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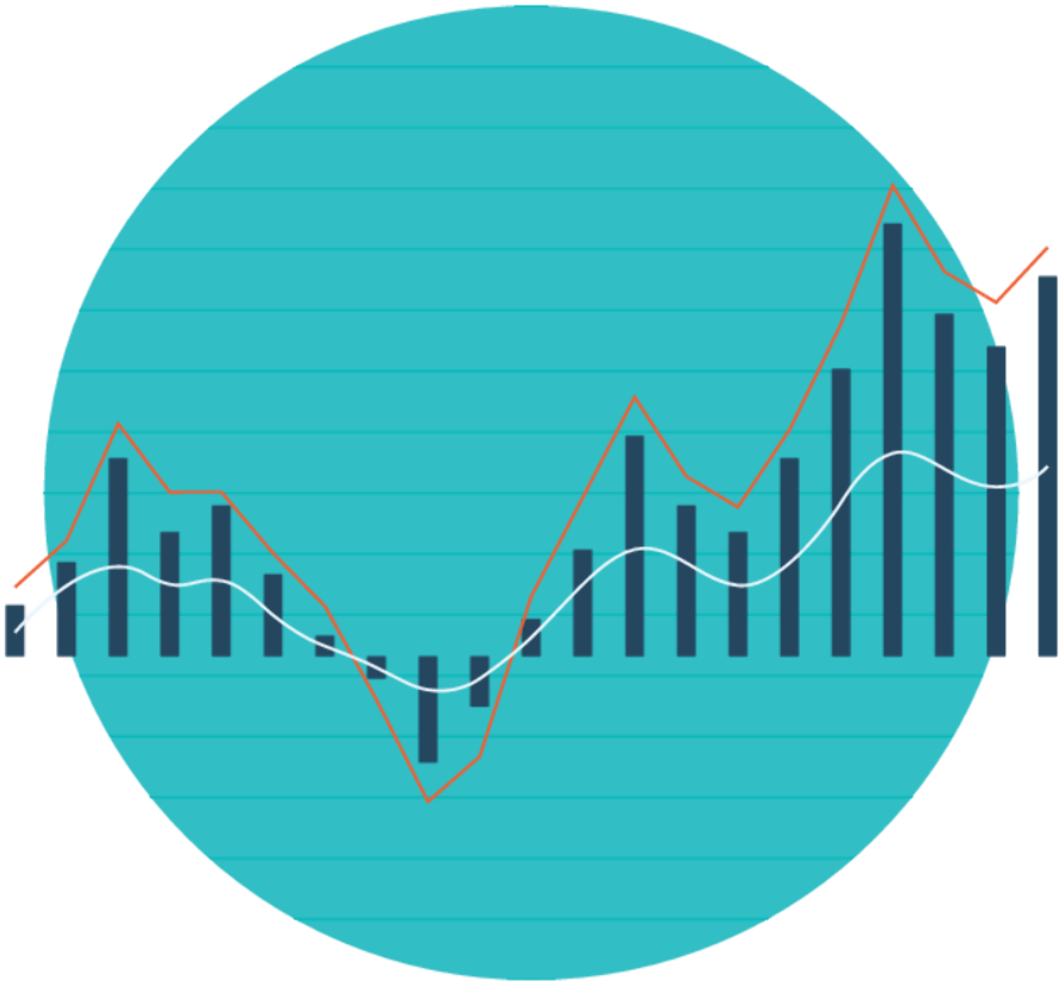

Sin Tax Analysis: Tobacco

Estimation of price elasticities of demand for cigarettes and rolling tobacco in the United Kingdom

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Abstract

Pressures on the NHS, demographic changes, further declines in North Sea oil and gas production, a social care system under strain, local councils needing financing support, calls to remedy the intergenerational divide. All these developments have in one thing in common—a likely need to raise more tax in future.

Governments of all political hues have always relied on so-called "sin taxes"—taxes on items with addictive or pollutive properties such as tobacco and alcohol—in order to both discourage consumption and raise more tax revenue. But there are now considerable policy challenges for these taxes which may significantly restrict their ability to raise more revenue in future. Lifestyle changes, manifested in falling smoking and drinking rates and the greater popularity of e-cigarettes, indicate that households have become more responsive to price rises and higher duties.

To provide evidence on whether households have become more responsive to price rises, this paper estimates the size of own and cross-price elasticities associated with consumption of the two major categories of tobacco products: cigarettes and rolling tobacco. Data from the Living Costs and Food Survey (LCF) from 2008 to 2016-17 has been used in conjunction with sample selection methods in order to accommodate the large number of households who do not consume tobacco.

A principle challenge of using LCF data to model the demand for tobacco lies in the dearth of information for both quantities consumed and prices. This study utilises different approaches to estimate both quantities and prices where data are unavailable. The own-price elasticity estimates for both cigarettes and rolling tobacco are both found to be negative and statistically significant, and the results are found to be stable when different specifications and price estimates are used.

The resulting elasticity estimates for cigarettes and rolling tobacco are comparable to those from more recent HMRC analyses which use product clearance data, rather than household survey data. The results indicate that households have become more responsive to price changes and suggest that the revenue-raising potency of Tobacco Duty us likely to have fallen in recent years. However, the underlying trend of consumption of cigarettes found to be negative while the trend for rolling tobacco is positive, consistent with HMRC clearance data.

Executive Summary

- Tobacco Duty has long provided a stable source of revenues for governments of all hues and persuasions. It accrued £8.8 billion for the Exchequer in 2017-18—and it's not hard to see why. Tobacco is highly addictive, so smokers are loathe to cut back even when faced with higher prices. A substantial tax on tobacco also has the clear rationale of funding the health spending needed to treat smoking-related illnesses.

- Governments of all persuasion and colours have increased Tobacco Duty in recent years. Persistent above-inflation increases in Tobacco Duty have consequently led to the UK levying one of the highest tax burdens on cigarettes among OECD countries; the latest OECD data show that the UK has the fifth highest average cigarette prices in 2016 (behind only New Zealand, Australia, Norway and Ireland), with Tobacco Duty and VAT making up over 80% of the typical retail price.

- At the same time, there has been an unmistakable phenomenon of falling tobacco consumption in the UK. In 2000 the ONS estimate that the average person smoked just under 14 cigarettes a day, and that around 27% of the population was a cigarette smoker. As of 2017, this has fallen to just under 11 cigarettes a day, and just 16.8% of the population. Deloitte analysis also shows that the average real expenditure on tobacco products per person is broadly the same as it was in 1988, despite a 19% rise in the adult population over the past thirty years.

- Furthermore, the popularity of e-cigarettes—which crucially do not attract Tobacco Duty due to the lack of tobacco content—has soared, particularly among young people. Action on Smoking and Health (ASH) estimate that there were 2.9 million "vapers" in the UK in 2017, a fourfold increase since 2012. ONS data also show that almost of a third of those aged in the 16-24 bracket reported having tried an e-cigarette in 2017.

- New Deloitte research using detailed and extensive ONS household data indicates that Tobacco Duty may now be past its peak as a significant revenue-raiser, and that higher duties may even be having a negative impact on revenue. For cigarettes—which form the bulk of the market—the research suggests that for each 1% increase in prices, household demand falls by between 1.1% and 1.3%, and that the underlying demand for cigarettes is falling by between 4% and 5% a year. For each 1% increase in rolling tobacco prices, demand falls by around 0.6%.

- This finding is backed up by the latest Spring Statement forecast from the OBR, who now expect Tobacco Duty revenues to actually start falling in the near term—from £9.1 billion in 2019-20 to £9.0 billion in 2023-24—and that's before inflation. Taking inflation into account, revenues have now fallen by around 16% since 2010, and that's despite the fact that the current duty rate is 60% higher than in March 2010, and over three-times as high as in 1988.

- In one sense Tobacco Duty has helped achieve a policy objective in getting people to smoke less while raising billions each year for the Exchequer. But the findings from the Deloitte analysis raise questions for the Chancellor of the Exchequer—where does he turn now for the higher revenue that will be needed in future? And should the Chancellor start to think more long-term about a more sustainable replacement for Tobacco Duty?

1. Background

Tobacco Duties raised a total of £8.8 billion of revenues in 2017-18, or approximately 1.7% of the total tax and National Insurance Contributions (NICs) raised in the UK; this contribution exceeded the revenue accrued from Vehicle Excise Duty (£6.4 billion), Insurance Premium Tax (£5.9 billion) and Inheritance Tax (£5.2 billion). The combination of demand for tobacco products and the duties levied on these products thus results in a sizeable contribution to the UK Exchequer.

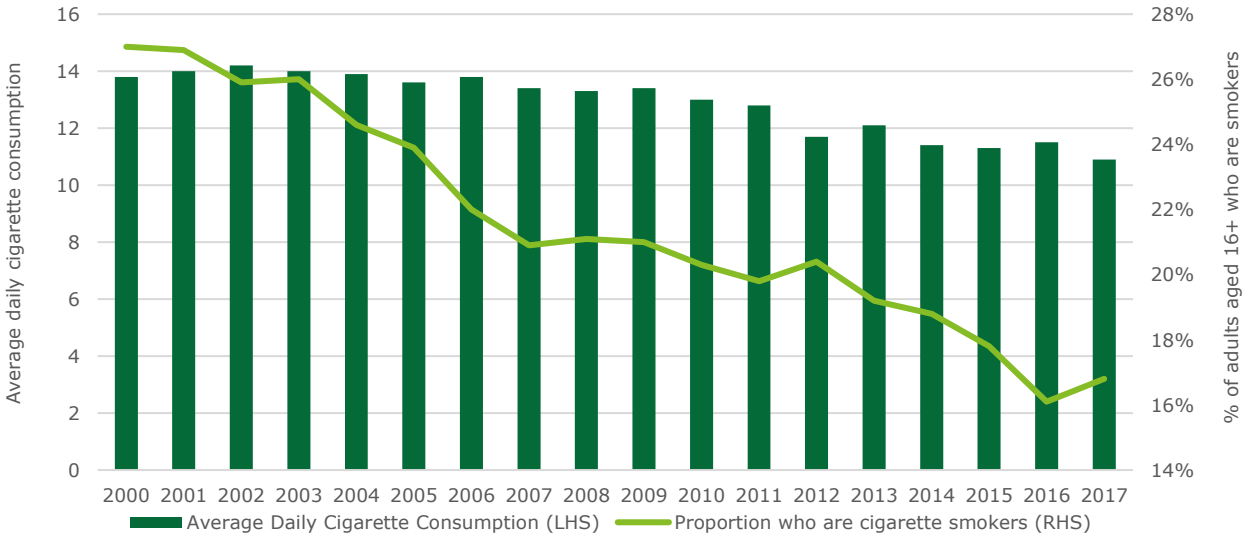
However, in recent years there has been an unmistakable phenomenon of falling tobacco consumption among households in the UK. A combination of greater awareness of the health impacts, an ever-higher tax burden borne by smokers and wider access to alternatives such as e-cigarettes are all likely to have contributed to this decline. This has direct implications for Tobacco Duty revenues, which are also falling in real terms.

The objective of this study is to estimate UK household demand for tobacco in light of these recent trends, with a particular focus on the demand for the most popular product categories: cigarettes and rolling tobacco. In particular, it seeks to estimate the size of the own-price elasticities associated with these products, thereby enabling comparisons again previous studies by Her Majesty's Revenue and Customs (HMRC).

1.1 Trends in smoking rates and tobacco consumption in the UK

The latest Office for National Statistics (ONS) Adult Smoking Habits in the UK publication[1] records fall in both the average daily consumption rate among cigarette smokers in Great Britain, and the proportion of persons aged 16 or over who are cigarette smokers, as shown in Figure 1 below. In 2000 the ONS estimate that the average person smoked just under 14 cigarettes a day, and that around 27% of the population in was a cigarette smoker. As of 2017, this has fallen to just under 11 cigarettes a day, and just 16.8% of the population.

Figure 1: Average daily cigarette consumption (LHS) and proportion of cigarette smokers (RHS) among adults aged 16 and over in Great Britain (based on weighted data since 2000)

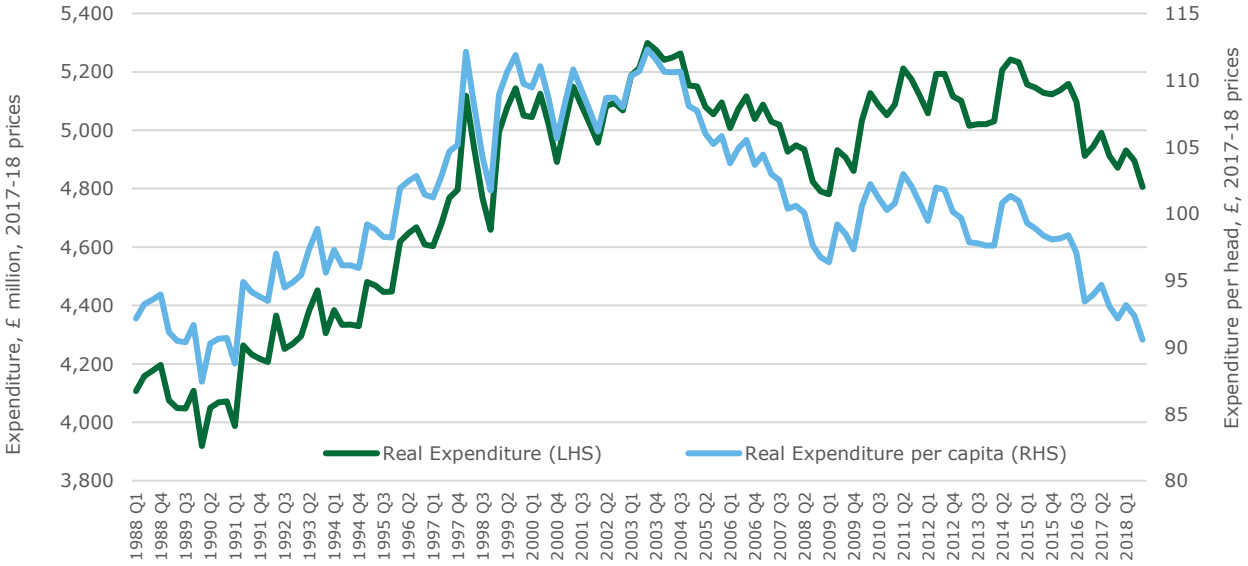


Note: Estimates prior to 2005 are based on a fiscal year rather than a calendar year. Source: ONS, Deloitte analysis

[1] ONS (2019). Adult smoking habits in the UK: 2017. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/adultsmokinghabitsingreatbritain/2017

The declining trend in cigarette consumption is also reflected in recorded household expenditure on tobacco products, recorded in ONS Consumer Trends data.[2] Figure 2 below shows the quarterly trend in household expenditure, expressed in 2017-18 prices, with this expenditure also expressed per adult aged 16 and over. In real terms, household expenditure on tobacco peaked at £5.3 billion in the third quarter of 2003; as of the first quarter of 2018, this had fallen to £4.8 billion. In 1988, the average person aged 16 or over spent just over £92 a year on tobacco (in 2017-18 prices); this is almost the same level recorded in the first quarter of 2018 (£91 per capita) despite the population increase over that period.

