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Econometric Analysis of Cigarette Consumption in the UK

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December 2010

HMRC Working Paper Number 9

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Abstract

The objective of this analysis is to estimate the price elasticity of demand for duty-paid cigarettes in the UK. In 2009-10 tobacco products generated close to £9bn in tax receipts for the UK exchequer, around 2% of all receipts from taxation. We use quarterly time-series data to pursue an Engle-Granger two-step cointegration procedure. The regression model uses the UK duty paid consumption of cigarettes as the dependent variable. Explanatory variables include the price of cigarettes and the price of substitutes. We also attempt to capture some of the factors that influence the size of the non-UK duty-paid sector, whether legal cross border shopping or illicit smuggled and counterfeit products. The results are both robust and stable over time. They also seem to accurately reflect observed changes in the tobacco market. Eight model specifications are considered and these produced stable and consistent results with the elasticity estimates ranging between -1.17 and -0.92.

We would like to thank Sourafel Girma, Nikolaos Spyropoulos, Phil Murfitt and Jon Franklin for their assistance.

1. Introduction

Smoking prevalence in the United Kingdom, as measured by the proportion of smokers in the adult population, has been declining now for decades. In the years after the Second World War, over two thirds of men and almost half of all women were classed as smokers. By the mid 1970s, cigarette smoking amongst men had declined to around half the population though there was not much change in female prevalence. Since then however, there has been a sharp decline for both sexes and across different age and socio-economic groups. The latest estimates show that prevalence rates for both men and women are now just over 20% (ONS, 2009).

Despite this decline, tobacco receipts, in real terms, have remained quite robust. In 2009-10 tobacco products generated close to £9billion in tax receipts for the UK Exchequer, around 2% of all receipts from taxation. Over £8billion of this comes from cigarettes with the vast majority of the remainder coming from hand rolling tobacco (HRT).

Taxation is the single largest component in the price of a packet of cigarettes and duty increases are generally passed on directly to the consumer in increased prices. When measured in terms of UK tax receipts, any duty increase will generate a direct and indirect effect. The direct effect is revenue positive: each packet of cigarettes sold will generate a higher amount of tax. The indirect effect is revenue negative: the increased price will tend to reduce the numbers of cigarettes that are sold or encourage consumers to switch to products that generate less revenue.

The objective of this analysis is to estimate the price elasticity of demand for cigarettes in the UK. Given that the focus of H.M. Revenue & Customs (HMRC) is on receipts rather than consumption, it is the price elasticity for duty-paid consumption that we are interested in. Obviously, the consumption of cigarettes purchased abroad or in the illicit market does not generate any UK duty receipts.

Though we concentrate on cigarettes in this study, the aim is to also consider HRT in the future.

HMRC uses these price elasticities within its tobacco costings model. The purpose of this model is to essentially determine the sum of the two opposing effects on receipts and estimate the final revenue impacts of different policy options. Price elasticities are not the only input in the model. Other important parameters include the baseline forecast for tobacco receipts, the current duty rates and prices for all tobacco products and data on market segmentation. As well as the split between cigarettes and other tobacco products, the model also includes the split between the different price categories of cigarettes.

As we might expect, the trend in consumption mirrors that for prevalence; there has been a persistent and significant downward trend over the past 3 decades, the entire estimation period for this study. Of course not all of this decline is due to increasing prices. Continuing awareness of the health risks and changes in consumer preferences have played a significant role. In addition, non-tax related policy decisions have also been important factors. These include the 2007 ban on smoking in public places, the increasing restrictions on advertising and the use of more explicit warnings on cigarettes packets. The creation of the Single European Market and the subsequent expansion of the European Union have had a major impact on the availability of cheap overseas tobacco. The 1990s also saw the rapid expansion of the illicit market; today this market is characterised by both smuggled and counterfeit products. As a counter to this expansion, HMRC has responded by increasing its enforcement and compliance efforts.

HMRC last carried out an estimate of price elasticities in 2004 (Cullum and Pissarides, 2004). Given the changes in the market since then, it was felt that this issue required revisiting. We use quarterly time-series data to pursue an Engle-Granger two-step cointegration procedure. The regression model uses the UK duty paid (UKDP) consumption of cigarettes as the dependent variable. Explanatory variables include the price of cigarettes and the price of substitutes. We also attempt to capture some of the factors that influence the size of the non-

UK duty-paid sector whether legal or illicit. The results are both robust and stable over time. They also seem to accurately reflect observed changes in the tobacco market.

The structure of this paper is as follows: Section 2 reviews some of the tobacco literature and previous HMRC estimates; Section 3 presents the cointegration methodology that underpins the analysis; Section 4 covers the data; Section 5 discusses model selection and goes into the regression analysis in more detail whilst Section 6 presents the results. Section 7 concludes.

2. The Literature

2.1 Modelling Tobacco Demand

It was once thought that the addictive nature of tobacco precluded it from the normal laws of economics, in particular that of the downward sloping demand curve. Standard demand theory states that as the price of a good goes up, its demand falls. Authors such as Schelling (1978, 1984) argued that smokers' behaviour was not rational and that they lacked self control. Consequently, price or tax increases will have less impact than on other consumption goods.

In contrast, there is now a fairly large literature demonstrating that demand is indeed negatively affected by price. Most of the research considers the demand for cigarettes and focuses narrowly on the issue of overall consumption. Whilst the estimated price elasticities from different studies are fairly widely dispersed, most tend to range between -0.3 and -0.5 (Chaloupka and Warner, 2000).

Addiction, or habit, is not something that is built into the standard demand model. However, it's modelling in tobacco demand is now longstanding and includes models based on myopic (e.g. Pollack, 1970) and rational addiction (Becker and Murphy, 1988). The myopic addiction model bases current consumption not just on current but also past prices. The rational addiction model goes further and argues that anticipated future price changes can affect current consumption. Both models deviate from the conventional model by allowing individuals to maximise an intertemporal utility function.

The inclusion of these dynamics affects the predicted consumer behaviour in a number of ways. The addictive nature of cigarettes means that the long-run effect of a price increase will be larger than the short-run effect. Furthermore, this distinction is increasing in the level of addiction. Those consumers with a greater preference for present consumption (perhaps those that are younger or on lower incomes) will be more price sensitive than those with a lower time preference for the present (perhaps older and relatively more wealthy). This latter prediction of course reinforces the conventional model, which also suggests that lower income groups would be more price elastic.

The number of cigarettes smoked is only one measure of consumption. Another consequence of increasing prices is the growth in downtrading. This describes consumers switching from a higher to a lower priced packet of cigarettes. This means that whilst they are reducing their consumption by value, they are able to maintain it by volume.

The key impact for HMRC is the price effect on the demand for duty paid tobacco. At present, UK cigarette taxation is made up of three elements: specific duty, ad valorem duty and VAT. The revenue from the latter two varies with the price of a packet of cigarettes. Data shows that over the past decade there has been a significant growth in downtrading and an increasing domination of the market by the lowest price categories of cigarettes. Whilst the static impact of an overall price increase is to increase the tax revenue, the behavioural effects – reduced volumes and/ or further downtrading will offset some of the revenue gain. The extent of the overall impact on revenue will depend on the change in volumes at each price point. Similarly, if a consumer is tempted to switch from cigarettes to hand rolling tobacco (HRT) we get the corresponding result.

The other major concern for HMRC is the risk that, following a price increase, demand will leak from the UK duty paid sector to either the legal cross border or the illegal smuggled and counterfeit sectors. Latest HMRC figures estimate that around 16% of the cigarettes consumed in the UK come from the non-UK duty paid sector – 11% from the illicit market and 5% from cross border shopping (HMRC, 2010). This figure is considerably higher for HRT (58%). Given this, we would expect the price elasticity for duty paid tobacco to be significantly higher than that for overall tobacco consumption.

2.2 Econometric Estimations

Gallet and List (2003) have conducted an extensive meta-analysis to examine the differences across the literature. They compare different studies to a baseline estimation, in this case a single equation, ordinary least squares (OLS), log-linear regression with smoking consumption as the dependent variable. They look at 86 studies from 1933 to 2001. Their sample is not limited to the UK. The main findings were:

- The rational addiction model tends to generate more inelastic elasticities than the baseline. This is what we would expect from an addiction model.
- Estimates from the myopic model are not significantly different from the baseline.
- The short-run elasticity is more inelastic than the long-run. Again, this is as we would predict for a good with addictive properties.
- The elasticity for teenagers is higher than the baseline whilst that for adults tends to be more inelastic. There is also some evidence that the participation elasticity is more elastic for younger smokers (Lewit et al, 1981, Chaloupka and Grossman, 1996). One explanation behind the discrepancy might be that adults are more addicted than younger smokers, so less likely to either reduce consumption or quit. Another explanation is that tobacco makes up a much higher proportion of a younger person's total expenditure than that of an older person (ONS, 2009). In that case we would expect consumption to be more price elastic.

- Compared to the baseline, demand by women is more inelastic whilst that for men is not significantly different to the baseline. This suggests that demand is more inelastic for women than for men.

- Estimations based on the Almost Ideal Demand System (AIDS) tend to produce more inelastic elasticities than the baseline.

- The linear and double-log specifications are not significantly different to the baseline.

- There is no significant difference between using time-series and cross-section data.

- Neither two stage least squares, three stage least squares nor full information maximum likelihood were significantly different to the OLS baseline. Regressions based upon generalised least squares and maximum likelihood studies tended to produce more inelastic elasticities, though the latter result is of marginal significance. Generalised method of moments estimations tend to result in more elastic elasticities.

The income elasticity from the literature is interesting in that the results from a number of studies suggest that, for more developed countries, cigarettes have switched from a normal to an inferior good. Earlier studies tended to report positive income elasticities whilst more recent research has been suggesting that the relationship is now negative; the demand actually falls as income levels rise. There is also some evidence that the price elasticity is more elastic in developing countries (Wilkins, Yurekli and Hu, 2001), perhaps not surprising given the lower levels of income.

Adda and Cornaglia (2006) show that whilst price increases may indeed lower consumption as measured by the number of sticks, some consumers, particularly those on lower incomes, will compensate by increasing how intensively they smoke each individual cigarette. This will, to some extent, mitigate the health benefits from lower numerical consumption. Similarly, Farrelly et al (2004) show how some smokers respond to tax increases by switching to cigarettes with higher tar and nicotine content. Whilst these findings are interesting from a health perspective, they are less relevant to the question of tax revenue.

2.3 Previous HMRC Studies

The first explicit attempt by HMRC (then HM Customs and Excise, HMCE) to estimate the own price elasticities of tobacco was Chambers (1999). Prior to this, the tobacco costings model used elasticities taken from the tobacco literature (e.g. Baker et al, 1990). The focus of the Chambers paper was not simply the estimation of tobacco elasticities but also those of beer, wine and spirits. The model was also developed to enable it to be used for forecasting purposes.

The author used consumer expenditure data from the ONS and receipts data from HMCE within a dynamic AIDS error correction model. The dataset covered the time period from 1963 to 1998. The model also included cross border shopping via the use of a dummy variable capturing the inception of the Single European Market in 1992. The average own price elasticity for tobacco, across the various models, was around -0.25.

The most recent HMRC tobacco modelling exercise was carried out by Cullum and Pissarides (2004). They used an AIDS model to look at the markets for cigarettes and HRT. This model also separated cigarettes into three different sub-categories and explicitly estimated the demand individually for the duty-paid domestic market, the cross-border market and the illicit market. The expenditure on tobacco products was modelled as a function of price and its share of total expenditure. The data sources were similar to those used in the current paper. Expenditure data was taken from the ONS and information on prices from the tobacco manufacturers.

The Cullum and Pissarides model captured far more detail than had been done previously but, inevitably, this also added complexity. However, at the time of this research there was considerable concern that earlier models had not captured the rapid rise in the growth of the non duty-paid sector. During the 1990s the size of this sector grew from virtually zero to over 20% of the cigarettes market and over 60% of the HRT market.

