115 (0.10)	-0.138 (0.11)
Higher socioeconomic[2]		0.043 (0.26)	0.001 (0.26)
Lower socioeconomic		-0.031 (0.18)	-0.004 (0.19)
1930-1934[3]		-6.449* (2.11)	-6.247* (2.22)
1935-1939		-5.445* (1.65)	-5.349* (1.84)
1940-1944		-3.919* (1.20)	-4.009* (1.29)
1945-1949		-2.522* (0.79)	-2.652* (0.85)
1950-1954		-0.974* (0.44)	-1.005* (0.46)
1960-1964		1.158* (0.39)	1.077* (0.38)
1965-1969		2.083* (0.66)	1.905* (0.67)
1970-1974		2.867* (0.91)	2.672* (0.95)
1975-1979		3.571* (1.17)	3.360* (1.23)
1980-1984		5.121* (1.43)	4.982* (1.51)
1985-1989		6.041* (1.67)	5.886* (1.77)
F-test1 (p-value) [4]	1.46 (0.19)		1.61 (0.11)
F-test2 (p-value) [5]	14.18* (0.00)		4.92* (0.00)
SSE[6]	166.09		200.46
Log-likelihood	-404.74		-444.98
REM: Hausman-test (p-value)		40.55* (0.01)	

Remarks : same as Table in Appendix 5-1.

Appendix 6: Estimated own-price elasticities using 4 different methods for creating subgroups

	Base case: 72 subgroups (by birth cohorts, gender and 3 social groups)	96 subgroups (by birth cohorts, gender and 4 social groups)	48 subgroups (by birth cohorts, gender and 2 regions)	96 subgroups (by birth cohorts, gender and 4 regions)	Mean
Off-beer	-0.980*	-1.032*	-1.124*	-1.114*	-1.062
Off-cider	-1.268*	-1.285*	-1.301*	-1.244*	-1.275
Off-wine	-0.384*	-0.422*	-0.167	-0.002	-0.244
Off-spirits	-0.082	-0.226	0.024	-0.215	-0.125
Off-RTDs	-0.585*	-0.630*	-0.329	-0.262	-0.451
On-beer	-0.786*	-0.976*	-0.802*	-0.693*	-0.814
On-cider	-0.591*	-0.527*	-0.669	-0.382	-0.542
On-wine	-0.871*	-0.620*	-0.255	0.079	-0.417
On-spirits	-0.890*	-0.957*	-0.825*	-0.879*	-0.888
On-RTDs	-0.187	0.056	-0.251	-0.283	-0.166

Remarks *: p-value <=0.05.

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