Figure 2: Real expenditure on tobacco products (in 2017-18 prices, LHS) and real expenditure on tobacco products per adult aged 16 or over (RHS)



Note: Tobacco expenditure using ONS series ADFL; UK population aged 16+ using ONS series MGSL. Source: ONS, Deloitte analysis

While cigarette consumption rates have been falling, use of e-cigarettes has increased as shown in the latest ONS E-cigarette use in Great Britain dataset.[3] The number of individuals reporting having tried an e-cigarette has increased since 2014; the proportion also reporting as an e-cigarette user has also increased.[4] Table 1 overleaf shows the estimates for the proportion of individuals in either having tried an e-cigarette or being a current user: both have increased since 2014. Disaggregating the 2017 statistics further by age group shows that younger people are far more likely to have tried an e-cigarette or be a current e-cigarette user.

Table 1: E-cigarette use in Great Britain, 2014 to 2017

	Individual years				2017 usage by age group				
Scenario	**2014**	**2015**	**2016**	**2017**	**16—24**	**25—34**	**35—49**	**50—59**	**60 +**
Tried an e-cigarette	15.2%	17.6%	18.6%	19.4%	31.7%	29.5%	23.3%	14.5%	7.4%
Been an e-cigarette user	10.0%	12.4%	13.4%	13.3%	16.6%	20.8%	16.7%	11.4%	5.5%
Current e-cigarette user	3.7%	4.5%	5.6%	5.5%	5.4%	7.3%	7.4%	5.4%	3.1%

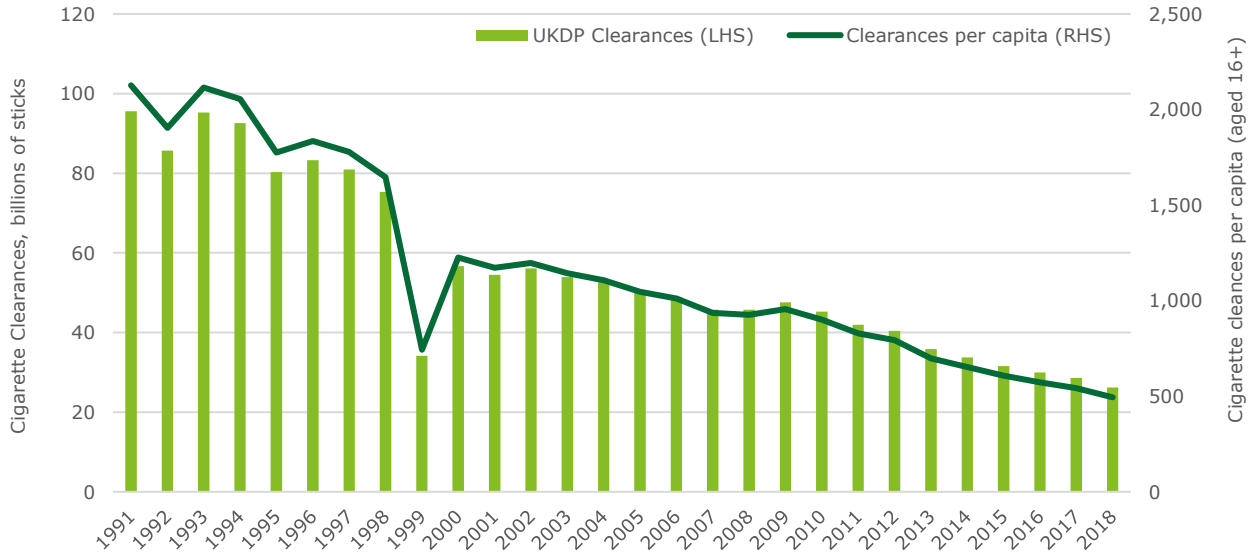
Source: ONS, Deloitte analysis

[2] ONS (2019). https://www.ons.gov.uk/economy/nationalaccounts/satelliteaccounts/bulletins/consumertrends/julytoseptember2018
[3] ONS (2019). E-cigarette use in Great Britain. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/drugusealcoholandsmoking/datasets/ecigaretteuseingreatbritain
[4] "Tried an e-cigarette" includes current e-cigarette users, those who said they used to use an e-cigarette but no longer use one, and those who said they tried an e-cigarette but did not go on to use it. "Been an e-cigarette user" includes current e-cigarette users and those who said they used to use an e-cigarette but no longer use one.

1.2 Trends in HMRC tobacco product clearances

The downward trends in both tobacco consumption and expenditure are also reflected in recorded clearances of UK Duty Paid (UKDP) tobacco products by Her Majesty's Revenue and Customs (HMRC). Figure 3 below shows trends in the total number of cigarette sticks cleared for consumption in the UK by HMRC, with this total also expressed per capita. In 1991, around 95.6 billion cigarette sticks were cleared for consumption by HMRC, or around 1,900 sticks per UK adult. In 2018, this had fallen to 26.2 billion cigarette sticks, or around 490 sticks per adult.

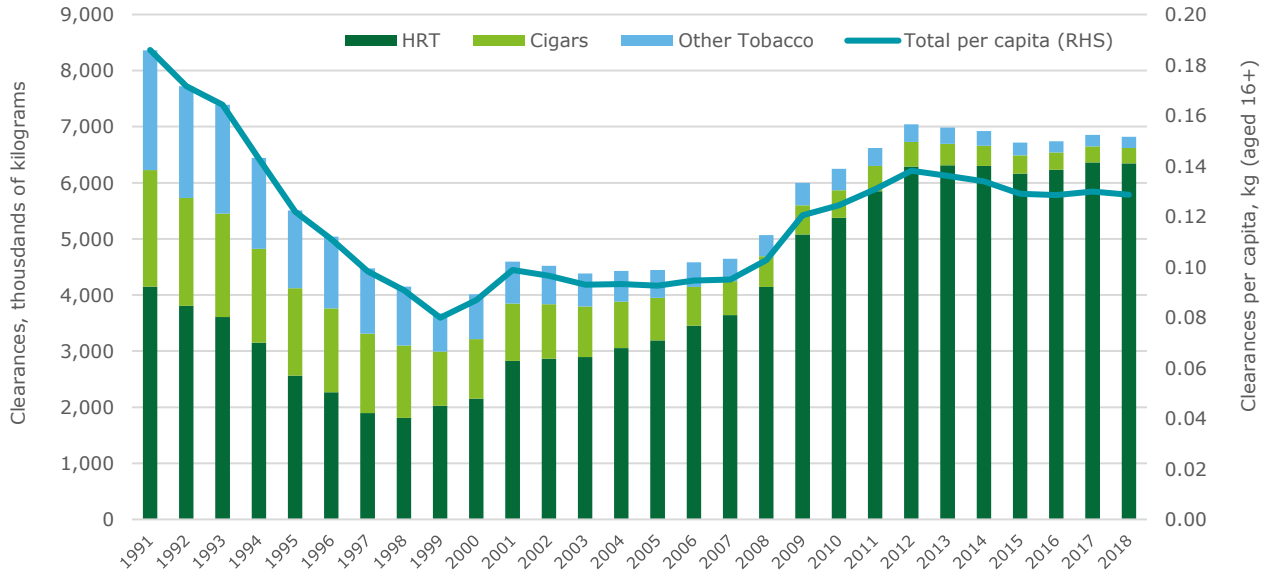
Figure 3: Total UKDP cigarette clearances (billions of cigarette sticks, LHS) and total cigarette clearances per capita (clearances per population aged 16 or over, RHS)



Note: the fall in clearances in 1999 is attributed to Budget-related timing effects. Source: HMRC, ONS, Deloitte analysis

Figure 4 below shows trends in total UK clearances of other (non-cigarette) tobacco products, more recently dominated by Hand Rolling Tobacco (HRT), and measured in kilograms. In 1991, a total of 8.4 million kg of non-cigarette products were cleared by HMRC for consumption, with nearly half consisting of HRT; this was equivalent to 0.19 kg per person. Due to the increasing popularity of HRT after 1998, clearances per capita had recovered to 0.13 kg per person by 2018.

Figure 4: Total UKDP clearances of other tobacco products (thousands of kilograms, LHS) and total clearances per capita (clearances per population aged 16 or over, RHS)



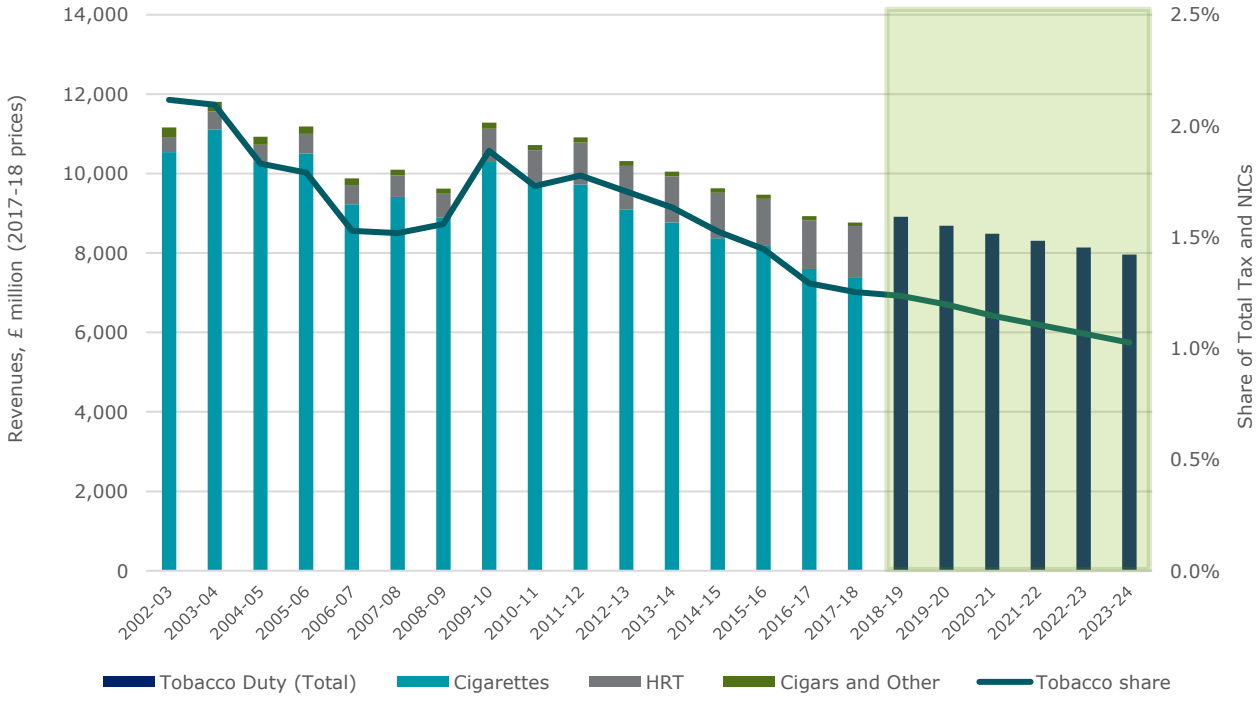
Note: the fall in clearances in 1999 is attributed to Budget-related timing effects. Source: HMRC, ONS, Deloitte analysis

1.3 Trends in Tobacco Duty rates and revenues

Tobacco Duty is an excise tax levied in the United Kingdom on cigarettes, HRT, cigars, pipe tobacco and other tobacco products. Cigarettes are taxed by through both an ad valorem component and a fixed duty component levied per 1,000 cigarettes; a Minimum Excise Tax (MET) rate is instead levied if the standard Tobacco Duty is lower than this minimum threshold. Duties on non-cigarette products are levied through a fixed duty component based on product weight.

Tobacco Duties have provided a consistent source of tax revenue for the Exchequer for many years, both through the duties raised in themselves, and the Value-Added Tax (VAT) raised on top of the underlying price of products and the duties applied. In 2017-18, accrued Tobacco Duty revenues totalled £8.8 billion, or approximately 1.3% of total UK taxes and National insurance Contributions (NICs); 84% of revenues are raised from cigarettes. However, duties have fallen recently when expressed in real terms and as a share of taxes, despite duty rate increases. Figure 5 below shows historical trends in Tobacco Duty revenues, with these revenues then expressed as a share of total taxes and NICs. The Office for Budget Responsibility (OBR) forecast from Spring Statement 2019[5] suggests that revenues in real terms will actually fall to around £8.0 billion by 2023-24, down from £11.2 billion in 2002-04, with the total tax share falling to just over 1.0%.

Figure 5: Historical and forecasted trends in accrued Tobacco Duty revenues (£ million, 2017-18 prices, LHS), and expressed as a share of total tax and NICs (RHS)



Note: ONS series GTAO and GCSU. Shaded area indicates forecast period.

Source: HMRC, OBR, ONS, Deloitte analysis.