Whilst attempting to capture the non-duty paid sector in such detail was perhaps justified at the time of that study, the size of the non duty-paid sector has declined in the ensuing years. In 2000 HMRC introduced a new tobacco strategy to counter the growth in the non duty-paid sector and it would appear that this has had a good degree of success, though other factors (exchange rates and inflation-only duty rises amongst others) have also likely played a role.

The estimated own price elasticity for cigarettes in Cullum and Pissarides was around -1.3. This is significantly higher than that in the Chambers paper though that is primarily because the latter considers overall consumption rather than specifically duty paid. This elasticity is probably on the high side in the current climate, where receipts from tobacco have risen sharply in recent years.

3. Methodology

A common feature of time-series data is its non-stationarity. It can result from a trend or seasonality and can be a major complication for empirical econometrics. Trended data may give rise to spurious regressions and unreliable student-t values and may also invalidate other test statistics. One simple solution would be to difference the series until stationarity is achieved. This would however, lead to a loss of the model's long-run properties. An evaluation of both the long-run relationship and short-run adjustments can be done by cointegration modelling. This is the approach adopted in this paper.

3.1 Pre-estimation Testing: Stationarity And Order Of Integration

One of the first steps in time-series analysis is determining whether the data is stationary. A data generating process {X} is said to be stationary if:

$$E(X_t) = const = \mu \quad (1)$$

$$Var(X_t) = const = \sigma^2 \quad (2)$$

$$Cov(X_t, X_{t+j}) = \sigma_j \quad (3)$$

Thus a data series is stationary if its mean, $E(X_t)$ and variance, $Var(X_t)$ are constant over time and the value of the covariance, $Cov(X_t,X_{t+j})$ between two periods depends only on the gap between the periods and not on the actual time at which this covariance is considered. If there is nonstationarity in the data then this can lead to spurious correlations between variables in a regression rather than represent any true economic relationship. Therefore, if the variables in a regression are not stationary then the usual inference about the significance of estimated coefficients from an OLS regression is no longer possible.

Before any sensible time-series analysis can be performed, it is essential to identify the order of integration of each variable. Nonstationary series for which stationarity can be achieved by differencing *d* times is said to be integrated of order *d*. The usual way of testing for the order of integration is to perform the Augmented Dickey Fuller (ADF) test for unit root. This test is based on the regression of a variable's first difference on its past values:

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{l} \delta_i \Delta y_{t-i} + \eta_t \quad (4)$$

Where y is the tested variable, $\Delta y_t = y_t - y_{t-1}$, and ε is the error term. The testing procedure involves examining the student-t ratio of δ. Rejection of the null hypothesis that $\delta = 0$, in favour of the alternative that $\delta < 0$, implies that the process is stationary (integrated of order zero). The number of lags *l* in (4) requires careful consideration; one way of establishing the number is by examining the plot of the autocorrelation function (these are presented in Figure 12 in the Annex). It is equally important to consider whether or not to account for a drift and/or trend in the data by inclusion of additional terms in the test equation.

The form of nonstationarity in time-series data can often be determined by a visual inspection. Indeed, since the distributions of Dickey-Fuller statistics are complicated and their critical values can only be approximated, the test results alone are rarely the sole determinant.

Assuming that all the variables in a regression are integrated of the same order *d*, one solution would be to estimate equations on the data differenced *d* times. Since such regressions would involve only stationary variables, the statistical interference would be straightforward. If we used this technique though, the long-run properties of the model would be lost and the explanatory power of the coefficients would be restricted. Instead, the focus in this paper will be on the long-run equilibrium equations estimated on variables in levels.

3.2 Modelling Cointegrated Series Through Error Correction

In order to model nonstationary variables in their levels, the data series need to be cointegrated. Time series {X} and {Y} are said to be cointegrated of order (*d*, *b*), where $d >= b >= 0$, if:

1. Both series are integrated of order *d*, and

2. There exists a linear combination of these variables, $\alpha X + \beta Y$ which is integrated of order (*d*-*b*).

A straightforward generalization of the above definition allows for cointegration of *n* variables not necessarily being integrated of the same order. The cointegrating vector then represents an adjustment process preventing the errors from the long-run equation from increasing with time. Hence the cointegrating vector allows for the stability of the long-run relationship over time.

The cointegration analysis in this paper follows the two step approach suggested by Engle and Granger (1987). This is particularly convenient for cases where all variables are integrated of order one.

3.3 The Two Step Engle-Granger Approach

Step one consists of an OLS estimation of the long-run regression on nonstationary variables in their levels. Since inference about the statistical significance of such a regression is restricted, it is difficult to assess whether it correctly represents the true relationship being modelled. Hence, it is important when using cointegration analysis that there are strong a priori arguments supporting the choice of the regression equation. The long-run relationship is of the general form:

$$Y_t = \alpha + \sum_{i=1}^{k} \beta_i X_{it} + \varepsilon_t \tag{5}$$

Where Y and X are vectors of the dependent and explanatory variables respectively, α is the constant, β is a vector of k coefficients and ε is the vector of disturbances.

Step two requires estimation of the unknown cointegrating vector $(1, -\beta_1, -\beta_2, \ldots, -\beta_k)$ and its testing for unit root. This is done by estimation of an ADF type equation of the form:

$$\Delta e_t = \delta e_{t-1} + \sum_{i=1}^{l} \delta_i \Delta e_{t-i} + \xi_t \tag{6}$$

Where e represents the OLS residuals from (5) and can be interpreted as the deviations of Y_t from its long-run path and l represents the number of lags. When using ADF type equations to test for cointegration, it is important to use the appropriate critical values; these differ from those used in single series testing. As before, it is also important to support the test results with a visual inspection of the data.

If the cointegrating vector proves to be stationary, then the data series is cointegrated and the results from the long-run equation can be interpreted as the parameters of the true long-run relationship.

In order to ensure that the short-run deviations do not undermine the long-run equilibrium, a dynamic error correction model needs to be constructed. In step two of the Engle-Granger procedure we estimate a short-run dynamic equation of the general form:

$$\Delta \mathrm{Y} = \alpha_2 + \sum_{i=1}^{k} \beta_{2i} \Delta \mathrm{X}_i + ECT + \varepsilon_2 \qquad (7)$$

Where the Error Correction Term (ECT) equals to the first lag of the cointegrating vector estimated in the previous step, X and Y are the original vectors of the dependent and regressors and Δ denotes the difference between observations in time *t* and *t-1*. We decided to omit lagged consumption variables since we felt that specification was more relevant to the estimation of overall consumption, which is not our primary concern.

3.4 The Johansen Procedure and the Cointegrating Rank

One of the shortcomings of the approach outlined in the previous section is the assumption that there only exists a single cointegrating vector. This is based on the fact that OLS residuals are actually the one linear combination of the regressors that minimises the deviations from the long-run path. Although the cointegrating vector estimated in such a way is valid, the number of such possible vectors may be up to the number of explanatory variables. The number of cointegrating relationships is referred to as the cointegrating rank and can be estimated using the Johansen procedure (Johansen 1991). Although this approach was specifically developed for use with systems of Vector Autoregression (VAR) equations, it can also be used as an auxiliary tool for the single equation Engle-Granger procedure.

Johansen's methodology takes its starting point in a general unrestricted VAR equation of order p:

$$\mathbf{Z}_t = \sum_{i=1}^{p} \mathbf{A}_i \mathbf{Z}_{t-i} + \in_t \tag{8}$$

Where $\mathbf{Z}_t$ contains all n variables of the model, $\in_t$ is a vector of random errors and $\mathbf{A}_i$ are coefficient matrices that do not contain any zero elements. This VAR equation can be re-written as:

$$\Delta\mathbf{Z}_t = \Pi\mathbf{Z}_{t-p} + \sum_{i=1}^{p-1} \Gamma_i \Delta\mathbf{Z}_{t-i} + \in_t \qquad \text{for } p \geq 2, \tag{9}$$

where

$$\Pi = -(\mathbf{I} - \mathbf{A}_1 - \ldots - \mathbf{A}_k) \qquad (\mathbf{I} \text{ is a unit matrix}), \tag{10}$$

and

$$\Gamma_i = -\mathbf{I} + \mathbf{A}_1 + \ldots + \mathbf{A}_i \tag{11}$$

Under some general conditions, if the coefficient matrix Π has reduced rank $\boldsymbol{r} < \boldsymbol{n}$, then there exist $n \times r$ matrices, α and β, each with rank r such that: $\Pi = \alpha\beta'$, $\beta'\mathbf{Z}_t$ is stationary while $\mathbf{Z}_t$ is integrated of order one. Now r is the number of cointegrating relationships, the elements of α are the adjustment parameters in the vector error correction model and each column of β is a separate, valid cointegrating vector.

The above considerations are based on the *Granger Representation Theorem* (Engle and Granger 1987) for which the Johansen methodology provides a useful empirical procedure identifying the number of cointegrating vectors. If the Johansen procedure indicates the existence of only one cointegrating vector, it can be regarded as confirmation of the single equation approach to which the Engle-Granger method was applied.

4. Data

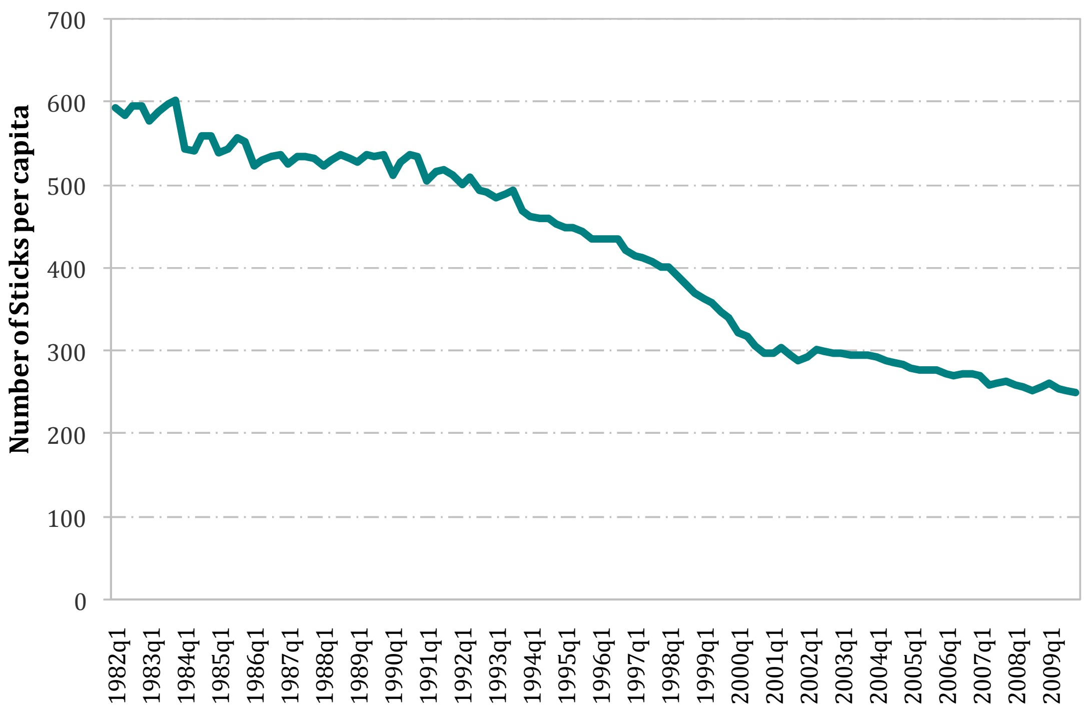
Standard demand theory indicates that the quantity demanded of a product depends on a number of factors: its own price, prices of related goods, consumers' disposable income, their preferences and the size of related markets (the presence and importance of substitute and complementary goods). Other factors specific to the tobacco market include the size of non duty paid consumption, the magnitude of addiction, legal restrictions, the restriction on commercial advertising and the use of public health messages.

4.1 Dependent Variable

For the purpose of this analysis, quarterly time-series data has been used covering the period between 1982q1 and 2009q4. The chosen dependent variable is the number of UK duty paid (UKDP) cigarette sticks consumed per capita, which we refer to as the volume. This has been derived from two separate data sources: expenditure on UKDP cigarettes from the ONS' 'Consumer Trends' publication and, secondly, pricing data received directly from the tobacco manufacturers.

Figure 1 describes this volume data. The first thing that is apparent is the long term decline in volumes consumed, reflecting a persistent decline in smoking prevalence. The second thing that stands out is the steeper trend during the 1990s. During this period there were a number of policy and market developments that contributed to this acceleration. On the policy side, there were the twin impacts of the creation of the Single European Market in 1992 and the introduction of the tobacco duty escalator in 1993. The first of these led to a much greater access to cigarettes from overseas whilst the second, by causing large domestic price increases will have aided the popularity of cross border shopping. The other factor over this period was the growth of the illicit smuggled and counterfeit market, which is linked to the opening of national borders (e.g. aiding transit within the EU) and the increase in the UK to overseas price gap.

Figure 1 UKDP Cigarettes Consumption

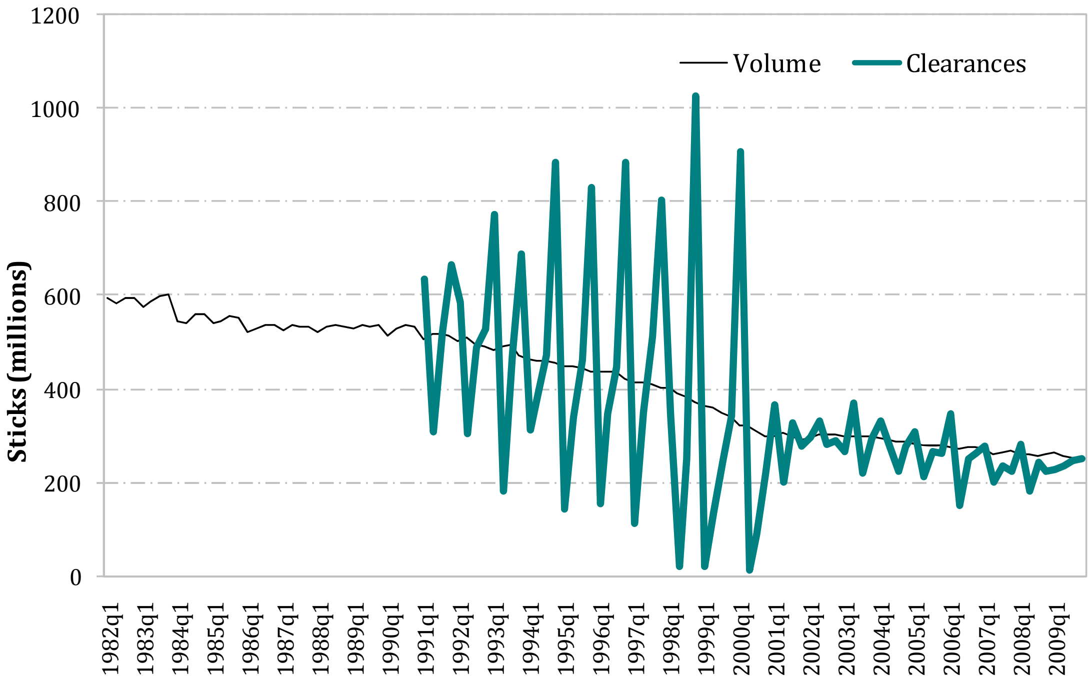


Mean = 419 Median = 436 St. Dev = 116 Skewness = -0.09 Kurtosis = 1.34

Given these factors, we would expect, a priori, the demand for cigarettes to be relatively more price elastic in the 1990s. Since Budget 2000, and until very recently, tobacco duty has only been increased in line with inflation. This resulted in much lower price increases and perhaps helps explain the flatter decline in the consumption of duty paid cigarettes in more recent years. Duty changes introduced at Budget 2009 were the first real increases since the year 2000.

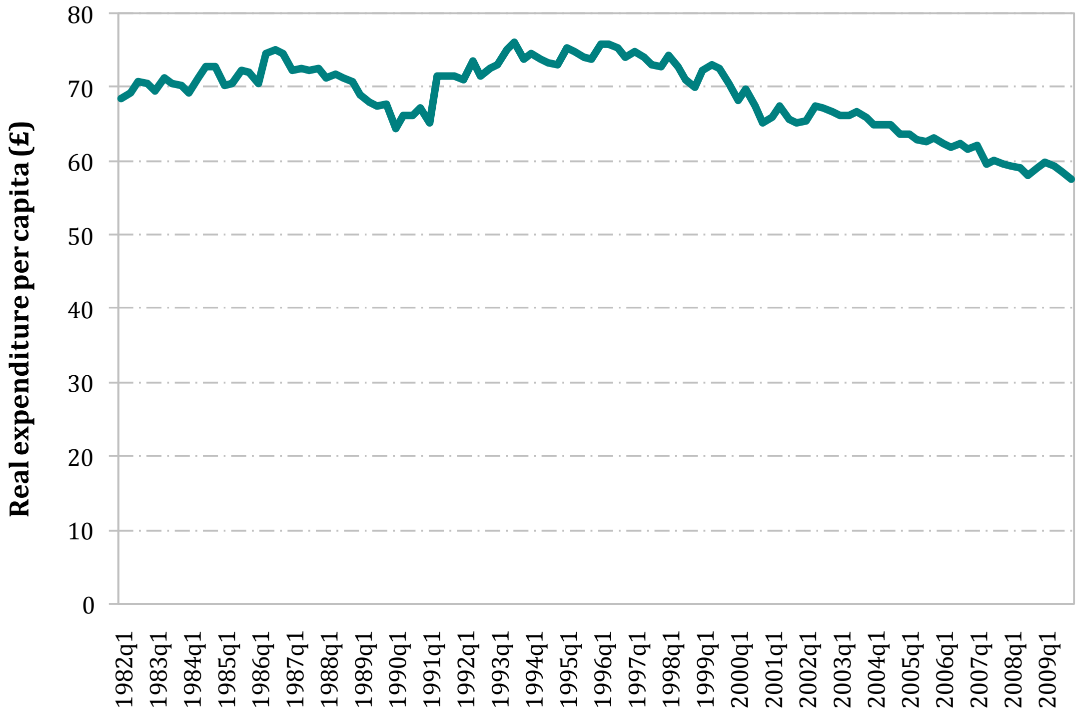
A second potential dependent variable, after volumes, was actual UK cigarette clearances. Clearances refer to all cigarettes that have been cleared, after duty, by HMRC for consumption in the UK. Clearly this most directly covers our area of interest and would, ideally, be the dependent variable of choice for this study. However, there were two main difficulties in using clearances. The biggest problem is that we could only obtain quarterly clearances data from 1991, which provided us with an insufficient number of observations for our regression. A second issue with the clearance data is the degree of volatility observed which, even if there were a greater number of observations, would have required either smoothing or use of additional dummy variables. Figure 2 shows a plot of clearances over the available time period. We have also included volume (from Figure 1) to show the similarity between the movements in the two series.

Figure 2 UKDP Clearances, 1991-2009



As well as using expenditure on cigarettes to derive our volume variable, we could also have used it directly as the dependent variable. However for the purpose of estimating price elasticity of demand, we felt that the number of sticks consumed was the better variable, mainly because expenditure is, to some extent, positively correlated with the actual price. For comparison purposes, Figure 3 presents the graph of real per capita expenditure on cigarettes. This clearly indicates that there has been a real terms decline since the early 1990s. Indeed, the decline has been sharper in more recent years, possibly an indicator of cigarettes becoming more price elastic over time.

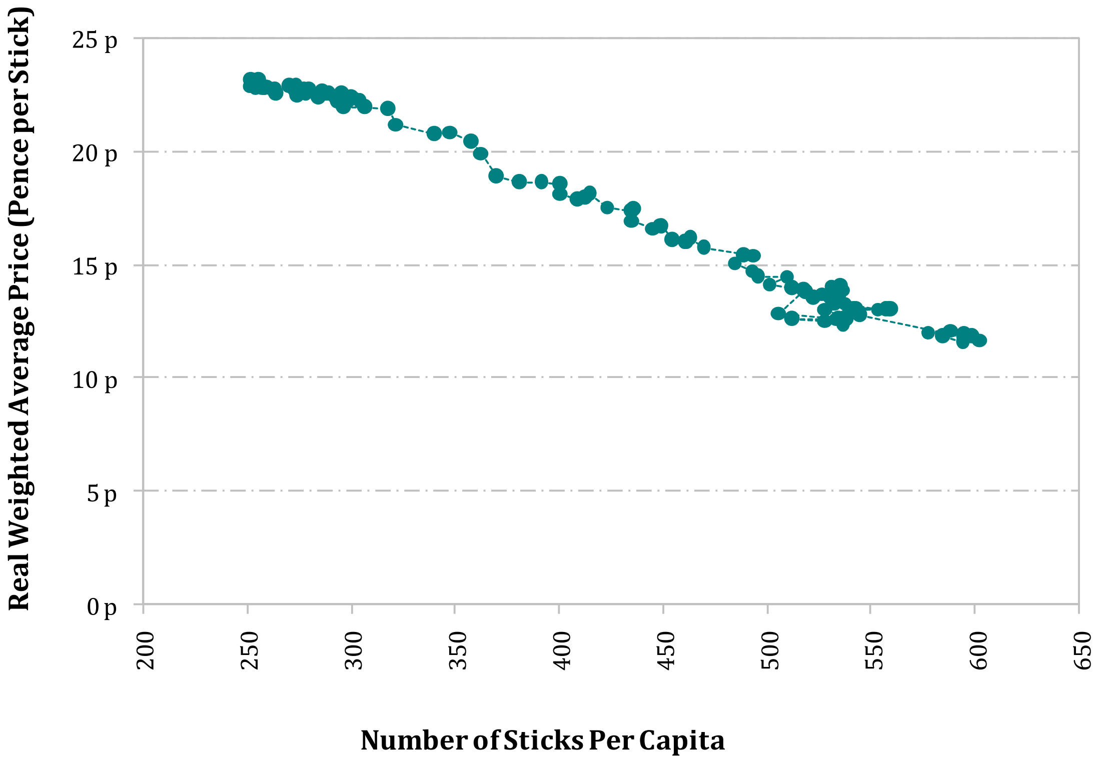
Figure 3 Real Per Capita Expenditure On UKDP Cigarettes (2005 prices)



One thing to note is that the pattern across the three potential dependents is fairly similar, reflecting the same long term decline in prevalence that we have already discussed.

Figure 4 attempts to construct the cigarettes demand schedule by plotting different combinations of sticks per capita and the real weighted average price over time. The main thing to note is that the schedule appears to be broadly linear and this is something we take into account when discussing the choice of functional form.