The fall in the Tobacco Duty share of total receipts lies in contrast to the decision of consecutive governments to increase Tobacco Duty rates. For cigarettes, at the time of writing these duties are currently set at 16.5% of the retail price plus £4.57 on a packet of 20 cigarettes. For HRT, cigars and other tobacco, rates at the time of writing were set at £7.04 on a 30g packet of HRT, £2.85 on a 10g cigar, and £3.76 on a 25g packet of pipe tobacco respectively.[6] Duty rates on cigarettes have been increased by the UK Government every year since 1978.

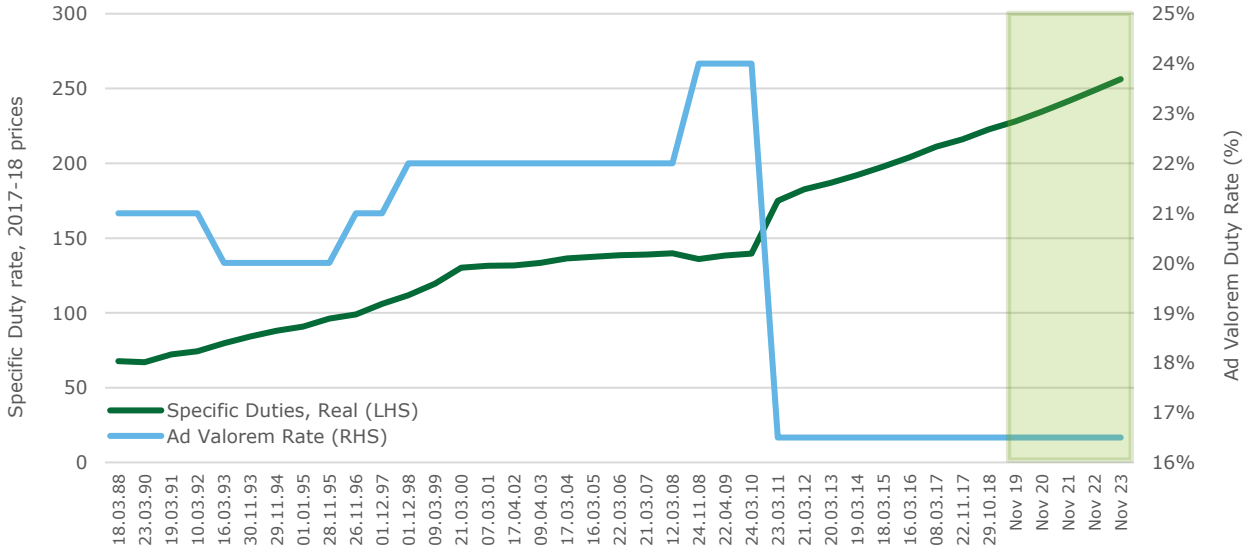
[5] OBR (2018). Economic and fiscal outlook—March 2019. http://obr.uk/efo/economic-fiscal-outlook-march-2019/

[6] .GOV (2018). Tax on shopping and services. https://www.gov.uk/tax-on-shopping/alcohol-tobacco

Figure 6 below shows specific cigarette duty rates since 1988[7] in pounds per 1,000 sticks expressed in real terms using 2017-18 prices, and the ad valorem duty rate. The specific duty rate has also been forecasted through to 2023-24 using the latest OBR forecasts for the Retail Price Index (RPI), based on the assumption that the duty rate will be to be increased by RPI plus 2% every November. The ad valorem duty rate is assumed to remain constant at 16.5%.

The specific duty rate on cigarettes grew by an average of 5.2% in real terms between 1988 and 2000; after this point, duties were increased broadly in line with inflation until 2011, with average growth in real terms of only 0.6% between 2000 and 2011. In March 2011, the specific duty rate on cigarettes increased from £119.03 to £154.95, and the ad valorem rate was reduced to 16.5%. In real terms, this represented a 25.2% increase; since then, successive fiscal events have seen duty rates increased by RPI plus 2%. In real terms, the current duty rate in force during the first quarter of 2019 is nearly 60% higher than the rate set in March 2010.

Figure 6: Real terms cigarette specific and ad valorem duty rates, specific duty in £ per 1,000 cigarette sticks (LHS, 2017-18 prices), and ad valorem duty (%, RHS)



Note: assumes that ad valorem rate remains at 16.5% in forecast period. Shaded area indicates forecast period.

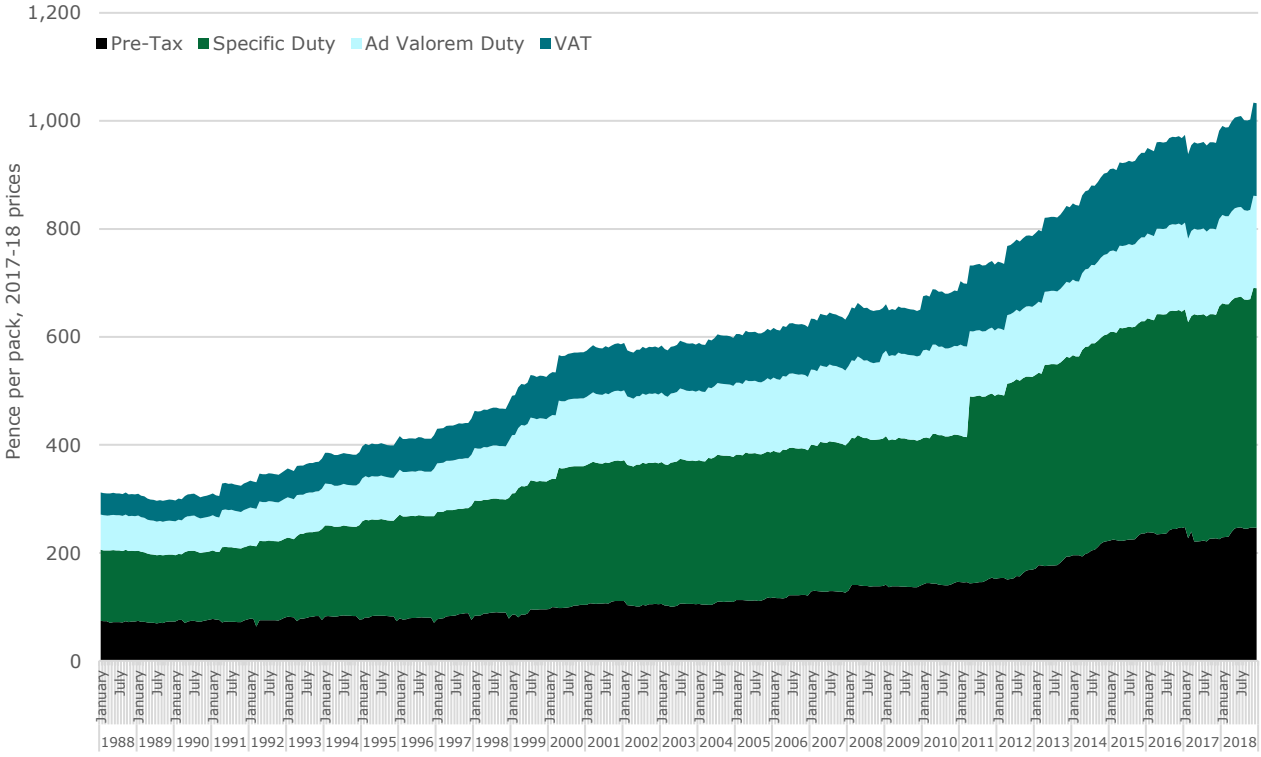
Duties forecast based on forecasted RPI growth plus 2%. Source: ONS, HMRC, OBR, Deloitte analysis

Over this period, the composition of the typical cigarette packet cost price by the underlying ("base") retail price and taxation has fluctuated, influenced by changes in manufacturing and inputs costs, duty rates and the main rate of VAT. Figure 7 overleaf shows the composition of the average price of a 20 pack of king size filter cigarettes, disaggregated by the base retail price, Tobacco Duty and VAT and expressed in 2017-18 prices. This has been sourced from the Office for National Statistics' (ONS) Consumer price inflation time series, and adjusted for inflation.

In January 1988, the average pack of 20 king size filter cigarettes cost £3.12 when expressed in 2017-18 prices; this comprised an underlying (pre-tax) price of £0.74, £1.32 of specific Tobacco Duty, £0.65 of ad valorem Tobacco Duty and £0.41 of VAT; the total tax burden represented 76.3% of the total price. By April 2000, after which duty rates had been increased on several occasions, the average price had increased to £5.66, and the tax share had increased to 82.7%. The introduction of much higher Tobacco Duty rates in April 2011 had a marked impact on the average price, which climbed to £7.32; a large increase in the Specific Duty rate led to the tax share increasing 80.4%. The latest data at the time of writing, up to January 2019, suggests that the average pack now costs £10.08 in 2017-18 prices; a large increase in the underlying price has led to the tax share falling back to 75.6%. Therefore, the average pack of 20 cigarettes is now over three-times as expensive as in January 1988 after accounting for inflation.

[7] HMRC (2018). Tobacco Bulletin - April 2018. https://www.gov.uk/government/statistics/tobacco-bulletin

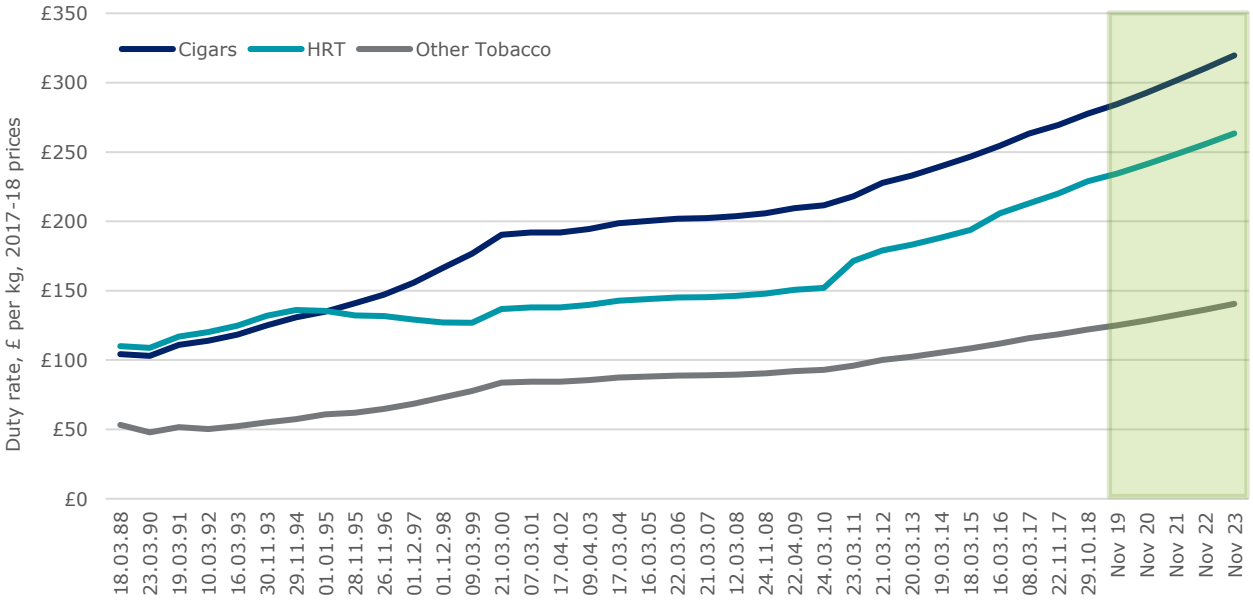
Figure 7: Composition of average price of 20 pack of king size filter cigarettes, 2017-18 prices



Note: prices up-to-date at time of writing. Source: ONS (series CZMP), HMRC, Deloitte analysis

Figure 8 below shows duty rates in real terms for cigars, HRT and other tobacco products over the same period; all duty rates are expressed in £ per kilogram. As with cigarettes, the HRT duty rate was increased considerably in March 2011, representing a 12.8% real-terms increase. Duty rates on cigars and other tobacco in contrast have grown steadily since 2000.

Figure 8: HRT, cigar and other tobacco duty rates, in 2017-18 prices

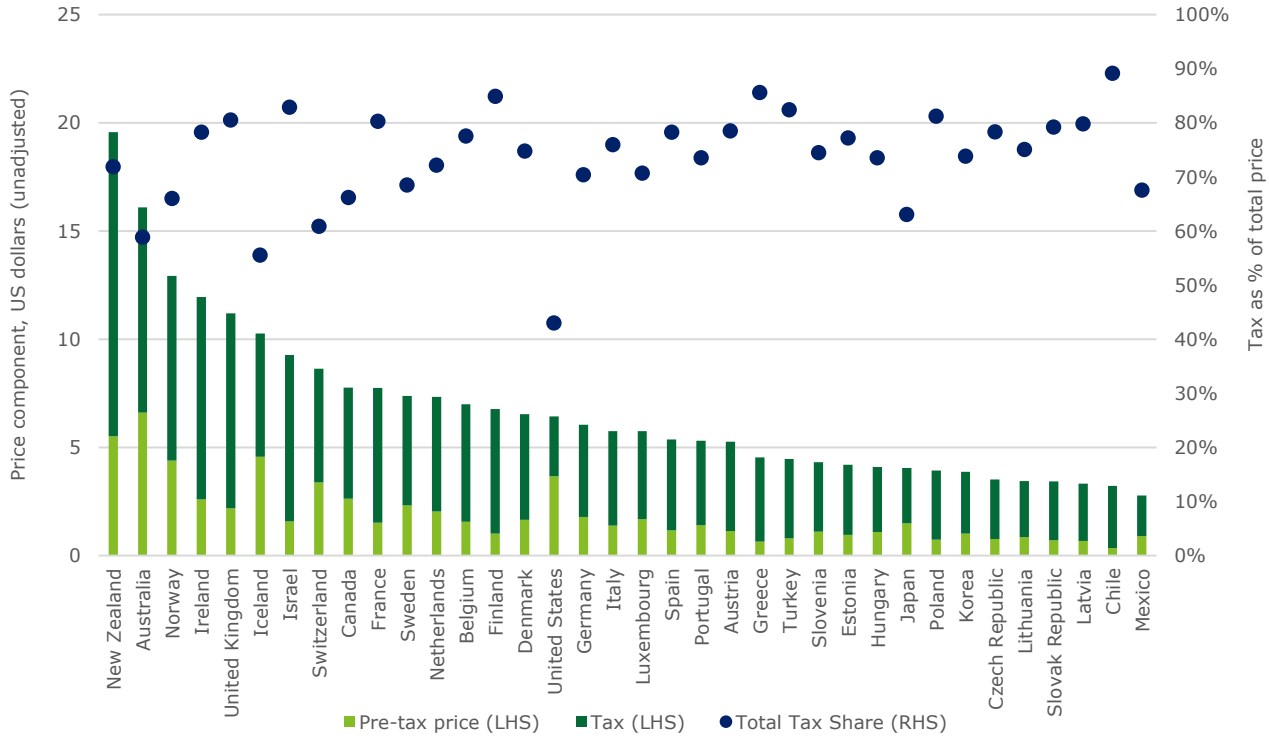


Note: shaded area indicates forecast period. Source: ONS, OBR, HMRC, Deloitte analysis

1.4 The burden of taxation on tobacco: comparisons across OECD countries

The tax burden which the UK imposes on cigarettes can be directly compared to the burden imposed by other countries. The Organisation for Economic Cooperation and Development (OECD) examine excise duties across the different OECD countries as part of the Consumption Tax Trends publication.[8] Pre-tax and post-tax prices for a standard pack of 20 cigarettes across OECD countries in 2016 is shown in Figure 9 below, based on the weighted average price.