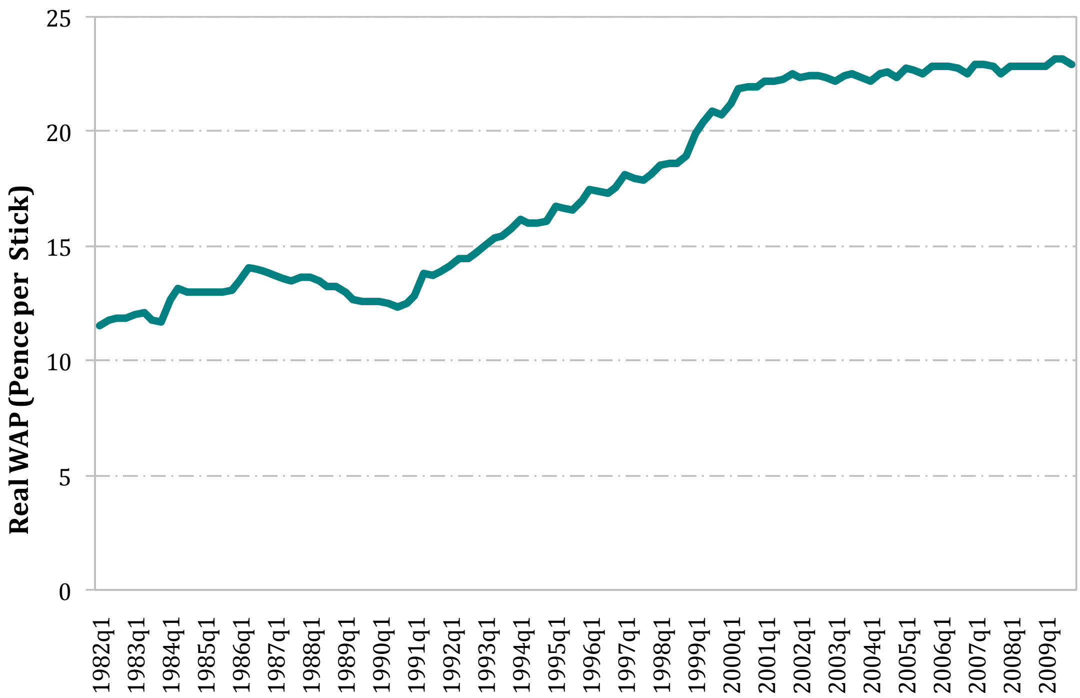
Figure 4 Constructed Demand Schedule



4.2 Price Variable

There are four main cigarette price categories in the UK with their relative popularity varying across time. For that reason we have calculated a 'weighted average price' (WAP). This is done using price and market share data that is provided directly from the tobacco manufacturers. The market share refers to each cigarette category. Manufacturers distinguish between different price categories, ranging from 'Premium' to ''Economy' and provide HMRC with typical prices for each category. By using a weighted average price we are, to some extent, capturing some of the impact of downtrading to cheaper products, which has been an important development in the pattern of cigarette consumption in recent years. Figure 5 plots the weighted average price over time and shows some descriptive statistics.

Figure 5 UKDP Weighted Average Price Of Cigarettes



Mean = 18 Median = 17 St. Dev = 4 Skewness = 0.08 Kurtosis = 1.34

One issue that might be of potential concern with both the data on volumes and prices is the presence of kurtosis, and the non-normality that it implies. However, although it is sometimes believed that linear regression requires that the outcome and predictor variables be normally distributed, it is actually the residuals that need to be normally distributed. Moreover, normality of the residuals is only required for the student-t statistics to be valid. The estimation of the regression coefficients does not require normally distributed residuals. As we will show later, valid t-tests are not strictly required for this analysis and issues concerning normality are of less importance.

4.3 Other Explanatory Variables

A number of other potential explanatory variables have been considered. These include households' total expenditure on consumption, the UK duty paid price of HRT, prices and volumes of illicit and cross border products, exchange rates and overseas travel numbers. These variables are graphed in Figure 10 in the Annex.

As already discussed, non duty paid consumption forms an important component of the UK cigarettes market. However, for modelling purposes the quality and quantity of the available data for that sector is somewhat limited, perhaps not surprising given the illegal nature of some of the activities. For the illicit market we have been able to obtain street prices from the mid-1990s but there are significant data gaps. There is also not a great deal of variability in the prices that we do have. The data for the cross border market is better. However, although HMRC have recently re-estimated cross border prices and quantities, these are only available back to 2000, which provides an insufficient number of observations. In order to prevent the loss of information from the earlier years, illicit and cross border shopping variables have not been included in the final set of explanatory variables. Instead we attempted to approximate the impact of non duty paid consumption by the exchange rate, travel numbers and overseas prices. Furthermore, since the street price for illicit cigarettes seems to be fairly flat, much of its impact will be captured in the price differential with the weighted average price of UK duty paid.

Figure 6 Correlations of Non-UKDP Consumption to Proxy Measures

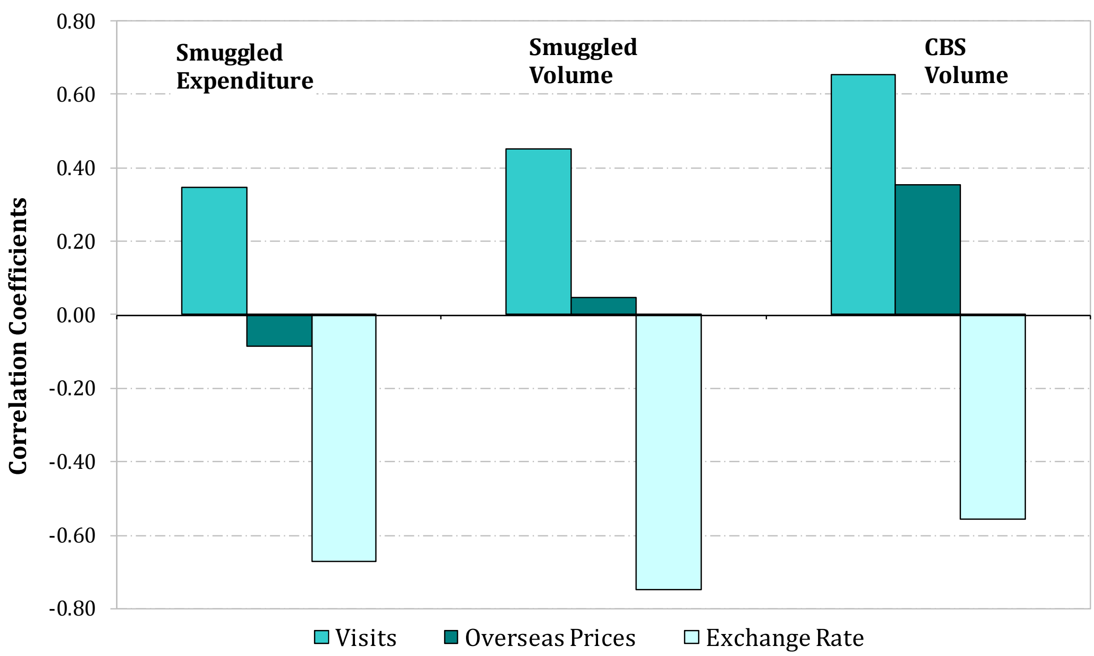
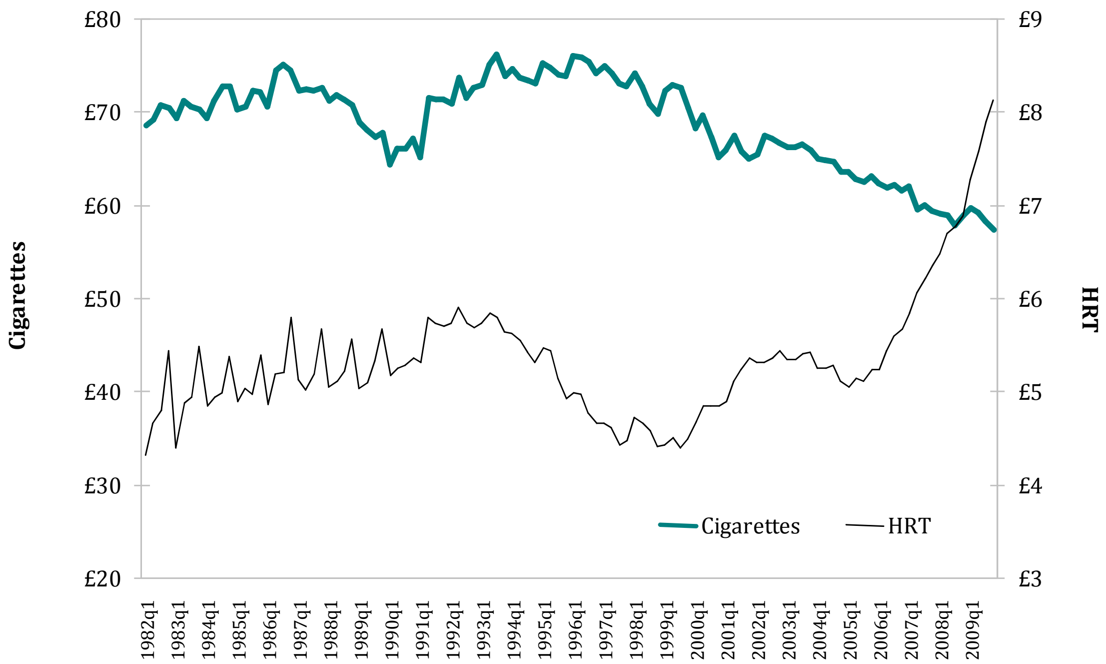


Figure 6 shows the correlation between the non-UK duty paid market and overseas visits, overseas prices, and the exchange rate. The strongest relationship is with the exchange rate (£/€), which shows a strong negative correlation for both the illicit and cross border markets. So a higher exchange rate is associated with a reduction in the size of the non UK duty paid market. This is not surprising since a decline in the value of sterling would reduce the price differential between the UK duty paid price and that overseas, reducing demand. For overseas smugglers, it would also reduce their UK profit margins and likely reduce the supply of illicit products.

Overseas visits show a positive relationship with both the illicit and cross border markets though the size is stronger for the latter. This is as we would expect since visits is a very good approximation for cross border activity, less so for illicit. Overseas cigarettes prices which are only available from 1990 do not show any relationship with the illicit goods and a weaker correlation with cross border. Based on the magnitude of the correlations, overseas prices series was not considered in further investigations.

Cigarettes make up nearly 90% of the UK tobacco market with the remaining 10% being dominated by HRT. Because of the relative sizes of these two sectors, HRT consumption is not expected to have a major impact on cigarette consumption. However, as shown in Figure 7, the recent fall in cigarette consumption has been accompanied by increasing consumption of HRT. To a large extent this can be explained by downtrading with consumers switching to cheaper products. Hence UK duty paid HRT price is considered an important variable, especially with the prices of other (non-UK duty paid) substitutes being unavailable.

Figure 7 Real Tobacco Expenditure Per Capita (2005 Prices)



Dummy variables have also been included in the model accounting for important developments in the market: introduction of European Single Market in 1992 and the UK Smoking Ban in 2007. Though restrictions in tobacco advertising have been in force for decades, various new restrictions have been imposed in the UK since 2003. Similarly, though warning messages on packets have been around for a long time, these have become more explicit and graphic in recent years. Dummy variables and an index measuring the presence of these commercial and social advertisements were also modelled. However, since they did not really add much in terms of explanatory power but did impose a cost in terms of degrees of freedom, they were eventually dropped.

Addiction components are also not incorporated in the model since the primary focus in this paper is on the impact of price increases rather than on the types of addiction in the UK tobacco market. Although the inclusion of lagged consumption among the explanatory variables helps mitigate the common time-series problem of autocorrelation, it was found to radically suppress elasticity estimates. The underlying negative pattern in cigarette consumption has been accounted for with a linear trend instead.

Since the data is quarterly, there are three quarterly dummies to prevent any loss of information through seasonal adjustments. Table 1 lists the final choice of variables and their sources.

Table 1 Final Chosen Set of Variables

Variable	Description	Source
Volume	UKDP Cigarettes Consumption; Sticks	ONS (divided by WAP Price)
Price	UKDP Cigarettes Weighted Average Price, Pence/ Stick	WAP Estimate using Industry Data
Price HRT	UKDP HRT Price, Pence/ 25g	Industry Data
Expenditure	UK Households Final Consumption Expenditure; £	ONS
Visits	Number of UK Tourists' Visits Overseas	ONS
Exchange rate	Sterling to Euro Exchange Rate	Bank of England
Smoking Ban	Dummy variable from 2007q2	
EU Single Market	Dummy variable from 1993q4	
Dummy 1984q1	Dummy capturing break in the data	
Quarters	Dummy for q1, q2, q3	

Consumption and expenditure per capita
Real prices and expenditure in 2005 terms

5. Model Selection And Regression Analysis

5.1 Data Mining

The initial examination of the data plots and correlograms in the Annex (Figures 10 and 12) indicate that most, if not all, the variables are non-stationary. More formal testing using various specifications of the Augmented Dickey Fuller (ADF) unit root test leads to the conclusion that all variables are integrated of order one. Table 2 shows the ADF results for the variables used in the final model specifications.

Table 2 Augmented Dickey Fuller Test Results

Augmented Dickey Fuller test resuts for the final choice of variables

	ADF Test Specification:			**Stationarity results:**	
Variable	*Lags*	*Trend*	*Intercept*	*ADF Statistic*	*Order of integration*
Volume	10	YES	YES	-2.845	I(1)
Price	10	YES	YES	-2.509	I(1)
HRT Price	4	YES	YES	-3.101	I(1)
Expenditure	10	YES	YES	-0.854	I(1)
Exchange Rate	5	YES	YES	-1.679	I(1)
Visits	12	YES	YES	-0.889	I(1)

Since the variables are non-stationary, data mining cannot be based on the traditional general to specific approach. Rather than including all possible regressors in the general equation and then reducing the model on the basis of statistical significance, the long-run equation must first be established according to the economic theory and knowledge of the market. Various relationships can then be compared based on model performance, stability of results and a priori knowledge of the market. The choice of the final models is dictated by the results of the cointegration tests, Akaike and Bayesian information criteria, the stability of results across time and the stability across different functional forms. Table 3 lists the best long-run relationships identified by the data mining.

Table 3 The Best Long-run Relationships

Model 1	**Model 1a**	**Model 2**	**Model 2a**
		The Dependent Variable	
		Volume	
		Explanatory Variables	
Price	Price	Price	Price
Price (HRT)	Price (HRT)	Price (HRT)	Price (HRT)
Expenditure	Expenditure	Expenditure	Expenditure
Visits	Visits	Exchange rate	Exchange rate
Trend	Trend	Trend	Trend
		Dummy Variables	
Smoking Ban	Smoking Ban	Smoking Ban	Smoking Ban
EU Single Market	EU Single Market	EU Single Market	EU Single Market
Quarterly Dummies	Quarterly Dummies	Quarterly Dummies	Quarterly Dummies
Dummy 1984		Dummy 1984	
		Estimation Period	
1982q1 - 2009q4	1984q1 - 2009q4	1982q1 - 2009q4	1984q1 - 2009q4

As suggested by data analysis and knowledge of the tobacco market, cigarette consumption depends on prices (own and substitutes), income (households total consumption expenditure) and size of the non duty paid market (main substitute for the duty paid consumption). The two chosen long-run relationships differ in the way non duty paid consumption is approximated. Model 1 uses travel numbers whilst for Model 2, the exchange rate is used. There appears to be a structural break in the data from 1984. Volumes seem to be quite significantly higher in 1982 and 1983. To capture this, we have added a dummy for 1984q1 to account for the lower levels of consumption since 1984q1.

However, to avoid leverage while preserving the number of degrees of freedom, we have also estimated both models for a shorter period from 1984. We call these Model 1a and Model 2a, and they are also presented in Table 3.

5.2 The Choice Of Functional Form

The majority of empirical studies of demand assume a logarithmic functional form. This choice is often motivated by convenience since it is straightforward to interpret the estimated coefficients as elasticities. However, one drawback of such an approach in the context of this study is that a logarithmic demand function carries the strong assumption of constant price elasticity. We would not expect this to be valid in the case of UK cigarette consumption where a number of factors – policy changes, the availability of non-duty paid products, changing tastes – all have an impact on consumers' responsiveness to price changes. Instead, we would expect price elasticities to vary across time. For this reason our model uses linear and log-linear demand functions, which allow for this. This is also broadly in line with the constructed demand schedule in Figure 4.

The different model specifications are evaluated using a number of methods. First, we consider the validity of the corresponding cointegrating vectors; second, we evaluate their long term performance; third, we conduct post-estimation testing.

The two demand functions estimated in this paper are of the following general forms:

General linear specification:

$$Y_t = \alpha + \sum_{i=1}^{k} \beta_i X_{it} + \varepsilon_t \qquad (12)$$

General log-linear specification:

$$\ln(Y_t) = \alpha + \sum_{i=1}^{k} \beta_i X_{it} + \varepsilon_t \qquad (13)$$

The choice between the linear and log-linear functional forms will be largely driven by model performance across time. This is discussed in more detail in the Results section.

5.3 Regression Analysis

Figure 13 in the Annex shows the plots of residuals from the two long-run relationships estimated for both linear and log-linear demand specifications and for the two chosen time periods. A visual inspection of the different series suggests that all are stationary. A more formal procedure that confirms this result is presented in Table 7, also in the Annex. The ADF test results for cointegration are all significant.

On the whole, the long-run residuals do not appear to be normally distributed (see Table 7). However, this does not undermine the validity of our chosen models. Normally distributed residuals are not a sufficient condition for ensuring valid Student-*t* statistics since these cannot be interpreted in cointegration modelling.

Omitted variables have been detected in all eight specifications (see Table 7). One plausible reason for this might be that the coverage of the non duty paid tobacco market is incomplete. Other areas that are not fully represented within the model are the policies restricting advertising, the requirement for health messages on cigarette packets and other, wider messages highlighting the health risks. Although such restrictions might be considered fairly recent phenomena, they have actually been in place for a long time. A ban on television advertising was introduced in 1965 whilst the first health warnings on packets appeared from 1971. Attempts were made to include smoking restrictions within the model but their inclusion did not improve model performance (other than the 2007 smoking ban). This might be because the most fundamental changes took place before our sample period; it could also be because much of it is subsumed in the trend decline.

Post-estimation test results also suggest there is some autocorrelation present in the models. Although an autoregressive distributed lags (ADL) approach could help mitigate the problem, addiction modelling is not the primary purpose of this paper. It was felt that preserving the number of degrees of freedom was preferable to the inclusion of the additional variables that would be required.

Heteroscedasticity testing provides some additional insight about the validity of the cointegrating vectors, since stationarity requires that a series displays constant variance. The Breusch-Pagan test for heteroscedasticity confirms a constant variance in the residuals from the log-linear models. This is not generally the case for the two linear specifications. However, autoregressive conditional heteroscedasticity (ARCH) effects have been detected in all specifications.

The most important model specification test in cointegration analysis is the identification and evaluation of the cointegrating vectors. Augmented Dickey Fuller cointegration test results indicate that the models which include the exchange rate produce marginally better cointegrating relationships. However, all eight specifications produce valid cointegrating vectors. The validity of the Engle-Granger single equation approach is confirmed by the results of the Johansen test for cointegrating rank. Both sets of regressors, whether including exchange rate or visits, produce a single corresponding cointegrating vector.

Since each of the long-run specifications performs well, the second step of the Engle-Granger approach is performed for all of them. Table 8 shows the post-estimation test results for the short-run dynamic specifications, constructed using lagged long-run residuals. Since the short-run models are estimated on stationary differenced series, their significance can be statistically tested. The F-statistic shows that all regressors are jointly significant in both models. Differencing the data set does not improve the distribution of residuals in terms of normality (see Table 8) but, as discussed earlier, this does not impose serious problems for the analysis. Omitted variables have been detected for most of the specifications. Both Durbin-Watson and Breusch-Godfrey statistics indicate that the problem of autocorrelation has been mitigated in the short-run models.

6. Results

Table 4 shows estimation results for the four long-run equations for both linear and log-linear specifications. Coefficient estimates and standard errors are given for each of the explanatory variables. Since the underlying data is not stationary, standard t-tests for the long-run equations may not be valid, and so are omitted.

Table 4 Long-run Results

Long Run results	Model 1		Model 1a		Model 2		Model 2a	
Time period	1982q1 - 2009q4		1984q4 - 2009q4		1982q1 - 2009q4		1984q4 - 2009q4	
Specification	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*
Price	**-22.427**	**-0.065**	**-22.374**	**-0.065**	**-21.967**	**-0.059**	**-21.507**	**-0.058**
	0.873	*0.003*	*0.879*	*0.003*	*1.322*	*0.005*	*1.334*	*0.005*
HRT price	**0.305**	**0.001**	**0.307**	**0.001**	**0.291**	**0.001**	**0.276**	**0.001**
	0.054	*0.000*	*0.055*	*0.000*	*0.067*	*0.000*	*0.068*	*0.000*
Expenditure	**0.006**	**0.000**	**0.007**	**0.000**	**0.002**	**0.000**	**0.003**	**0.000**
	0.009	*0.000*	*0.009*	*0.000*	*0.009*	*0.000*	*0.009*	*0.000*
Exchange rate					**17.323**	**0.128**	**23.858**	**0.142**
					16.423	*0.057*	*16.556*	*0.059*
Visits	**0.000**	**0.000**	**0.000**	**0.000**				
	0.000	*0.000*	*0.000*	*0.000*				
Trend	**-0.867**	**-0.003**	**-0.884**	**-0.003**	**-1.028**	**-0.004**	**-1.086**	**-0.004**
	0.176	*0.001*	*0.176*	*0.001*	*0.195*	*0.001*	*0.195*	*0.001*
Smoking Ban	**-14.894**	**-0.072**	**-14.627**	**-0.071**	**-14.943**	**-0.071**	**-14.512**	**-0.070**
	3.642	*0.013*	*3.638*	*0.013*	*3.684*	*0.013*	*3.668*	*0.013*
Q1	**-3.214**	**0.006**	**-2.408**	**0.007**	**-2.600**	**0.007**	**-1.739**	**0.009**
	2.901	*0.010*	*2.970*	*0.011*	*2.904*	*0.010*	*2.951*	*0.011*
Q2	**7.795**	**0.036**	**9.041**	**0.039**	**3.502**	**0.020**	**4.472**	**0.022**
	3.364	*0.012*	*3.473*	*0.013*	*2.594*	*0.009*	*2.631*	*0.009*
Q3	**11.704**	**0.042**	**12.414**	**0.045**	**2.890**	**0.013**	**3.175**	**0.014**
	5.192	*0.018*	*5.414*	*0.020*	*1.952*	*0.007*	*2.001*	*0.007*
Constant	**729.618**	**6.678**	**710.956**	**6.683**	**724.212**	**6.643**	**704.296**	**6.644**
	30.312	*0.108*	*31.567*	*0.116*	*30.920*	*0.108*	*32.109*	*0.115*
Dummy 1984q1	**-15.454**	**0.010**			**-15.038**	**0.010**		
	3.137	*0.011*			*3.161*	*0.011*		
European Single Market	**-0.910**	**0.054**	**-0.875**	**0.055**	**-1.918**	**0.049**	**-2.007**	**0.049**
	3.017	*0.011*	*3.014*	*0.011*	*3.056*	*0.011*	*3.039*	*0.011*

For the long-run equations, the coefficients for both cigarette price and HRT price have the correct signs. Total household expenditure is treated as a proxy for income but its estimated coefficient, though slightly positive, is too small to draw any substantive conclusions. The exchange rate has a positive effect, which is in line with intuition. The magnitude is also quite large. The regressions do not seem to show any real impact on volumes from the number of overseas visits. This is surprising since we would expect this variable to be closely related to cross border shopping. It is likely that some of the impact of this is being picked up elsewhere in the regression. The effect of the linear time trend is relatively strong and negative which corresponds to the underlying pattern of falling consumption. The dummy for smoking ban has a negative effect on volumes while the effect of the European Single Market seems quite unstable and dependent on the functional form.