Figure 9: Tax burden on a pack of 20 cigarettes in 2016 in OECD countries, in US dollars



Note: Pre-tax price includes producer and distributor margins. For Canada and the USA, average prices and taxes reflect the fact that different rates are applied by state/province over and above the applicable federal tax. Source: OECD, Deloitte analysis.

Based on the latest data for 2016, the UK had the fifth highest average price for a pack of 20 cigarettes in the OECD ($11.20), behind only New Zealand, Australia, Norway and Ireland, with tax, including both duties and VAT, making up over 80% of the total Recommended Retail Price (RRP). This outcome is largely due to two factors: the UK has both a relatively high standard VAT rate levied on all tobacco products, and also levies a very high Specific Duty rate on cigarettes when compared to other OECD countries.

So, despite the decision of successive governments to increase the Tobacco Duty rate considerably in excess of inflation, and the UK having one of the heaviest tax burdens on tobacco products among OECD countries, the Exchequer contribution made by Tobacco Duty is set to continue to fall. Given this background of ever-increasing Tobacco Duty rates, the objective of this study is to estimate the own- and cross-price elasticities of demand for the main categories of tobacco products in the United Kingdom: cigarettes and rolling tobacco. This will help to assess whether the responsiveness of smokers to price rises has further increased, and from this whether there is likely scope to further raise tax revenue from this particular source.

[8] OECD (2019). Consumption Tax Trends 2018, VAT/GST and excise rates, trends and policy issues. https://www.oecd-ilibrary.org/taxation/consumption-tax-trends-2018/selected-excise-duties-in-oecd-countries_ctt-2018-5-en

2. Literature Review

2.1 The demand for tobacco

It is clear from the array of previous studies that the demand for tobacco products is affected by a variety of factors, although prices and income are typically of particular interest. These other factors include the availability of other products, advertising and licensing restrictions, social norms, and personal circumstances. For the price elasticity of demand, studies to date broadly suggest that the demand curve for tobacco products slopes downward and that demand is still somewhat inelastic, although elasticities have increased over time in line with higher duties.

The majority of studies in this area have typically focused on the demand for cigarettes, as it is typically the most popular tobacco product category. Aside from metastudies, previous research can then be broadly broken down into those which draw upon data for total clearances in a particular country, and those which draw upon household cross-sectional surveys. There are advantages and disadvantages associated with both approaches. The former potentially provides a more accurate picture of non-illicit consumption of tobacco products, but does not enable analysis of consumption across different individuals and households. Conversely, the latter does enable the examination of these different factors, but there are potential problems with self-reporting of tobacco consumption in survey data, with households either potentially under-reporting their consumption, or problems of possible bias in elasticity estimates if there is an association between those not sampled and higher levels of tobacco consumption.

2.2 Studies focusing on tobacco demand in the United Kingdom

Her Majesty's Revenue and Customs (HMRC) and the former HM Customs and Excise (HMCE) have previously estimated the size of tobacco elasticities. Two notable studies are Chambers (1999) and Cullum and Pissarides (2004). Both studies used a dynamic Almost Ideal Demand System (AIDS) modelling framework, designed to empirically model consumer behaviour, as first proposed by Deaton and Muellbauer (1980). The former study focused on tobacco, while the latter examined demand for cigarettes and Hand Rolling Tobacco (HRT) separately. The two studies estimated average own price elasticities of -0.25 and -1.3 respectively.

Czubek and Johal (2010) estimate the price elasticity of demand for cigarettes in the UK. They use an Engle-Granger approach and draw upon ONS expenditure on cigarettes and pricing data received directly by tobacco manufacturers to firstly estimate the volume of UK Duty Paid (UKDP) cigarettes sold, before estimating income and price elasticities with the exchange rate and overseas visits as control variables to account for cross-border shopping. The long-run elasticity for cigarettes is found to be -1.05 in their preferred model, assessed at the sample average. In the 2015 update, which uses more recent data, the long-run elasticity for cigarettes is found to have increased to -1.19. A negative underlying time trend for consumption is found, suggesting that consumption is continuing to fall regardless of the influence of other factors.

Separately, Reed, Arnott and Langley (2013) also use an Engle-Granger twostep cointegration model to estimate the price elasticity of cigarettes in the United Kingdom, using monthly data on cigarette clearances and weighted average prices of cigarettes. They find that price elasticities range from -0.78 to -0.35, with these elasticities slightly lower than HMRC estimates but in line with other published studies.

2.3 Other studies focusing on tobacco demand

Gallus et al (2006) analyse the variation in demand for tobacco according to price of cigarettes across Europe, and estimate the price elasticity of demand for cigarettes using a double-log multiple linear regression. Estimated price elasticities were found to be -0.46 and -0.74 for local and foreign brands respectively; the inverse relation between cigarette price and consumption was stronger in countries not in the EU. On average, smoking consumption in Europe decreases by between 5% and 7% following a 10% increase in the real price of cigarettes.

Aristei and Pieroni (2008) examine the determinants of tobacco expenditures among Italian households, and utilise a Box-Cox double-hurdle model to separately model the decision to participate in tobacco consumption and the degree of consumption. While not focusing on the influence of prices, income and demographic factors are shown to have a significant effect on tobacco consumption; gender differences in both smoking participation and tobacco consumption patterns is found, while the prevalence of high education level and white collar occupations reduces the likelihood of both smoking and tobacco expenditure levels.

Nguyen, Rosenqvist and Pekurinen (2012) estimate the demand for tobacco in Europe using data from eleven countries, applying conventional, partial adjustment and rational addiction models covering periods ranging from 30 to 60 years. They find that for cigarettes, the short-run price elasticities of demand obtained ranged from –0.30 to –0.40, while the long-run elasticities ranged from –0.21 to –1.49, with the typical value around –1.0; they also find that higher real disposable income is associated with higher consumption. For the United Kingdom in particular, the income elasticity for cigarettes is found to range from 0.13 to 0.23 (with 0.23 taken from the preferred model); the long-run price elasticity for cigarettes ranges from -0.38 to -1.485.

Kennedy, Pigott and Walsh (2015) focus on the demand for cigarettes in the Republic of Ireland, which is similar to the UK in levying relatively high duties on tobacco products. They utilise a number of econometric models to estimate the price elasticity of demand for taxed cigarette consumption in Ireland. They find that the price elasticity for cigarettes ranges from -1.6 to -2.0, averaging at -1.8, suggesting that a tobacco tax increase in Ireland could perversely lead to an overall reduction in the Exchequer receipts associated with cigarettes.

Jamrich and Pokrivcak (2017) estimate the price elasticity of demand for cigarettes in Slovakia by applying a Heckman sample selection model and using household survey data for the period 2006 to 2012. They estimate that the income elasticity of demand for cigarettes is 0.11, and the price elasticity of demand is -0.92; in terms of participation, they estimate that the income elasticity of demand for cigarettes is 0.19, with of alcohol consumption and employment having a positive effect. Households with light cigarette consumption are more sensitive to price change than moderate and heavy smoking households.

Jawad et al (2018) consider the price elasticity of demand of non-cigarette tobacco products, providing a meta-analysis of results from 36 studies, 15 countries and 125 elasticity estimates. They find that a 10% price increase would reduce demand by: 8.3% for cigars; 6.4% for rolling tobacco; 5.7% for bidis (thin cigarettes or mini-cigars filled with tobacco flake and wrapped in a leaf); and 2.1% for smokeless tobacco. In addition, results from studies that assessed cross-price elasticities suggested a substitution effect between cigarette and non-cigarette products.

3. Dataset

3.1 The Living Costs and Food Survey (LCF)

The data used in this analysis was exclusively sourced from the Living Costs and Food Survey (LCF). The LCF collects information on spending patterns and the cost of living that reflect household budgets. It is conducted jointly by the Office for National Statistics (ONS) and the Department for the Environment, Food and Rural Affairs (Defra) throughout the year, across the whole of the UK, and is the most significant survey on household spending in the UK. The LCF features responses from approximately 12,000 households each year, of which typically around 50% provide responses. Two modules have been used to construct the dataset: the main LCF survey and the Family Food Module, the latter of which records expenditures on different items and the quantities purchased. Further information on which specific data fields have been used to construct the variables used in the empirical models can be found later in this paper.

The latest version of the LCF available through the UK Data Archive at the time of writing was the Living Costs and Food Survey, 2006-2017.[9] Data has been used for the calendar years 2008 to 2014, in addition to the first quarter of 2015, and the financial years 2015-16 and 2016-17. While ordinarily it would be advantageous to include data covering all available years, no data for the recorded number of cigarettes and quantity of rolling tobacco consumed appears in recorded diary data prior to 2008. This also means that only household data following the ban on smoking in public places in England in July 2007 has been used.

3.2 Missing quantities of tobacco purchased

While the LCF is designed to record weights and measures for food and drink purchases in order to inform data sent to Defra, it was not expressly designed to record quantities for non-food items such as cigarettes, rolling tobacco and other tobacco products. This represents a significant drawback of using the LCF for analysing the consumption of cigarettes and other tobacco products. However, in some instances where respondents have reported expenditure on cigarettes, LCF diary coders have also included information on quantities purchased, for instance by the size of cigarette pack purchased. For example, it has been recorded for some respondents that they have purchased two packs of 20 cigarettes, and spent a fixed amount on these. The combination of recorded expenditure and quantities of cigarettes has thus enabled the estimation of the price of an individual cigarette for all those households reporting expenditures.

The estimation approach is as follows. Firstly, prices for those households reporting both expenditure and quantities of tobacco consumed are simply calculated by dividing expenditures by quantity for each year of data. From these calculated prices, the Weighted Average Price (WAP) per cigarette is estimated, reflecting changes in prices over time. Expenditure has been divided by the weighted average price to infer the quantity purchased. As tobacco is typically sold in set quantities—for example, in packs of 20, 100, 200 and 400 cigarettes, with packets of 10 also available prior to their ban in April 2017—this estimated quantity can then be rounded to the nearest set quantity. Finally, prices are then estimated by dividing stated expenditures by this rounded quantity estimate. Table 2 overleaf shows the assumed set quantities of cigarettes purchased based on the implied quantity.

[9] LCF data can be found here: https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=7047

Table 2: Assumed set quantities of cigarettes implied by rounding, number of cigarettes

Quantity implied by WAP	Rounded quantity	Quantity implied by WAP (alt)	Rounded quantity (alt)
Less than 15	Pack of 10	Less than 15	Pack of 10
Between 15 and 20	Pack of 20	Between 15 and 20	Pack of 20
Between 20 and 100	Multiple packs of 20	Between 20 and 100	Multiple packs of 10
Between 100 and 150	Pack of 100	Between 100 and 150	Pack of 100
Between 150 and 200	Pack of 200	Between 150 and 200	Pack of 200
200 or more	Multiple packs of 200	200 or more	Multiple packs of 200

A similar approach has been used to estimate prices of rolling tobacco, but instead of prices being expressed per cigarette, they are expressed per gram of tobacco. 12.5g and 25g packs of rolling tobacco were banned in May 2017, with 30g set as the minimum weight that can be sold. After May 2017, rolling tobacco has typically been sold in packs of 30g or 50g. It is therefore assumed the majority of rolling tobacco in the years 2008 to 2016-17 was purchased in packs of 12.5g, 25g, 30g, 40g or 50g. Table 3 below shows the assumed set quantities of rolling tobacco purchased based on the implied quantity.

Table 3: Assumed set quantities of rolling tobacco implied by rounding, in grams

Quantity implied by WAP	Rounded quantity	Quantity implied by WAP (alt)	Rounded quantity (alt)
Less than 11.25	Pack of 10	Less than 11.25	Pack of 12.5
Between 12.5 and 15	Pack of 12.5	Between 12.5 and 18.75	Pack of 12.5
Between 15 and 25	Pack of 25	Between 18.75 and 25	Pack of 25
Between 25 and 31.25	Pack of 25	Between 25 and 31.25	Pack of 25
Between 31.25 and 37.5	Packs of 25 and 12.5	Between 31.25 and 37.5	Packs of 25 and 12.5
Between 37.5 and 43.75	Pack of 50	Between 37.5 and 43.75	Pack of 50
Between 43.75 and 50	Pack of 50	Between 43.75 and 50	Pack of 50
Above 50	Multiple packs of 25	Above 50	Multiple packs of 25

While the approach of using a WAP is a reasonable approximation for estimating quantities where households have reported low expenditures per transaction, its effectiveness is potentially weakened when households report higher levels of expenditure, due to the possibility of bulk purchases and discounting. Similarly, some households may have faced lower prices when making tobacco purchases through internet-based retailers.[10] For instance, a household reporting high expenditure on tobacco in a single transaction may indicate a bulk purchase of 100 or 200 cigarettes in a supermarket, but it could also indicate a transaction with an internet-based retailer or wholesaler where prices could be considerably lower. For example, in December 2018 a pack of 200 Benson and Hedges Gold King Size cigarettes was advertised for around £54.95 on one wholesaler's website;[11] the equivalent cost in Tesco was just over £113.[12] Weighted average prices have therefore been estimated at different levels of reported expenditure in order to accommodate potential bulk discounting effects on price.