The results from the corresponding short-run error correction models (ECM) can be found in Table 9 in the Annex. Each of the short-run dynamic regressions on differenced data includes an error correction term among the regressors. This ensures that any deviations in the value of the dependent variable in any given period do not persistently undermine the long-run equilibrium. Since the ECM equations are estimated on stationary data, the standard tests of statistical inference can be applied and the statistical significance of coefficients is indicated. Given the fact that error correction models are estimated in first differences, a high explanatory power is not expected. However the coefficients are mostly of the correct sign and the t-values show the estimated own price coefficients to be highly significant. The error correction terms represent the short-run dynamic processes of adjustment, ensuring that the long-run equilibrium is maintained. Results show that the error correction terms in the short-run equations are statistically significant and negative, which confirms the validity of the chosen long-run relationships.

6.1 Elasticities

The coefficient estimates from the linear and semi-log functional forms of demand are not directly interpreted as elasticities. Instead, values of price elasticities of demand are derived using estimated coefficients as well as the price and volume data for cigarettes consumption. The standard approach is to calculate elasticities at the mean values. Depending on the specification of the regression equation, the elasticities are estimated as follows:

Linear demand specification:

$$E_d = \hat{\beta}\frac{\overline{P}}{\overline{V}} \tag{14}$$

Log-linear demand specification:

$$E_d = \hat{\beta}\overline{P} \tag{15}$$

Where E_d denotes the price elasticity of demand (volume of cigarettes consumed), $\hat{\beta}$ is the estimated own-price coefficient and $\overline{P}$ and $\overline{V}$ are the mean values of own-price and volume of consumption over the period of estimation.

Elasticities from the short-run error correction model are calculated using the same formulas. Since, at any given time, it is quite likely that we will be away from the long-run equilibrium, it is important to also consider the short-run evolution of the variables or dynamic adjustment. Table 5 shows the price elasticities of cigarettes demand estimated from various specifications of the two main models.

Table 5 Elasticity Estimates

Model 1		Model 1a		Model 2		Model 2a	
Linear	**Semi-Log**	**Linear**	**Semi-Log**	**Linear**	**Semi-Log**	**Linear**	**Semi-Log**
Long-Run Equilibrium							
-0.94	-1.15	-0.99	-1.17	-0.92	-1.04	-0.95	-1.05
Short-Run ECM							
-0.70	-0.51	-0.67	-0.52	-0.74	-0.55	-0.69	-0.57

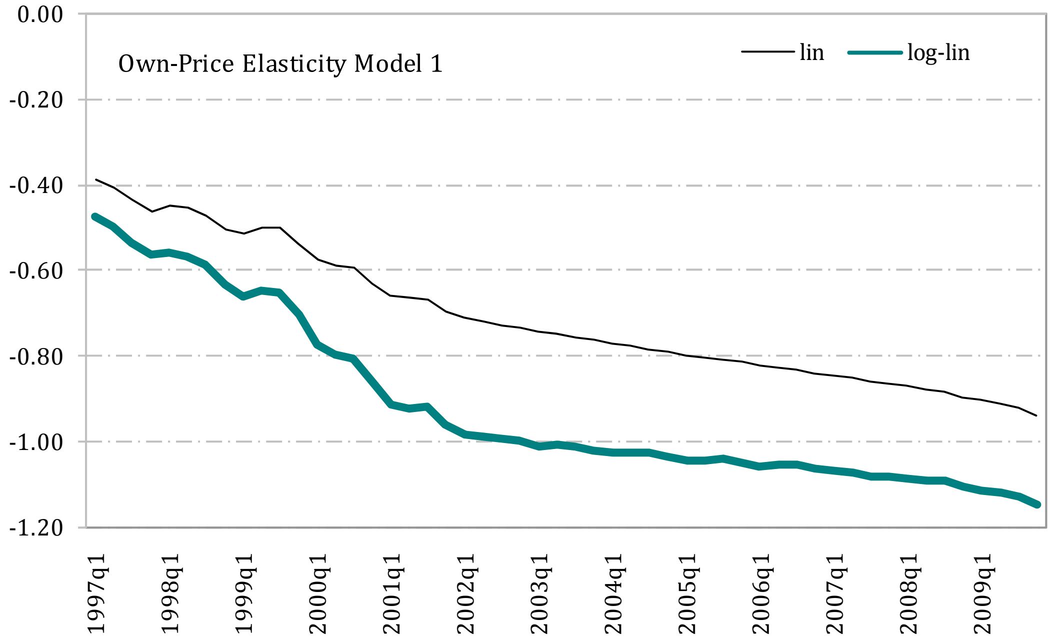
Compared to the linear models, the log-linear specification produces higher long-run price elasticities in absolute terms. Elasticities from both models are robust to using the shorter data sample. Estimates across the eight specifications are relatively consistent: own-price elasticities range between -1.17 and -0.92.

As expected, short-run elasticities are much lower in absolute terms than the long-run ones. This is a sensible result since consumers are better suited to adjust their consumption patterns in the longer term. It is also what we would expect from the consumption of a good with addictive properties.

Though each of these models performs satisfactorily, for the final preferred specification we chose Model 2a, with an elasticity of -1.05. This was chosen based on a number of smaller contributing factors rather than a single dominant one. Firstly, Model 2a performed marginally the best in cointegration testing. Secondly, it was felt that exchange rate rather than overseas visits was the better variable to include. Whilst the latter is a useful proxy for levels of cross border shopping, the exchange rate captures both this but also the incentives to use the illicit market. The final motivation for Model 2a is that the results were more stable when using the shorter time frame and for the log-linear specification.

Figures 8 and 9 are an attempt to evaluate the stability of the results from each of the models. This is done by establishing what the estimated elasticity would have been if the regression had been carried out in previous years. As before, models 1 and 2 were estimated from 1982q1 whilst Models 1a and 2a were estimated from 1984q1. There are not really sufficient observations for this exercise to be valid for years before 2003. It is clear from the graphs that each of the eight specifications is fairly smooth for recent years. This suggests to us that elasticity estimates are relatively stable. As we would expect, the estimated elasticities are increasing over time; this is inevitable if, ceteris paribus, volumes are declining and prices increasing. For our final chosen Model 2a with a log-linear functional form, the estimated elasticity five years ago would have been -0.93. The increase is sharper for Model 1 than for Model 2.

Figure 8 Stability Testing: Model 1



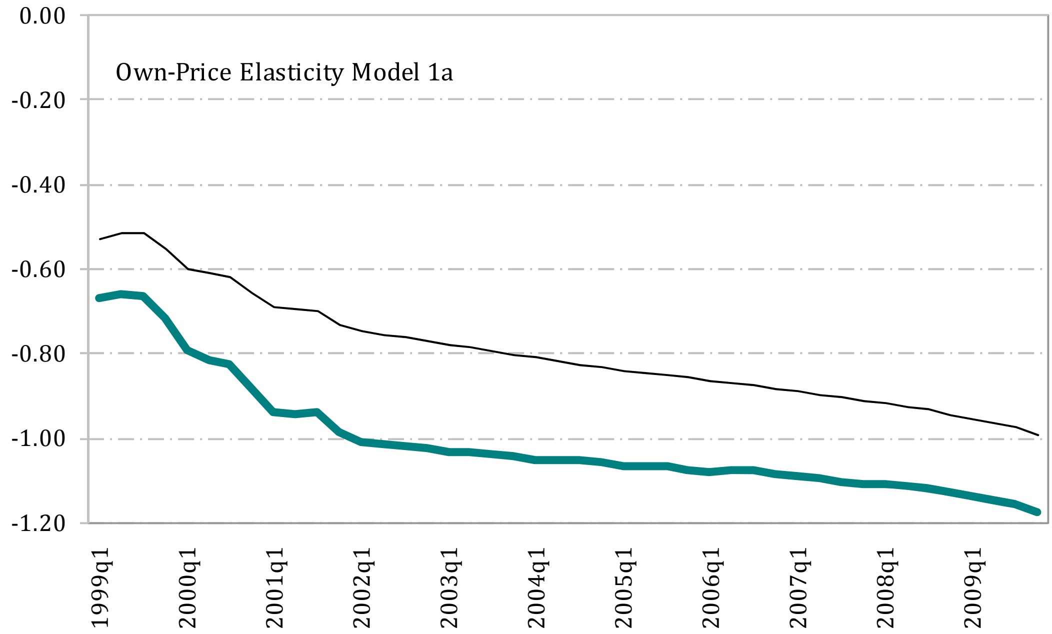
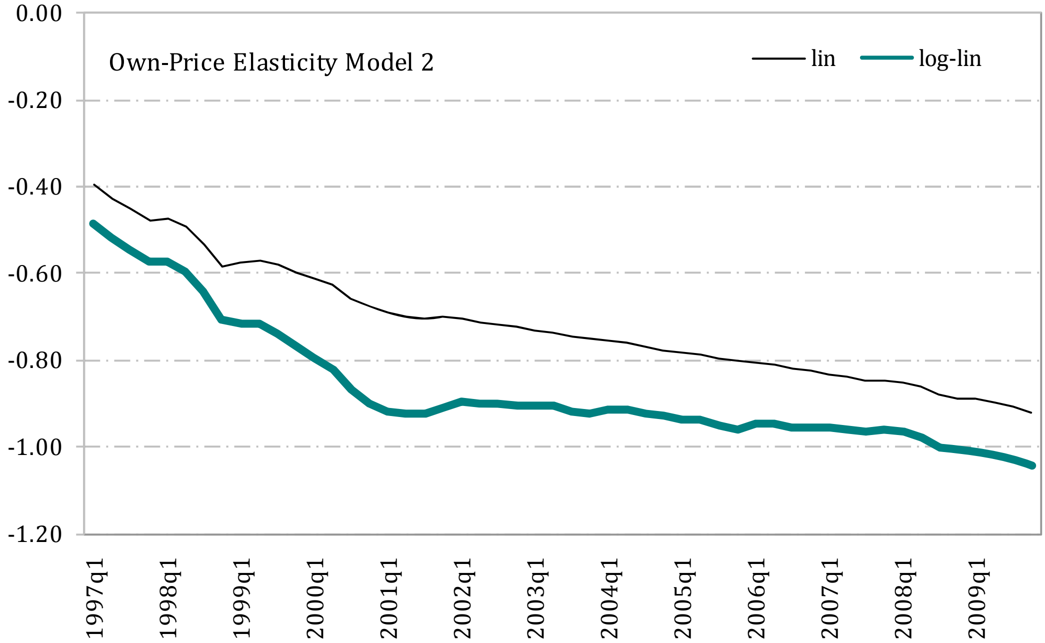
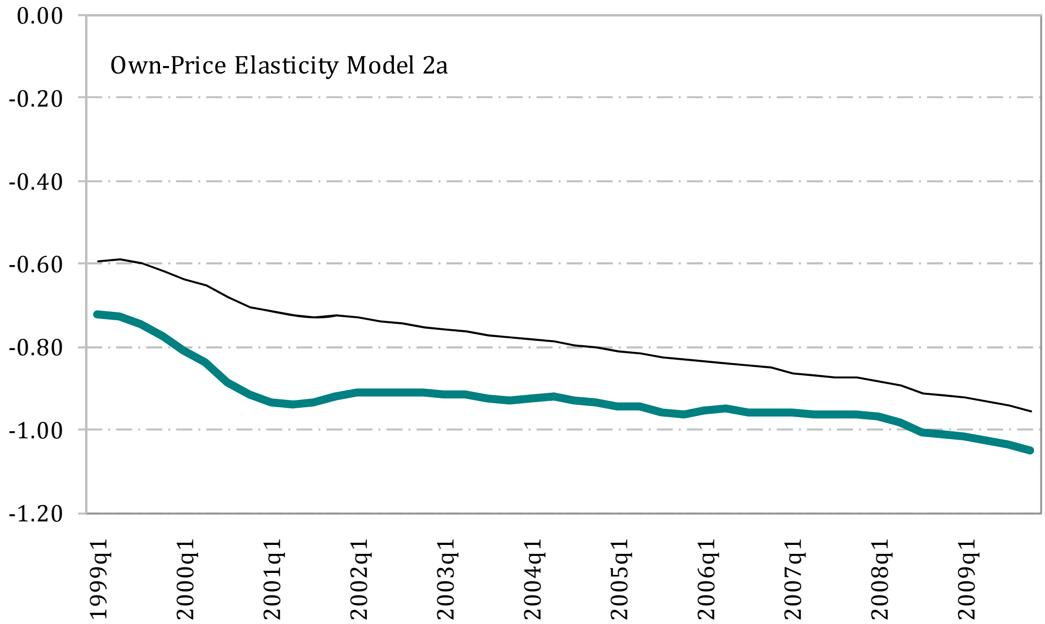


Figure 9 Stability Testing: Model 2





6.2 Ready Reckoner Figures

This section shows how the revenues generated from the estimated elasticities compare to those published in HMRC's most recent Tax Ready Reckoner (HM Treasury and HM Revenue & Customs, 2009). The Ready Reckoner shows an illustrative revenue change from a 1% increase in specific duty for all tobacco; the revenue includes additional VAT. Table 6 shows the previously published figure and how that is changed under the different elasticity scenarios. At that time, December 2009, it was decided that the estimation from the Cullum and Pissarides model was now outdated and an interim elasticity was used until this present estimation work could be completed.

Table 6 Revenue Yields From A 1% Increase In Specific Duty

		Elasticity	2010/2011	2011/2012	2012/2013
Interim Model PBR 2009		-0.88	£35m	£35m	£35m
Previous Estimation		-1.26	£10m	£10m	£10m
Model 1	*Linear*	-0.94	£30m	£30m	£30m
	Semi-Log	-1.15	£15m	£15m	£15m
Model 1a	*Linear*	-0.99	£25m	£25m	£25m
	Semi-Log	-1.17	£15m	£15m	£15m
Model 2	*Linear*	-0.92	£30m	£30m	£30m
	Semi-Log	-1.04	£25m	£25m	£25m
Model 2a	*Linear*	-0.95	£30m	£30m	£30m
	Semi-Log	-1.05	£25m	£20m	£20m

A 1% increase in specific duty, for our chosen elasticity of -1.05, results in an increase in revenue of £25million in the first year and £20 million in years 2 and 3. The drop off in years 2 and 3 is purely down to rounding. The figures are broadly equivalent across the different elasticities. The two most elastic estimates produce figures of £15 million. Other than the relative closeness of the elasticity estimates, the other reason that these revenue figures are quite similar is due to the various other inputs in the costing model, which are common to all. These are mentioned in the Introduction.

7. Conclusions

The aim of the analysis presented in this paper was to estimate the own price elasticity of cigarettes consumption in the UK. The results will be used to capture the behavioural impacts of tobacco policy on tax revenue. For this reason, duty paid rather than total consumption was modelled. Because of the dominant position of cigarettes in the UK tobacco market, other products like HRT were not investigated at present.

A well established time-series methodology using cointegration modelling was adopted. Using the two-step Engle-Granger approach, the long-run relationship between cigarettes consumption and price was investigated along with the short-run dynamic models of adjustments. Both provided estimates that were broadly consistent with the literature and our knowledge of the market. The final specifications were estimated using quarterly data available from 1982. As well as cigarettes consumption and prices, other factors specific to tobacco demand were also modelled. Linear and log-linear functional forms were adopted, mainly to avoid making the strong assumption of a constant elasticity. In total, eight specifications were considered and these produced stable and consistent results with the elasticity estimates ranging between -1.17 and -0.92.