For cigarettes, shop codes have also been used as an alternative means to calculate the price per cigarette. Within the LCF diary data, shop codes are recorded alongside each recorded transaction and detail the specific supermarket, store, wholesaler or outlet in which transaction took place. Prices are then estimated by grouping shops by category: supermarkets, high street stores;

[10] The LCF seeks to capture detailed information on household expenditure in the UK; spending outside the UK is captured separately in respondent diaries as aggregated amounts of cash/spending on cards etc.
[11] Bargain Cartons, Online Cigarettes (Dec 2018). https://www.bargaincartons.com/product-page/benson-hedges-gold-1-carton
[12] Tesco.com. Benson and Hedges Gold King Size 200 Pack (Dec 2018). https://www.tesco.com/groceries/en-GB/products/295664471

internet-only retailers; convenience stores and petrol stations; and other shops. Shop codes and information for their respective shops have been provided by the ONS separately.

3.3 Missing prices for non-smoking households

Another drawback of using the LCF is that tobacco product prices are missing for those households which do not record expenditure on any tobacco products; these households must still be included in the final dataset to avoid bias. Therefore, prices for these households are estimated using the averages of responses where prices are "known". Following Sousa (2014), average prices are calculated based on the year, region and household size to reflect regional differences in prices and potential discounting when households buy larger quantities. In instances where this average is incalculable, the average based on the region and year is used instead. In the absence of any other data, this is considered to be a reasonable adjustment.

3.4 Adjustment of prices for inflation

All tobacco prices have been adjusted for inflation using the monthly Consumer Price Index[13] (ONS series D7BT) with calendar year 2015 chosen as the base period. This ensures consistency when estimating own-price, cross-price and income elasticities using data across different years.

3.5 Descriptive statistics from the LCF dataset

The LCF dataset is balanced and nationally-representative. Table 4 below shows in each year the total number of households from whom survey responses were received, the average number of individuals across all households, and the average number of people in households who were eligible to smoke during the period. The legal age for buying tobacco increased to 18 in October 2007 in England and Wales, in March 2007 in Scotland and September 2008 in Northern Ireland.

Table 4: Total number of responding households, average household size and average number in household of smoking age (aged 18 or over) as taken from LCF data

Measure	2008	2009	2010	2011	2012	2013	2014	2015 q1	2015-16	2016-17
Total number of households	5,845	5,825	5,263	5,692	5,596	5,144	5,134	1,320	4,916	5,043
Average household size	2.37	2.36	2.31	2.36	2.36	2.36	2.36	2.36	2.36	2.37
Average number aged 18 or over	1.82	1.83	1.79	1.81	1.82	1.82	1.84	1.84	1.82	1.84

Note: figures subject to rounding. Source: LCF, Deloitte analysis

The number of households responding to the LCF has declined slightly in recent years, but fortunately the thousands of responses received over ten consecutive annual surveys still provides a rich dataset for the study. Further descriptive statistics covering other household and person-level variables used in this study are provided in Annex A. Table 5 below shows trends in the income and expenditure variables used in the study, expressed as averages across the sampled LCF households, and adjusted for inflation. As might be expected, incomes and expenditure continue to grow over time. The Average Weekly Expenditure is the preferred measure used in the study, with the rationale for this provided later in this paper.

[13] ONS (2019). CPI INDEX 00: ALL ITEMS. https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/d7bt/mm23

Table 5: Average income and expenditure measures used in the study

Measure	2008	2009	2010	2011	2012	2013	2014	2015 q1	2015-16	2016-17
Average Weekly Expenditure (EFS)	£456	£440	£449	£440	£437	£446	£453	£435	£459	£472
Average Total Expenditure	£555	£518	£519	£513	£511	£512	£517	£490	£526	£537
Average Gross Weekly Income	£825	£777	£771	£760	£751	£738	£765	£762	£785	£801
Average Disposable Income	£675	£640	£638	£627	£622	£617	£643	£633	£659	£674

Note: figures subject to rounding. Source: LCF, Deloitte analysis

Table 6 below shows the proportions of households recording consumption of tobacco and specific tobacco categories over the period considered. The proportion of households reporting expenditure on tobacco has gradually fallen over time, falling from just under 24% to 17% over the nine-year period. This trend is mirrored by the falling consumption of cigarettes, although the reported consumption of rolling tobacco has remained broadly stable.

Table 6: Consumption of tobacco and related products by proportion of households

Product	2008	2009	2010	2011	2012	2013	2014	2015 q1	2015-16	2016-17
Tobacco	23.8%	24.4%	22.9%	23.4%	20.8%	20.2%	18.2%	15.2%	16.0%	16.6%
Cigarettes	19.0%	19.8%	17.3%	17.6%	15.8%	14.8%	12.6%	10.2%	10.9%	10.7%
Rolling tobacco	5.5%	6.0%	7.0%	7.6%	6.5%	6.6%	6.0%	6.2%	5.0%	5.5%
Cigars and/or pipes	0.7%	0.5%	0.6%	0.6%	0.6%	0.4%	0.6%	-	0.3%	0.4%
E-cigarette devices, refills	-	-	-	-	-	0.7%	0.9%	0.9%	1.5%	1.9%
Cigarette papers and filters	4.0%	4.3%	4.4%	5.0%	4.0%	4.4%	3.9%	2.9%	3.3%	2.9%
Cigarette lighters	1.7%	1.8%	1.8%	1.9%	1.9%	2.2%	1.8%	1.2%	1.4%	1.2%

Note: figures subject to rounding. Source: LCF, Deloitte analysis

No data for e-cigarette devices and/or refills exists prior to 2013. Otherwise, dashes indicate where data has been suppressed

Finally, Tables 7 and 8 overleaf provide an overview of the average prices in the dataset for cigarettes and rolling tobacco, expressed through the Weighted Average Price (WAP) and in both nominal and real terms (adjusted using the CPI). For both cigarettes and rolling tobacco, these prices are estimates as derived using the approaches described in Tables 1 and 2 earlier in this section, in addition to the shop code approach for estimating the price of cigarettes. For cigarettes, prices are expressed per cigarette; for rolling tobacco, prices are expressed per gram of loose tobacco. Unfortunately the dataset does not have enough granularity to generate information on the quality of different tobacco products.

As might be expected, the estimated average price of these two major tobacco categories is increasing over time in line with higher rates of Tobacco Duty and underlying pre-tax inflation, with estimated price data for the first quarter of 2015 representing an outlier due to the smaller sample size. Prices are broadly similar across the different estimation approaches.

Table 7: Estimated Weighted Average Price of cigarettes, pence per cigarette

	Nominal Prices				Real Prices			
Year	**From diary quantities**	**Estimated across full sample**	**Alternate Method**	**Shop codes**	**From diary quantities**	**Estimated across full sample**	**Alternate Method**	**Shop codes**
2008	24.8	25.1	23.9	24.7	29.3	29.7	28.2	29.1
2009	25.1	25.6	25.5	25.3	29.0	29.6	29.4	29.2
2010	24.3	26.5	26.7	26.7	27.2	29.6	29.8	29.8
2011	29.1	29.9	30.0	29.8	31.2	32.0	32.1	31.9
2012	30.1	31.9	31.8	32.3	31.4	33.2	33.1	33.7
2013	31.9	34.7	34.6	34.5	32.4	35.2	35.2	35.0
2014	36.6	36.3	36.2	36.6	36.6	36.3	36.2	36.7
2015q1	38.8	38.5	38.5	39.0	39.0	38.7	38.7	39.2
2015-16	37.3	36.7	36.8	37.1	37.3	36.7	36.7	37.1
2016-17	37.7	37.8	37.0	37.6	37.3	37.4	36.6	37.2

Note: figures subject to rounding. Source: LCF, Deloitte analysis

Table 8: Estimated Weighted Average Price of rolling tobacco, pence per gram

	Nominal Prices		Real Prices	
Year	**Estimated across full sample**	**Alternate Method**	**Estimated across full sample**	**Alternate Method**
2008	21.7	21.3	25.6	25.2
2009	22.2	22.1	25.7	25.6
2010	27.1	26.5	30.3	29.6
2011	26.3	25.3	28.1	27.1
2012	29.3	28.4	30.5	29.6
2013	30.7	29.6	31.2	30.1
2014	33.4	32.4	33.4	32.4
2015q1	32.7	31.3	32.9	31.5
2015-16	33.3	31.2	33.3	31.2
2016-17	38.3	37.2	37.9	36.7

Note: figures subject to rounding. Source: LCF, Deloitte analysis

4. Model Choice and Specifications

4.1 The problem of zero observations and the choice of model

As shown earlier, a large number of households report having no expenditure on any tobacco products through the years covered in the sample; this could be either due to these products being too expensive, the influence of cultural and lifestyle factors on their preferences, under-reporting by households or perhaps simple measurement error. If these households were to be discarded from the sample, those remaining households who have committed expenditure to tobacco products will have been selected non-randomly, thereby introducing sample selection bias into any resulting elasticity estimates.

In the absence of these zero observations, the application of the Ordinary Least Squares (OLS) estimator would be appropriate, subject to the usual post-estimation tests for the normality of residuals, multicollinearity and heteroscedasticity. Use of the OLS estimator would also be appropriate if the characteristics of smoking and non-smoking households were believed to be similar, therefore indicating a lack of selection bias. However, assuming that there is a basis for this bias existing, the OLS estimator would fail to take into account the sample selection bias discussed above, rendering it unsuitable to estimate elasticities. In other words, an OLS model would in effect be attempting to determine the influence of factors on the decision to smoke as well as the impact of a change of prices on the quantity of tobacco consumed. Any approach must therefore attempt to circumvent this issue. Fortunately, a number of modelling approaches exist which are designed to deal with the problem of sample selection, but this analysis makes use of two tried-and-tested models: the Tobit Model and Heckman Correction Model, discussed in more detail below.

4.2 The Tobit Model

The Tobit Model, first proposed by James Tobin in 1958, addresses the sample selection bias which arises when there is a large quantity of zero observations present—in this instance, with a large number of households reporting zero expenditure on tobacco products. This is perhaps unsurprising as it would be expected that the majority of households do not smoke, and the LCF diary data only covers a two-week period. The application of standard Ordinary Least Squares (OLS) estimator in these circumstances, when data points are censored at zero, would create biased model coefficient estimates.

In the model, there is a latent variable Q_i^*representing the quantity of a product demanded, which is dependent on P_i, the price of that product in addition to the prices of other products. The latent variable Q_i^* could be negative as in reality some households will not consume certain products for health or cultural reasons, or because the price is too high—with these households constrained by zero demand. This is referred to as a corner solution: some households will refuse to purchase a particular good regardless of the price of that good or other goods; conversely, some will purchase the good regardless. Taking this into account, there is a coefficient which determines the relationship between quantity and price, and an error term ε_i which captures random disturbances. The actual quantity demanded is equal to the latent quantity when demand is in excess of 0, and equal to 0 when not.

From the above, Q_i^* is the latent quantity demanded; X_i is the list of independent variables; β is the list of model coefficients associated with these variables; and the error term ε_i is assumed to be normally distributed. The stated quantity demanded Q_i is strictly non-negative.

$$Q_i^* = X_i\beta + \varepsilon_i$$

$$Q_i = \begin{cases} Q_i^*, if\ Q_i^* < 0 \\ 0\ \ \ , if\ Q_i^* \geq 0 \end{cases}$$

The estimator for β, β', is calculated by maximising the following log likelihood function below.

$$\ln(L(\beta)) = \sum_{y_i>0} \ln\left(\frac{1}{\sigma}\ \phi\ \left(\frac{y_i - X_i\beta}{\sigma}\right)\right) + \sum_{y_i=0}\left(1 - \ \Phi\left(\frac{X_i\beta}{\sigma}\right)\right)$$

The terms ϕ and Φ represent the density function and cumulative density function of the standard normal distribution; σ is the standard deviation. The first part of the log likelihood function above covers all non-zero observations and corresponds to the standard OLS regression; the second part covers zero-only observations and corresponds to a standard Probit model. The coefficients are then estimated using a Maximum Likelihood Estimation (MLE) approach with respect to β. For this analysis, the estimated Tobit model is then as follows:

$$Q_i^* = \alpha + \sum_{i=1}^{4} \beta_i P_i + \gamma_j X_j + \varepsilon_i$$

Here, P_i represents the range of prices for tobacco products, covering cigarettes, rolling tobacco, cigars and e-cigarette products. The term X_j represents the control variables, or the list of other factors which are expected to influence both the decision to smoke and the quantity of tobacco products purchased: household income, socio-economic status, owner-occupier status among others, including a linear time trend. The coefficients for β are interpreted as the effect on the uncensored, latent quantity demanded, rather than the actual observed quantity demanded.

4.3 The Heckman Correction Model

While the application of the Tobit Model attempts to address the likely presence of corner solutions among some household preferences for tobacco, it would seem unlikely that all of the zero observations of tobacco consumption result from standard corner solutions. In other words, it seems more likely that some households will choose to abstain from tobacco consumption, and some will face corner solutions. Hence a modelling framework which firstly determines whether a household chooses to consume tobacco, and then if so determines what quantity is consumed, would likely be more appropriate.

The Heckman Correction Model offers an alternative means to deal with the selection bias that would otherwise manifest by focusing on a non-random sample—in this context, focusing on the preferences for only households that smoke. The Heckman Correction Model differs from the Tobit Model by applying a two-stage approach; the first stage involves estimating the probability of an individual or household having a non-zero response (in this case, reporting expenditure on tobacco or not), represented by a participation equation. The second stage, represented by a quantity equation, determines the factors which influence the quantity consumed and incorporates a transformation of the probabilities estimated in the participation equation. In effect, the inclusion of this transformation of probabilities solves the selection bias and is treated as another explanatory variable.

The Heckman model can be expressed as per the following two equations described below, the first representing the participation equation, and the second the quantity equation. The first takes the form of a Probit model specification, whereupon the dependent variable is constrained to be either one or zero.

$$d_i = Z_i'\gamma + \varepsilon_i \quad (1)$$

$$y_i = x_i'\beta + \delta\lambda_i + u_i \quad (2)$$

For the participation equation (1), d_i equals to one if participation occurs, i.e. the households consumes tobacco, and zero if not. The term Z_i' represents a number of explanatory variables though to influence this participation decision, such as the decision to consume similar products (for cigarettes, rolling tobacco or cigars) or related products (such as alcoholic beverages) and ε_i is an error term.

For the quantity equation (2), y_i is the quantity of tobacco product consumed, x_i' is the list of factors which are thought to influence the level of consumption, and u_i is once again a normally-distributed error term capturing random disturbances. The term δ represents the inclusion of the sample selection bias, and is captured through a function of the inverse Mills ratio, calculated for every observation. If following computation the coefficient on λ is found to be indistinguishable from zero, there is no evidence of sample selection bias, and an OLS approach can be used instead. However, if the coefficient on λ is statistically different from zero, it must be reported alongside the other model coefficients.

As the quantity equation follows a Probit model, the overall estimation must use a MLE approach. The estimator for β (β') is generated by maximising the following log likelihood function shown below.

$$L = \prod_{y_i=0} 1 - \Phi\left(\frac{Z_i'\gamma}{\sigma_d}\right) \prod_{y_i>0} \Phi\left\{\left(Z_i'\gamma + \frac{\sigma_{dy}}{\sigma_y^2}(y_i - x_i'\beta)\right)\sqrt{\sigma_d^2 - \frac{\sigma_{dy}^2}{\sigma_y^2}}\right\} \times \frac{1}{\sigma_y}\phi\left(\frac{(y_i - x_i'\beta)}{\sigma_y}\right)$$

This log likelihood function must be solved either iteratively (using the Full Information Maximum Likelihood approach, FIML) or using a two-step alternative estimator (Limited Information Maximum Likelihood, LIML). The FIML approach is preferred as although it is computationally demanding, it is generally more efficient and has been found previously to perform better with larger datasets—as is the case here, as the compiled LCF dataset consists of over 30,000 data points over ten individual surveys.

4.4 Choosing instruments for the Heckman Correction Model

One of the difficulties associated with the Heckman Correction Model approach is the high collinearity that can be observed between the inverse Mills ratio and the other explanatory variables included in the quantity equation; this multicollinearity can lead to inconsistent model coefficient estimates. As the participation and consumption equations share the same vector of predictors, the transformed predicted value in the first stage correlates strongly with the predictors in the second stage.

One typical solution to circumvent this issue is to include an additional set of variables which form part of the participation equation but not the quantity equation. Akin to instrumental variables, these predictors should influence the choice of participation but then have no relationship to the error term within the quantity equation. In other words and in this context, these additional variables should influence the decision to smoke but not the quantity smoked. Failure to include these exclusion restriction variables, using weak exclusion variables, or using exclusion variables that are themselves endogenous, will yield inconsistent and potentially biased estimates.

Fortunately, there are a number of candidate variables present within the LCF dataset which could be potentially used as instruments. In line with previous studies on alcohol consumption, they relate to factors driven by culture, health, and personal preferences. The most straightforward instrument would be **whether the household consumes other types of smoking products**, with the rationale for being that if a household consumes cigarettes for example, they are likely to consume rolling tobacco, cigars or vaping products as well. The consumption of these other products are captured through dummy variables, and provide additional insight on whether households view consumption of different products as being related.

A similar potential instrument is **whether the household consumes supplementary products used to aid tobacco consumption**. For all tobacco, one example of such a product could a **disposable cigarette lighter**; for rolling tobacco, supplementary products could include **cigarette papers and filters**, in addition to ashtrays and cigarette rolling machines. Again, the consumption of these supplementary products are captured through dummy variables, to ensure that the relationship is between the decision to smoke, rather than the quantity of product smoked.

A number of potential instruments have been rejected for inclusion in the participation equation. **Religion** has not been chosen as an instrument, for two reasons: firstly, the LCF dataset does not specifically contain information on household or individual religious beliefs, and it would therefore be necessary to proxy for this using some other household characteristic. Secondly, religious views on smoking vary widely, with the practice of smoking having only become prevalent in the centuries after the establishment of Judaism, Christianity and Islam. Ordinarily, **pregnancy** would be a potentially useful instrument, given that tobacco consumption during pregnancy is strongly discouraged; however, tobacco consumption is recorded at household level, so unless a household consists solely of an expectant mother, it is impossible to distinguish changes in consumption at an individual level.

4.5 Choosing Control Variables for the Tobit and Heckman Correction Models

Alongside prices, a number of control variables have been included in the models to ensure that the effect of price changes is adequately isolated. Without at least some attempt to control for these other non-price factors, there is a high risk of omitted variable bias influencing the results—with the model coefficients for prices inadvertently and unhelpfully capturing the effects of other factors as well. In line with previous studies, a number of standard control variables have been included to account for differences in preferences. These include a **linear time trend**, **region**, **socioeconomic group** and **ethnicity**, with the first of these reflecting changing preferences over time which are not captured through the other variables. The others reflect likely differences in consumption preferences across regions, skill levels and ethnic groups.

Alongside prices, **income** is one of the most important factors driving both the decision to smoke and the quantity of tobacco consumed. All other things being equal, higher incomes make tobacco consumption and vaping more affordable, with their consumption expected to be a normal good. However, this relationship is unlikely to be linear, and this is reflected in the models by expressing this variable in logs, and in separate specifications including both income and income squared. However, **household expenditure** has been used in the preferred and separate model specifications, given that it is expected that there will be less measurement error by households (who might for instance confuse pre-tax and post-tax income, or solely consider "income" as being from employment with other income sources disregarded), and more consistency over time in expenditure versus income. There is some evidence that **home ownership** has a depressing effect on tobacco consumption, and also acts as a proxy for economic stability; owner-occupier status is recorded within the LCF.

However, simply using reported household income or expenditure does not reflect the resource or consumption requirements for households of different sizes. It is therefore necessary to adjust household income and expenditure by some measure of household size to ensure that any measure of affordability of tobacco products is comparable across households. This process is known as **equivalisation of income or expenditure**, for which there are a number of tried-and-tested approaches: assigning values to the first adult, subsequent adults and children ("OECD equivalence scale" and "OECD modified equivalence scale"); and taking the square root of the total household size ("square root scale"). The different methods are explained in further detail here;[14] for this analysis, the square root scale approach has been used.

[14] OECD (undated). What are Equivalence Scales? Technical Note. http://www.oecd.org/eco/growth/OECD-Note-EquivalenceScales.pdf

Within the household, to control for the positive effect of a higher number of adults on levels of tobacco consumption, **the number of adults aged at or above the legal smoking age** have been included. The legal minimum age at which tobacco can be bought in England, Scotland and Wales increased from 16 to 18 in October 2007, so this is measured as the number of adults aged 18 or over. The composition of households by different age groups, and a greater predilection for smoking among older generations, has also been reflected by the inclusion of a control for those **households exclusively consisting of those aged 70 years old or more**. The **gender of the Household Reference Person (HRP)** has also been captured to help observe whether gender influences consumption.

Finally, two additional control variables have been included, following Aristei and Pieroni (2008). The first is **high expenditure on alcoholic beverages,** captured by a dummy variable for those households in the 75th percentile for expenditure on alcoholic beverages. The rationale for including this particular control is that there is likely to be complementarity between smoking and drinking, as shown for example by Decker and Schwartz (2000) and Pierani and Tiezzi (2008). In addition, it might be expected that the presence of younger children in the household would have a downward impact on tobacco consumption; **the presence of any children aged 5 or under** in the household is also included as a dummy variable.

4.6 The regression equations

For the estimation of elasticities using both the Tobit Model and Heckman Correction Model, a double log ("log-log") specification has been applied. The main advantage of using the log-log specification is that it is isoelastic: elasticities are constant across different levels of quantity demanded, and the coefficient results can be interpreted directly as elasticities without further transformation. Semi-log specifications have also been subsequently applied to act as robustness checks; elasticities have been computed at the sample mean, as the coefficients cannot in themselves be interpreted as elasticities.

Table 9 below lists the variables used in the final model specifications, with the instruments listed included in the Heckman Correction Model specifications. The variables included in the Tobit Model specifications are the same, with the exception of the instruments which are discarded. A constant value is also included in the model. The consumption of cigarettes and rolling tobacco variables are interchangeable depending on the dependent variable (for example, the consumption of cigarettes is not used as an instrument when the dependent variables is the quantity of cigarettes consumed, to avoid multicollinearity.)

Table 9: Variables used in the final specifications using the Heckman Correction Model

Dependent Variable	Explanatory Variables	Instruments	Controls
Quantity of cigarettes	Price of cigarettes	Consumption of cigarettes	Log equivalised real expenditure (or income)
Quantity of rolling tobacco	Price of rolling tobacco	Consumption of rolling tobacco	Home ownership (owner-occupier status)
		Consumption of cigars	Number of people in household of smoking age
		Consumption of e-cigarette refills	Households with members all aged 70 or over
		Consumption of cigarette filters and papers	Male House Reference Person
		Consumption of lighters	Heavy-drinking household
			Children aged 5 or under
			Region
			Marital status
			Socio-economic group
			Ethnicity
			Linear Time Trend

5. Model results

5.1 Results using preferred modelling specification

The estimated price elasticities are shown in Table 10 below. The own-price elasticities are found to be highly statistically significant, and imply that overall demand for cigarettes in the UK is price elastic, while demand for rolling tobacco is price inelastic. The results suggest that, all other things being equal, a 1% increase in the real prices of cigarettes and rolling tobacco would reduce household demand by 1.3% and 0.6% respectively. Given that the majority of tobacco consumed in the UK is in the form of cigarettes, and that the results suggest that households are now quite responsive to cigarette price changes, further increases in duty rates may have a sufficiently strong negative impact on consumption to offset the otherwise tax revenues generated.

Table 10: Elasticity estimates using the log-log specification

	Quantity	
Price	**Cigarettes**	**Rolling Tobacco**
Cigarettes	-1.32***	-0.03
	(0.12)	(0.16)
Rolling Tobacco	0.43***	-0.57***
	(0.12)	(0.18)

Note: figures subject to rounding; own-price elasticities highlighted. Standard errors shown in parentheses. Asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1). Source: LCF, Deloitte analysis

Cross-price elasticities for the two tobacco product categories have also been estimated, which are smaller in magnitude; only the cross-price elasticity for rolling tobacco is statistically significant. The associated coefficient estimates should not be directly interpreted as the impact of an increase of a price of one tobacco category on demand for another. This is because the modelling approach applied here analyses uncompensated or Marshallian demands, unavoidably incorporating both the income and substitution effects resulting from a price change.[15]

Table 11 below shows the own-price and cross-price elasticities estimated using the alternative log-linear specification. Elasticity estimates have been obtained by multiplying the resulting model coefficients, set out in full in Annex C, by the sample average. Notably, the elasticity estimate for cigarettes is close to that previously estimated by Czubek and Johal (2010, updated 2015).

Table 11: Implied elasticity estimates using the log-linear specification

	Quantity	
Price	**Cigarettes**	**Rolling Tobacco**
Cigarettes	-1.11***	-0.06
	(0.00)	(0.00)
Rolling Tobacco	0.41***	-0.72***
	(0.00)	(0.00)

Note: figures subject to rounding; own-price elasticities highlighted. Standard errors shown in parentheses. Asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1). Source: LCF, Deloitte analysis

[15] Following standard demand theory, an increase in the price of a good will have both an income and substitution effect. The substitution effect involves a consumer shifting consumption away from the higher-priced good to another; the income effect involves the consumer choosing a new set of goods following the reduction in their purchasing power. In the model estimated here, while a measure of the income effect is incorporated through the inclusion of the weekly expenditure variable, this effect cannot be stripped out to solely leave the substitution effect. The use of a Hicksian demand function, in which a consumer minimises their expenditure to achieve a certain desired level of utility, would enable the identification of the substitution effect in isolation, but this is not examined here.

5.2 Other results

The inclusion of the weekly household expenditure variable as a proxy for income enables the estimation of an income elasticity. Table 12 below sets out the estimated coefficients and associated standard errors taken from the preferred modelling specification again with the preferred double-log functional form. In addition, estimates are also provided for models using both weekly expenditure and a quadratic term, to capture any non-linear income effects. The results do not suggest evidence of a non-linear relationship between income and demand, but the own-price elasticities for cigarettes and rolling tobacco remain robust regardless.

Table 12: Elasticity estimates with both weekly expenditure and a quadratic term

Model	Variable	Cigarettes	Rolling Tobacco
Preferred Model	Weekly Expenditure	0.40***	0.21***
		(0.02)	(0.03)
	Own-price elasticity	-1.32***	-0.57***
		(0.12)	(0.18)
Preferred Model with quadratic for weekly expenditure	Weekly Expenditure	-0.14	0.30
		(0.16)	(0.20)
	Weekly Expenditure (squared)	0.28***	-0.04
		(0.01)	(0.09)
	Own-price elasticity	-1.34***	-0.57***
		(0.12)	(0.18)

Note: figures subject to rounding; own-price elasticities highlighted. Standard errors shown in parentheses. Asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1). Source: LCF, Deloitte analysis

The estimated effects of other variables are shown in Table 13 below, which are again taken from the preferred model specification. These effects are broken down into the decision to participate in either cigarette or rolling tobacco consumption and the quantity consumed. The estimated time trend is also shown, capturing the underlying trends in participation and consumption. A full set of the results for all non-price and income variables can be found in Annex C of this paper.