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Annex

Figure 10 Variables Plots, Data In levels

Figure 11 Variables Plots, Data In First Differences

Figure 12 Autocorrelations For Main Variables

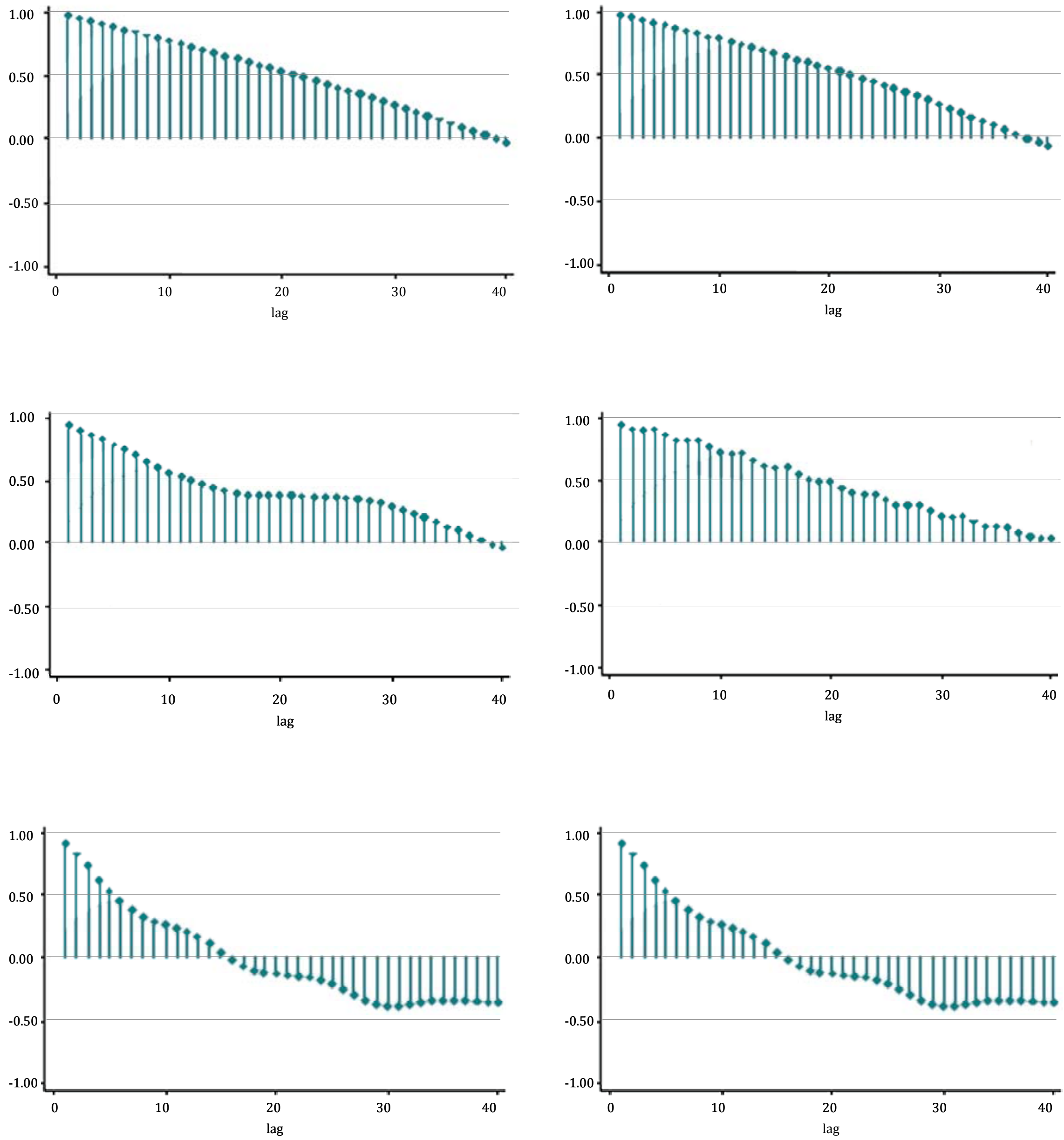

Figure 13 Residuals From Long-Run Specifications

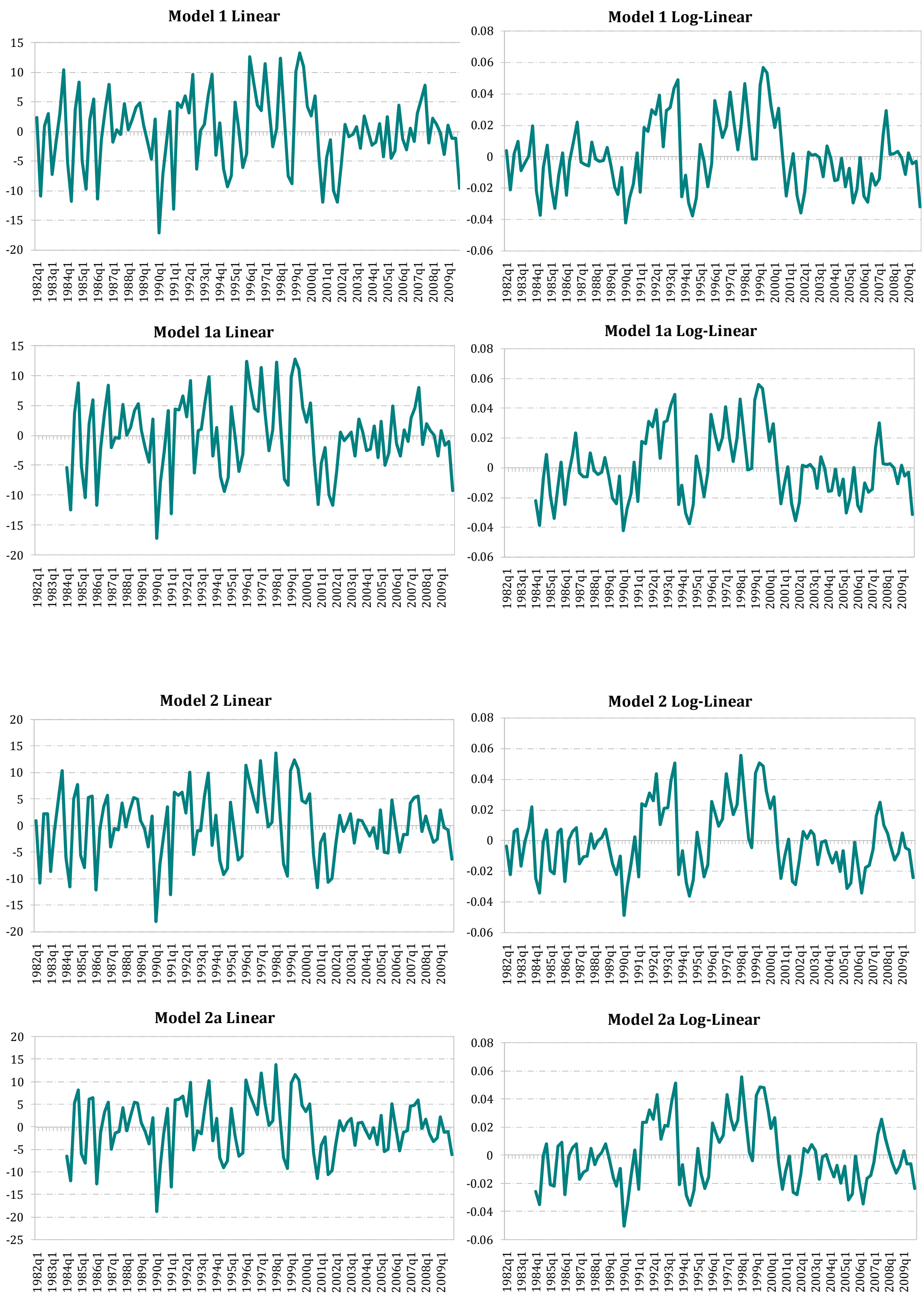

Figure 14 Residuals From Short-Run Specifications

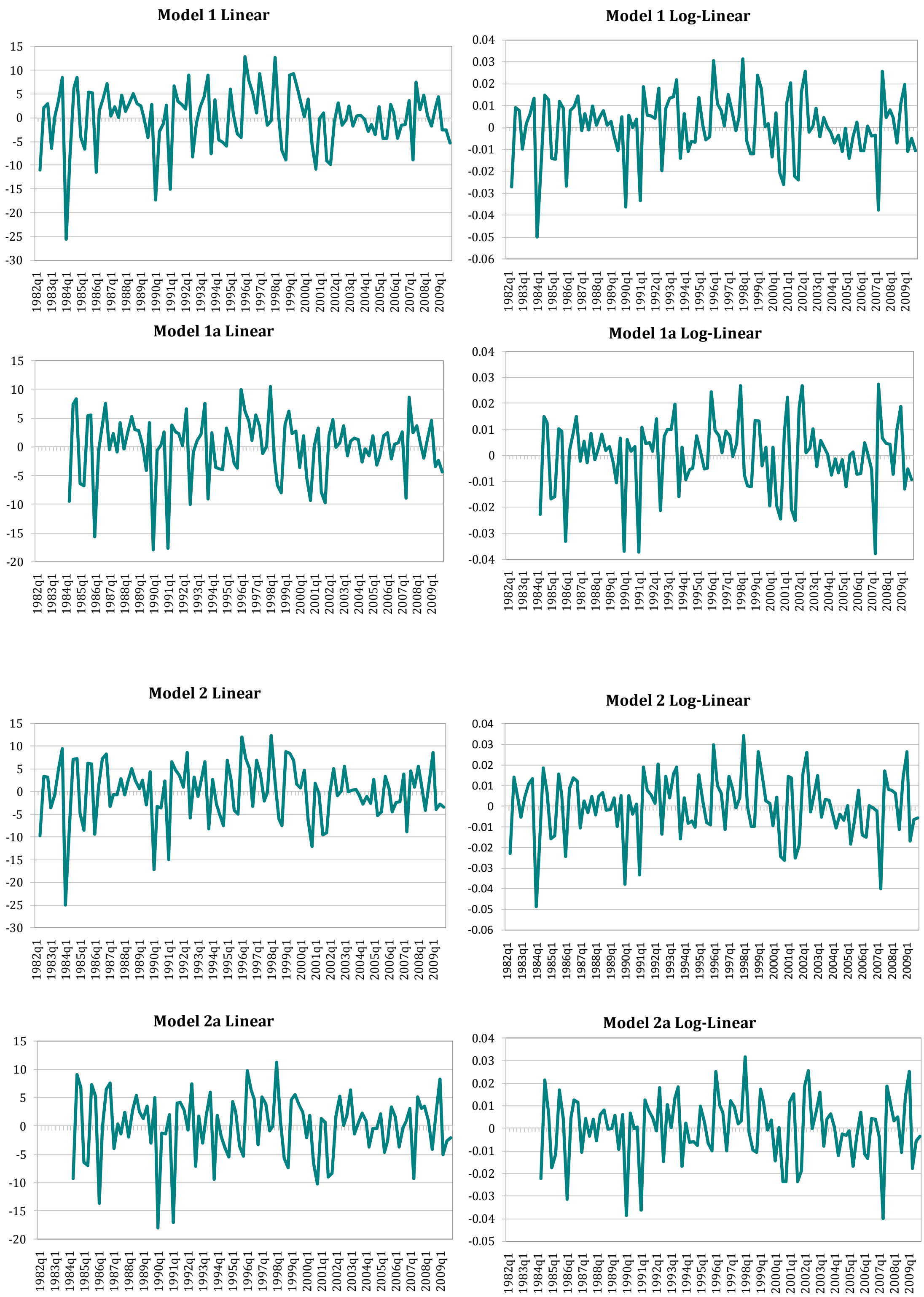

Table 7 Post-estimation Testing: Long-Run Specifications

	Model 1		**Model 1a**	
Time period	**1982q1 - 2009q4**		**1984q4 - 2009q4**	
Specification	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*
Residual Sum of Squares	4152.554	0.053	3828.621	0.052
Root Mean Sq. Error	6.444	0.02294	6.4162	0.02354
Akaike ic.	746.496	-518.408	692.150	-476.284
Bayesian ic.	779.118	-488.5045	721.2379	-449.8403
Residuals: white noise *H0: white noise residuals*	75.339 ***	140.336 ***	59.162 **	141.419 ***
Residuals: normality *H0: Normally distributed residuals*	0.890	4.680 *	0.910	4.360
Ommited variables *H0: no omitted variables*	8.400 ***	54.740 ***	9.150 ***	54.880 ***
Autocorrelation: Durbin Watson	1.526	0.812	1.445	0.757
Autocorrelation: Breusch-Godfrey *H0: no serial correlation*	6.205 **	39.513 ***	7.719 **	39.577 ***
Heteroscedastisity: Breusch-Pagan *H0: Constant variance*	1.870	0.000	2.910 *	0.510
ARCH effects *H0: no ARCH effects up to 4 lags*	7.825 *	27.841 ***	9.701 **	25.381 ***
Cointegration:ADF *H0: no cointegration*	-8.165 ***	-5.176 **	-7.569 ***	-4.839 *
Johansen Vector Error Correction rank	1.000	1.000	1.000	1.000

	Model 2		**Model 2a**	
Time period	**1982q1 - 2009q4**		**1984q4 - 2009q4**	
Specification	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*
Residual Sum of Squares	4245.162	0.052	3882.495	0.050
Root Mean Sq. Error	6.5155	0.02271	6.4612	0.0232
Akaike ic.	748.966	-518.693	693.603	-477.343
Bayesian ic.	781.5883	-486.0712	722.6911	-448.2544
Residuals: white noise *H0: white noise residuals*	88.892 ***	139.476 ***	65.469 **	145.332 ***
Residuals: normality *H0: Normally distributed residuals*	1.050	4.290	1.350	3.830
Ommited variables *H0: no omitted variables*	7.220 ***	53.270 ***	7.620 ***	53.770 ***
Autocorrelation: Durbin Watson	1.559	0.820	1.481	0.753
Autocorrelation: Breusch-Godfrey *H0: no serial correlation*	5.445 **	39.354 ***	6.757 **	39.963 ***
Heteroscedastisity: Breusch-Pagan *H0: Constant variance*	2.870 *	0.060	4.370 **	0.800
ARCH effects *H0: no ARCH effects up to 4 lags*	8.682 *	26.413 ***	10.298 **	22.609 ***
Cointegration:ADF *H0: no cointegration*	-8.325 ***	-5.246 **	-7.773 ***	-4.889 **
Johansen Vector Error Correction rank	1.000	1.000	1.000	1.000

Table 8 Post-estimation Testing: Short-Run Specifications

	Model 1		Model 1a	
Time period	1982q1 - 2009q4		1984q4 - 2009q4	
Specification	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*
Residual Sum of Squares	4193.708	0.023	2981.191	0.019
F- Statistic	14.240 ***	9.050 ***	12.290 ***	8.160 ***
Root Mean Sq. Error	6.5085	0.01529	5.6925	0.01419
Akaike ic.	742.135	-601.728	660.932	-573.949
Bayesian ic.	774.6497	-569.2138	689.9143	-544.9666
Residuals: white noise	81.216 ***	64.882 **	65.652 **	47.966
H0: white noise residuals				
Residuals: normality	17.380 ***	9.740 **	15.940 ***	8.410 **
H0: Normally distributed residuals				
Ommited variables	9.890 ***	3.100 **	3.070 **	0.690
H0: no omitted variables				
Autocorrelation: Durbin Watson	1.919	2.061	2.103	2.151
Autocorrelation: Breusch-Godfrey	0.285	0.542	2.115	1.490
H0: no serial correlation				
Heteroscedastisity: Breusch-Pagan	43.300 ***	14.160 ***	8.280 **	1.520
H0: Constant variance				
ARCH effects	2.513	3.190	7.896 *	3.057
H0: no ARCH effects up to 4 lags				

	Model 2		Model 2a	
Time period	1982q1 - 2009q4		1984q4 - 2009q4	
Specification	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*
Residual Sum of Squares	4182.269	0.024	3075.720	0.020
F- Statistic	14.300 ***	8.430 ***	11.630 ***	7.030 ***
Root Mean Sq. Error	6.4996	0.01556	5.782	0.01467
Akaike ic.	741.832	-597.893	664.148	-567.029
Bayesian ic.	774.3465	-565.3783	693.1296	-538.0469
Residuals: white noise	128.402 ***	126.636 ***	132.672 ***	110.888 ***
H0: white noise residuals				
Residuals: normality	15.290 ***	7.350 **	10.860 **	6.270 **
H0: Normally distributed residuals				
Ommited variables	9.760 ***	2.720 **	2.480 *	0.580
H0: no omitted variables				
Autocorrelation: Durbin Watson	1.982	2.066	2.122	2.154
Autocorrelation: Breusch-Godfrey	0.021	0.479	2.492	1.424
H0: no serial correlation				
Heteroscedastisity: Breusch-Pagan	35.010 ***	13.470 ***	6.680 **	1.490
H0: Constant variance				
ARCH effects	1.865	26.413 ***	8.841 *	4.574
H0: no ARCH effects up to 4 lags				

Table 9 Estimation Results: Short-Run

Short Run results	Model 1		Model 1a		Model 2		Model 2a	
Time period	1982q1 - 2009q4		1984q4 - 2009q4		1982q1 - 2009q4		1984q4 - 2009q4	
Specification	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*	*Linear*	*Semi-Log*
ΔPrice	-16.539 ***	-0.028 ***	-10.336 ***	-0.018 **	-18.138 ***	-0.033 ***	-12.735 ***	-0.023 **
	2.970	*0.007*	*2.832*	*0.007*	*2.882*	*0.007*	*2.773*	*0.007*
ΔHRT price	0.176 *	0.000 *	0.121	0.000	0.243 **	0.001 **	0.207 **	0.001 **
	0.103	*0.000*	*0.093*	*0.000*	*0.099*	*0.000*	*0.091*	*0.000*
ΔExpenditure	-0.010	0.000	-0.006	0.000	-0.006	0.000	0.000	0.000
	0.017	*0.000*	*0.016*	*0.000*	*0.017*	*0.000*	*0.016*	*0.000*
ΔExchange rate					-55.029 *	-0.070	-38.211	-0.038
					28.634	*0.069*	*26.572*	*0.067*
ΔVisits	0.000	0.000 **	0.000 **	0.000 **				
	0.000	*0.000*	*0.000*	*0.000*				
Smoking Ban	-0.918	-0.004	-0.180	-0.003	0.574	-0.001	1.152	0.000
	2.287	*0.005*	*2.021*	*0.005*	*2.363*	*0.006*	*2.119*	*0.005*
ΔQ1	-8.391 *	-0.022 **	-7.528 *	-0.019 *	-5.194	-0.012	-3.317	-0.008
	4.712	*0.011*	*4.411*	*0.011*	*4.436*	*0.011*	*4.163*	*0.011*
ΔQ2	1.741	0.006	4.449	0.012	0.175	0.000	1.610	0.003
	3.892	*0.009*	*3.556*	*0.009*	*3.732*	*0.009*	*3.454*	*0.009*
ΔQ3	7.750 *	0.027 **	12.316 **	0.033 **	1.053	0.002	1.848	0.003
	4.603	*0.011*	*4.291*	*0.011*	*1.983*	*0.005*	*1.860*	*0.005*
Constant	-0.649	0.000	-0.906	-0.002	-0.811	-0.001	-0.935	-0.002
	2.490	*0.006*	*0.993*	*0.002*	*2.484*	*0.006*	*1.013*	*0.003*
Dummy 1984	-0.593	-0.002			-0.301	-0.002		
	2.694	*0.006*			*2.695*	*0.006*		
European Single Market	-0.141	-0.003	-1.311	-0.005 *	-0.479	-0.004	-1.459	-0.005
	1.387	*0.003*	*1.234*	*0.003*	*1.395*	*0.003*	*1.262*	*0.003*
Error Correction Term	-0.785 ***	-0.310 ***	-0.641 ***	-0.288 ***	-0.817 ***	-0.352 ***	-0.717 ***	-0.332 ***
	0.111	*0.070*	*0.102*	*0.065*	*0.105*	*0.071*	*0.098*	*0.068*