A negative underlying time trend is observed both for the decision to consume cigarettes and the volume consumed, but only the participation result is found to be statistically significant. These results would imply that the proportion of those deciding to smoke cigarettes is falling by around 5 per cent each year, and that underlying consumption is falling by about 0.2 per cent each year; participation in rolling tobacco consumption appears to be growing each year however. Households comprising only older members, owner-occupiers are less likely to consume cigarettes, while heavier-drinking households are both more likely to smoke cigarettes and are more likely to consume greater amounts.

Table 13: Other estimates from the preferred model using the log-log specification

Variable	Cigarettes		Rolling Tobacco	
	Participation	Consumption	Participation	Consumption
Linear Time Trend	-0.05***	-0.00	0.02***	0.02**
Household all aged 70 or over	-0.45***	-0.15**	0.16***	0.17**
Heavy Drinking Household	0.18***	0.11***	-0.47***	-0.01
Owner-Occupier	-0.11***	-0.06*	0.11***	-0.05
At least one child aged under 5	0.11***	-0.06*	-0.15***	-0.17***

Note: figures subject to rounding; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)
Source: LCF, Deloitte analysis

5.3 Robustness checks

Tables 14 and 15 below show the results of further robustness checks applied to the cigarette and rolling tobacco models for the income and price elasticity estimates, using different methods including: quarterly data; different income and expenditure control variables; different end years for the data sample; and the alternative price calculations set out in the previous section. The results are found to be broadly stable in each case, with the price elasticities slightly trending upwards over time.

Table 14: Robustness checks for cigarette model using the log-log functional form

		Log Real Weekly Expenditure	Log Real Price of Cigarette	Log Real Price of Rolling Tobacco	Sample
Main Model	Main Model	0.40***	-1.32***	0.43***	49,778
	Quarterly Data	0.36***	-1.31***	0.48***	49,778
Other Income Variables	Total Expenditure	0.32***	-1.32***	0.46***	49,777
	Total Income	0.12***	-1.21***	0.41***	49,690
	Disposable Income	0.11***	-1.20***	0.41***	49,665
Other chosen end years for data sample	2011	0.40***	-1.14***	0.30*	22,625
	2012	0.39***	-1.22***	0.25	28,221
	2013	0.40***	-1.24***	0.36**	33,365
	2014	0.40***	-1.25***	0.38**	38,499
	2015q1	0.40***	-1.24***	0.37**	39,819
	2015-16	0.42***	-1.27***	0.37***	44,735
Other Price Approaches	Cigarette, Shop Code	0.39***	-1.08***	0.45***	49,778
	Cigarettes	0.36***	-1.38***	0.47***	49,778
	Cigarettes, Rolling Tobacco	0.36***	-1.38***	0.28**	49,778

Note: figures subject to rounding; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)

Table 15: Robustness checks for rolling tobacco model using the log-log functional form

		Log Real Weekly Expenditure	Log Real Price of Cigarette	Log Real Price of Rolling Tobacco	Sample
Main Model	Main Model	0.21***	-0.03	-0.57***	49,778
	Quarterly Data	0.22***	-0.05	-0.56***	49,778
Other Income Variables	Total Expenditure	0.21***	-0.04	-0.57***	49,777
	Total Income	0.08***	-0.04	-0.57***	49,690
	Disposable Income	0.10***	-0.03	-0.57***	49,665
Other end years for data sample	2011	0.16***	-0.04	-0.63*	22,625
	2012	0.19***	-0.23	-0.74**	28,221
	2013	0.19***	0.00	-0.75**	33,365
	2014	0.19***	-0.00	-0.73***	38,499
	2015q1	0.20***	-0.06	-0.77***	39,819
	2015-16	0.21***	-0.08	-0.57***	44,735

Other Price Approaches	Cigarette, Shop Code	0.21***	-0.08	-0.57***	49,778
	Rolling Tobacco	0.21***	-0.03	0.23**	49,778
	Cigarettes, Rolling Tobacco	0.21***	0.03	-0.28**	49,778

Note: figures subject to rounding; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)

5.4 Other modelling specifications

Other modelling specifications in order to test the robustness of the model coefficients for the different alcohol categories. These alternative specifications include Ordinary Least Squares (OLS) on both the full sample and a subsample of non-zero observations, and the aforementioned Tobit Model. In order to exploit the full data sample, the preferred Heckman model specification and the alternative specifications have been tested with the linear-log specification. Otherwise, in the case of the Tobit model and the OLS model with full sample, the log transformation of the dependent variable would result in the loss of zero observations. Following convention, the elasticities have been estimated at the sample average.[16] The Full Information Maximum Likelihood (FIML) estimator is typically not as stable when using levels in the left-hand side of the equation, so the Heckman Model with two-step estimator has been used instead.

Table 16 below shows the results of the alternative models for cigarettes; only the income and own-price and cross-price elasticities are shown. The elasticities estimated using the Tobit model and OLS model with full sample are significantly different, suggesting an upward bias; the difference is less pronounced for the OLS model with the subsample of non-zero cigarette consumption. However, given the results of the Chi-Square tests for the preferred modelling specifications, as shown in the full model results in Annex C, this provides evidence that the Heckman model is providing more consistent results, with less risk of bias.

Table 16: Elasticities using alternative cigarette models using the linear-log functional form

Specification	Cigarettes (Own-price)	Rolling Tobacco (Cross-price)
Heckman, twostep	-1.21***	0.67***
Tobit Model	-0.50***	0.14**
OLS, full sample	-1.23***	0.69***
OLS, subsample	-0.53***	0.18

Note: figures subject to rounding; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)

The results for the rolling tobacco model using the same alternative modelling specifications, as shown in Table 17 below, are found to be similar. There is once again evidence of an upward bias on the elasticity estimates found using both OLS specifications, although this is less pronounced for the OLS applied to households with non-zero rolling tobacco consumption.

Table 17: Elasticities using alternative rolling tobacco models using the linear-log functional form

Specification	Cigarettes (Own-price)	Rolling Tobacco (Cross-price)
Heckman, twostep	0.00	-0.54***
Tobit Model	-0.02*	-0.11***
OLS, full sample	-0.02	-0.55***
OLS, subsample	-0.25*	-0.65***

Note: figures subject to rounding; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)

[16] When using a linear-log functional form, the own-price elasticity is conventionally estimated using the transformation of the own-price coefficient by dividing it by the quantity consumed; in this case, the quantity consumed is taken as the sample average.

Annex A: Further Descriptive Statistics

This annex sets out the descriptive statistics for the other variables used in the study not already covered earlier in the paper. For the Region, Socioeconomic Group, Marital Status and Ethnicity variables, the reference category is shown emboldened, as it necessary to create a reference category for which the effects of the other categories can be compared against.

Table A.1: Households by former Government Office Region (GORS) and other variables

Region	Proportion	Variable	Proportion
North East	5%	Consumers of alcoholic beverages	53.0%
North West and Merseyside	11%	With all members aged 70 or above	16.1%
Yorkshire and the Humber	9%	With at least one child aged under 5	33.6%
East Midlands	8%	Owner-occupiers (outright, mortgage)	12.4%
West Midlands	9%	Married or Civil Partnership	49.9%
East of England	10%	Co-habitee	10.6%
London	9%	Single	14.7%
South East	13%	Widowed	10.6%
South West	9%	Divorced, Separated or Former Civil Partner	14.3%
Wales	5%		
Scotland	9%		
Northern Ireland	5%		

Source: LCF, Deloitte analysis

Table A.2: Households by socioeconomic group and ethnicity by Reference Person (HRP)

Socioeconomic group	Proportion	Ethnicity	Proportion
Large employers and higher managerial	7%	White	73%
Higher Professional	13%	Mixed Multiple Ethnic	2%
Lower managerial and professional	17%	Asian or Asian British	2%
Intermediate occupations	6%	Black or Black British	1%
Small employers and own account workers	6%	Other Ethnic Group	1%
Lower supervisory and technical occupations	5%	Not Known	21%
Semi-routine occupations	7%		
Routine occupations	6%		
Never worked and long term unemployed	2%		
Students	1%		
Occupation not stated	1%		
Not classified	29%		

Source: LCF, Deloitte analysis

Annex B: Constructing the dataset using LCF data

This annex sets out information on how the dataset has been constructed using data taken from the LCF for the years 2008 to 2016-17. Data has been sourced from three main sources within the LCF: the main household-level data, personal-level data, and raw household diary data.

B.1 Household and person-level data

Information for individual households has been sourced and compiled from the main LCF household-level datasets, and have collectively been used to generate most of the control variables. Each household is attributed a case number within the LCF, which forms the basis of each observation. The household-level variables used are described in Table B.1 below.

Table B.1: LCF household-level variables

LCF Code	Variable	Description
A049	Household Size	Number of individuals in household
Year	Year	Yeah of survey
SampQtr	Sample Quarter	Calendar quarter in which household data collected
GORX	Government Office Region (GORS)	Region where the household is located
P600	Weekly total consumption expenditure	Weekly total consumption expenditure using EFS criteria
P550P	Total expenditure	Total expenditure, by adults and children (anonymised)
P344	Gross Household income	Gross normal weekly household income
P389	Disposable household income	Normal weekly disposable household income

Table B.2: Household-level variables derived using LCF household-level data

LCF Code(s)	Variable	Description
A043-A047	Number at smoking age	Number of individuals in household who are eligible to smoke, proxied by aged 18 or above
A047	Older household	Households in which all members are aged 70 or over
SexHRP	Sex of House Reference Person	Gender of HRP (Male or Female)
A121	Owner-occupier	Households which are outright owners of their main dwelling, or own with a mortgage
A040, A041	Children under 5	Households which have at least one child aged five or under living in the household
FS21	Heavy Drinking Household	The top 75th percentile of households by expenditure on alcoholic beverages in each year.

Table B.3: Household-level variables derived using LCF person-level data

LCF Code(s)	Variable	Description
A006	Marital status	Marital status of HRP, condensed into: Married or Civil Partnership; Co-habitee; Single; Widowed; and Divorced, Separated or Former Civil Partner
A121	Ethnicity	Ethnicity of HRP: White, Mixed Multiple Ethnic, Asian or Asian British, Black or Black British, and Other Ethnic Group
A094	Socioeconomic group	Socioeconomic group of HRP by 12 category grouping

B.2 Tobacco consumption data

Information for the consumption of the two main tobacco products of interest—cigarettes and rolling tobacco—has been sourced from the raw LCF household diary data as described in Table B.4 below.

Table B.4: Household-level variables derived using LCF person-level data

EFS Expenditure Code(s)	Variable	Description
2.1.1.1.1	Cigarettes	Consumption of cigarettes excluding cigarette papers
2.1.1.3.1	Rolling Tobacco	Consumption of rolling tobacco excluding pipe tobacco

In addition to cigarettes and rolling tobacco, information for the consumption of other tobacco products (cigars and pipes), e-cigarette products and smoking-related accessories (chiefly lighters and cigarette papers) has also been captured as described in Table B.5 below.

Table B.5: Household-level variables derived using LCF person-level data

EFS Expenditure Code(s)	Variable	Description
2.1.1.2.1	Cigars	Consumption of cigars
2.1.1.3.1	Pipes	Consumption of pipe tobacco (excluding rolling tobacco and snuff)
12.3.2.2.1, 2.1.1.3.1	E-cigarettes	Consumption of e-cigarette devices, including electronic nicotine delivery systems, electronic smoking devices; consumption of e-cigarette refill products including vaping fluid
2.1.1.1.1	Cigarette papers	Cigarette papers and filters, including Rizla papers, and excluding cigarettes
12.3.1.1.1, 12.3.2.2.1	Other accessories	Consumption of other related accessories including ashtrays, cigarette cases, and cigarette rolling machines
12.3.1.1.1, 12.3.2.2.1	Disposable lighters	Cigarette lighters and disposable lighters

Annex C: Full Model Results

This annex sets out the full results of the models for cigarettes and rolling tobacco. The results for the participation and quantity equations within the preferred modelling specification are set out, using both the log-log and log-linear formats.

Table C.1: Regression outputs from the participation equation using log-log specification

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
Log Price of Cigarettes	0.187	0.006	Semi-routine occupations	0.317***	0.131**
	(0.127)	(0.145)		(0.041)	(0.060)
Log Price of Rolling Tobacco	0.0031	-0.257*	Routine occupations	0.361***	0.190***
	(0.085)	(0.147)		(0.042)	(0.061)
Log equivalised weekly expenditure	-0.0141	-0.281***	Never worked and long-term unemployed	0.297***	0.427***
	(0.013)	(0.021)		(0.059)	(0.078)
Consumption of Cigarettes	-	0.384***	Students	-0.127*	-0.00569
	-	(0.027)		(0.070)	(0.098)
Consumption of Rolling Tobacco	0.466***	-	Occupation not stated	0.261***	0.357***
	(0.033)	-		(0.068)	(0.094)
Consumption of Cigars	0.243**	0.433***	Not classified	0.0924**	0.0615
	(0.099)	(0.129)		(0.037)	(0.055)
Consumption of Pipes	0.0161	1.570***	Not stated	0.018	0.0337
	(0.256)	(0.253)		(0.019)	(0.029)
Consumption of Electronic Cigarettes	0.133	0.189*	Mixed Multiple Ethnic	-0.138***	-0.429***
	(0.096)	(0.113)		(0.058)	(0.103)
Consumption of Cigarette Paper	0.204***	2.117***	Asian or Asian British	-0.213***	-0.385***
	(0.040)	(0.034)		(0.085)	(0.132)
Consumption of Cigarette Lighter	0.893***	0.400***	Black African, Caribbean, Black British	-0.311***	-0.285**
	(0.057)	(0.064)		(0.085)	(0.132)
Male Household Reference Person	-0.132***	0.0456*	Other ethnic group	-0.0836	-0.0761
	(0.017)	(0.026)		(0.102)	(0.139)
Number at smoking age or above	0.219***	0.161***	North East	0.0922**	-0.139**
	(0.012)	(0.017)		(0.042)	(0.071)
Household members all aged 70 or over	-0.455***	-0.470***	North West and Merseyside	0.0676**	0.0542
	(0.030)	(0.047)		(0.034)	(0.055)
Heavy Drinking Household	0.179***	0.113***	Yorkshire and the Humber	0.0737**	0.0461
	(0.021)	(0.032)		(0.036)	(0.057)
Owner-Occupier	-0.113***	-0.146***	East Midlands	-0.00248	0.114**
	(0.017)	(0.026)		(0.037)	(0.058)
At least one child aged under 5	0.109***	0.0446	West Midlands	0.0302	0.127**
	(0.022)	(0.032)		(0.036)	(0.056)

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
Co-habitee	0.333***	0.290***	Eastern England	-0.0903**	0.214***
	(0.023)	(0.033)		(0.036)	(0.054)
Single	0.355***	0.320***	South East	-0.0600*	0.145***
	(0.027)	(0.038)		(0.033)	(0.052)
Widowed	0.215***	0.02	South West	-0.228***	0.285***
	(0.033)	(0.053)		(0.038)	(0.054)
Divorced, Separated or Former Civil Partner	0.414***	0.277***	Wales	-0.00826	0.137**
	(0.027)	(0.040)		(0.044)	(0.065)
Higher Professional	-0.0841**	-0.0815	Scotland	0.190***	0.0742
	(0.039)	(0.057)		(0.035)	(0.057)
Lower managerial and professional	0.0241	-0.0695	Northern Ireland	0.386***	-0.0256
	(0.036)	(0.055)		(0.039)	(0.066)
Intermediate occupations	0.0541	-0.133**	Linear Time Trend	-0.0470***	0.0223***
	(0.043)	(0.067)		(0.006)	(0.008)
Small employers and own account workers	0.218***	0.0158	Constant	-2.048***	-0.168
	(0.043)	(0.064)		(0.507)	(0.680)
Lower supervisory and technical occupations	0.346***	0.0858			
	(0.043)	(0.065)	Observations	49,778	

Standard errors in parentheses; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)

Table C.2: Regression outputs from the quantity equation using log-log specification

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
Log Price of Cigarettes	-1.323***	-0.032	Not classified	0.360***	0.13
	(0.124)	(0.163)		(0.066)	(0.080)
Log Price of Rolling Tobacco	0.429***	-0.574***	Not stated	0.00687	-0.0439
	(0.124)	(0.180)		(0.031)	(0.038)
Log equivalised weekly expenditure	0.404***	0.213***	Mixed Multiple Ethnic	-0.358***	-0.0774
	(0.024)	(0.030)		(0.082)	(0.141)
Male Household Reference Person	-0.0239	-0.00181	Asian or Asian British	-0.264**	-0.475***
	(0.028)	(0.031)		(0.103)	(0.165)
Number at smoking age or above	0.0525***	-0.0557***	Black African, Caribbean, Black British	-0.577***	-0.299**
	(0.020)	(0.021)		(0.131)	(0.135)
Household members all aged 70 or over	-0.146**	0.171**	Other ethnic group	-0.344	0.148
	(0.057)	(0.079)		(0.248)	(0.212)
Heavy Drinking Household	0.111***	-0.0102	North East	0.132*	0.283***
	(0.035)	(0.044)		(0.068)	(0.090)
Owner-Occupier	-0.0553*	-0.0466	North West and Merseyside	0.194***	0.182**
	(0.029)	(0.038)		(0.057)	(0.076)
	-0.0619*	-0.171***		0.123**	0.280***

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
At least one child aged under 5	(0.035)	(0.040)	Yorkshire and the Humber	(0.059)	(0.077)
Co-habitee	0.0174	-0.0714*	East Midlands	0.0217	0.128
	(0.040)	(0.043)		(0.063)	(0.078)
Single	-0.0464	-0.413***	West Midlands	0.120**	0.202***
	(0.045)	(0.048)		(0.058)	(0.075)
Widowed	0.00642	-0.0749	Eastern England	0.014	0.135*
	(0.054)	(0.074)		(0.061)	(0.073)
Divorced, Separated or Former Civil Partner	-0.0152	-0.318***	South East	0.0183	0.0946
	(0.045)	(0.050)		(0.057)	(0.072)
Higher Professional	0.0688	-0.0982	South West	-0.149**	0.0981
	(0.072)	(0.086)		(0.067)	(0.073)
Lower managerial and professional	0.102	-0.109	Wales	0.0873	0.176**
	(0.065)	(0.084)		(0.071)	(0.088)
Intermediate occupations	0.146*	0.0029	Scotland	0.316***	0.210***
	(0.075)	(0.094)		(0.057)	(0.081)
Small employers and own account workers	0.210***	0.0175	Northern Ireland	0.469***	0.252***
	(0.075)	(0.097)		(0.060)	(0.094)
Lower supervisory and technical occupations	0.252***	0.00931	Linear Time Trend	-0.00235	0.0205**
	(0.073)	(0.092)		(0.008)	(0.010)
Semi-routine occupations	0.290***	-0.0446	Constant	4.675***	5.145***
	(0.070)	(0.083)		(0.587)	(0.798)
Routine occupations	0.343***	0.0245	atan(rho)	0.331***	-0.215***
	(0.072)	(0.084)		(0.054)	(0.024)
Never worked and long-term unemployed	0.257***	0.0397	log(sigma)	0.0342**	-0.218***
	(0.094)	(0.100)		(0.015)	(0.011)
Students	-0.337***	-0.156	Inverse Mills Ratio	0.33	-0.17
	(0.116)	(0.129)		Chi-Square	Chi-Square
Occupation not stated	0.209**	0.101	LR test of independence	36.90***	79.65***
	(0.101)	(0.103)			
			Observations	49,778	

Standard errors in parentheses; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)

Table C.3: Regression outputs from the participation equation using log-linear specification

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
Log Price of Cigarettes	0.0206***	-0.001	Semi-routine occupations	0.287***	0.134**
	(0.004)	(0.004)		(0.041)	(0.060)
Log Price of Rolling Tobacco	0.000833	0.0012	Routine occupations	0.331***	0.199***
	(0.003)	(0.005)		(0.042)	(0.061)
Log equivalised weekly expenditure	-0.000179***	-0.000823***	Never worked and long-term unemployed	0.266***	0.504***
	(0.000)	(0.000)		(0.059)	(0.078)
Consumption of Cigarettes	-	0.378***	Students	-0.150**	-0.00711
	-	(0.026)		(0.070)	(0.099)
Consumption of Rolling Tobacco	0.465***	-	Occupation not stated	0.234***	0.413***
	(0.033)	-		(0.068)	(0.094)
Consumption of Cigars	0.243**	0.425***	Not classified	0.0630*	0.0873
	(0.099)	(0.130)		(0.037)	(0.055)
Consumption of Pipes	0.0053	1.559***	Not stated	0.0173	0.0334
	(0.255)	(0.251)		(0.019)	(0.029)
Consumption of Electronic Cigarettes	0.13	0.177	Mixed Multiple Ethnic	-0.143***	-0.411***
	(0.096)	(0.112)		(0.058)	(0.102)
Consumption of Cigarette Paper	0.201***	2.115***	Asian or Asian British	-0.232***	-0.361***
	(0.040)	(0.034)		(0.085)	(0.132)
Consumption of Cigarette Lighter	0.891***	0.397***	Black African, Caribbean, Black British	-0.324***	-0.261**
	(0.058)	(0.064)		(0.085)	(0.132)
Male Household Reference Person	-0.133***	0.0460*	Other ethnic group	-0.0924	-0.0622
	(0.017)	(0.026)		(0.102)	(0.139)
Number at smoking age or above	0.220***	0.153***	North East	0.106**	-0.120*
	(0.012)	(0.017)		(0.043)	(0.071)
Household members all aged 70 or over	-0.460***	-0.460***	North West and Merseyside	0.0786**	0.0584
	(0.030)	(0.047)		(0.034)	(0.055)
Heavy Drinking Household	0.189***	0.102***	Yorkshire and the Humber	0.0910**	0.0536
	(0.021)	(0.033)		(0.036)	(0.057)
Owner-Occupier	-0.119***	-0.148***	East Midlands	0.0123	0.118**
	(0.017)	(0.026)		(0.037)	(0.058)
At least one child aged under 5	0.0987***	0.0598*	West Midlands	0.0493	0.130**
	(0.022)	(0.032)		(0.036)	(0.056)
Co-habitee	0.332***	0.292***	Eastern England	-0.0800**	0.209***
	(0.023)	(0.033)		(0.036)	(0.054)
Single	0.347***	0.348***	South East	-0.0503	0.147***
	(0.026)	(0.038)		(0.033)	(0.052)
Widowed	0.209***	0.0281	South West	-0.217***	0.280***
	(0.033)	(0.053)		(0.038)	(0.054)

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
Divorced, Separated or Former Civil Partner	0.408***	0.292***	Wales	0.00659	0.146**
	(0.027)	(0.040)		(0.044)	(0.066)
Higher Professional	-0.0955**	-0.0983*	Scotland	0.207***	0.0831
	(0.039)	(0.058)		(0.036)	(0.058)
Lower managerial and professional	0.00301	-0.0812	Northern Ireland	0.392***	-0.0248
	(0.036)	(0.055)		(0.039)	(0.066)
Intermediate occupations	0.0264	-0.143**	Linear Time Trend	-0.0661***	0.0142*
	(0.043)	(0.067)		(0.006)	(0.008)
Small employers and own account workers	0.190***	0.0158	Constant	-2.015***	-2.294***
	(0.043)	(0.064)		(0.137)	(0.196)
Lower supervisory and technical occupations	0.321***	0.0798			
	(0.043)	(0.065)	Observations	49,778	

Standard errors in parentheses; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1)

Table C.4: Regression outputs from the quantity equation using log-linear specification

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
Log Price of Cigarettes	-0.0364***	-0.002	Not classified	0.270***	0.0764
	(0.003)	(0.005)		(0.066)	(0.081)
Log Price of Rolling Tobacco	0.0146***	-0.0262***	Not stated	0.00822	-0.0418
	(0.004)	(0.005)		(0.031)	(0.038)
Log equivalised weekly expenditure	0.000694***	0.000383**	Mixed Multiple Ethnic	-0.392***	-0.0676
	(0.000)	(0.000)		(0.083)	(0.143)
Male Household Reference Person	-0.0176	-0.000958	Asian or Asian British	-0.278***	-0.476***
	(0.028)	(0.031)		(0.103)	(0.159)
Number at smoking age or above	0.0755***	-0.0400*	Black African, Caribbean, Black British	-0.607***	-0.314**
	(0.021)	(0.021)		(0.130)	(0.134)
Household members all aged 70 or over	-0.161***	0.178**	Other ethnic group	-0.343	0.144
	(0.058)	(0.079)		(0.246)	(0.216)
Heavy Drinking Household	0.154***	0.0148	North East	0.0913	0.249***
	(0.036)	(0.045)		(0.068)	(0.092)
Owner-Occupier	-0.0523*	-0.0455	North West and Merseyside	0.167***	0.171**
	(0.029)	(0.038)		(0.058)	(0.076)
At least one child aged under 5	-0.102***	-0.185***	Yorkshire and the Humber	0.0974	0.261***
	(0.035)	(0.041)		(0.060)	(0.077)
Co-habitee	0.0157	-0.0794*	East Midlands	0.0142	0.115
	(0.040)	(0.042)		(0.063)	(0.079)
Single	-0.0788*	-0.442***	West Midlands	0.0971	0.185**
	(0.045)	(0.048)		(0.059)	(0.076)
Widowed	0.00355	-0.0752	Eastern England	0.0187	0.136*
	(0.055)	(0.075)		(0.061)	(0.073)

	Cigarettes	Rolling Tobacco		Cigarettes	Rolling Tobacco
Divorced, Separated or Former Civil Partner	-0.035	-0.335***	South East	0.0151	0.087
	(0.045)	(0.050)		(0.058)	(0.072)
Higher Professional	0.0846	-0.0768	South West	-0.149**	0.0985
	(0.073)	(0.087)		(0.068)	(0.073)
Lower managerial and professional	0.111*	-0.096	Wales	0.07	0.157*
	(0.066)	(0.085)		(0.072)	(0.089)
Intermediate occupations	0.143*	0.00113	Scotland	0.293***	0.192**
	(0.075)	(0.095)		(0.058)	(0.082)
Small employers and own account workers	0.192**	0.00952	Northern Ireland	0.474***	0.246***
	(0.075)	(0.097)		(0.061)	(0.094)
Lower supervisory and technical occupations	0.234***	-0.00226	Linear Time Trend	-0.00714	0.0283***
	(0.074)	(0.092)		(0.008)	(0.010)
Semi-routine occupations	0.255***	-0.0705	Constant	4.325***	4.972***
	(0.070)	(0.083)		(0.215)	(0.219)
Routine occupations	0.288***	-0.00718	atan(rho)	0.334***	-0.222***
	(0.073)	(0.085)		(0.056)	(0.024)
Never worked and long-term unemployed	0.0849	-0.0585	log(sigma)	0.0440***	-0.215***
	(0.094)	(0.099)		(0.015)	(0.011)
Students	-0.364***	-0.155	Inverse Mills Ratio	0.336	-0.176
	(0.116)	(0.131)		Chi-Square	Chi-Square
Occupation not stated	0.072	0.00714	LR test of independence	35.98***	84.89***
	(0.103)	(0.103)			
			Observations	49,778	

Standard errors in parentheses; asterisks indicate significance level (*** p<0.01; ** p<0.05; * p<0.1

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