Europe Economics

TPD2 and standardised tobacco packaging — What impacts have they had so far?

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Contents

Summary

This report was commissioned from Europe Economics by JTI (Japan Tobacco International). In it, we have considered the impacts of TPD2 and plain packs requirements, introduced in the UK and France between 2016 and 2017, upon tobacco consumption and prevalence, in three types of models: simple linear trend models, time series models and simultaneous equations models.

- A simple trend model considers whether the prior trend in tobacco consumption or prevalence was changed at the time TPD2 and plain packs requirements were introduced.
- A time series model makes the simple trend model more sophisticated by considering the possibility that the prior evolution was more complex than simply a trend, possibly reflecting lags, seasonality and moving averages, and also taking account of prices.
- A simultaneous equations model allows for the possibility that TPD2 and plain packs requirements might have their effects on prevalence or consumption either directly or via having an impact on prices, which in turn had an impact on consumption or prevalence.

We have found:

- No statistically significant impacts on prevalence in the UK[1].
- No statistically significant impact on consumption in France.
- A statistically significant and positive association between the introduction of TPD2 and plain packs requirements and tobacco consumption in the UK (i.e. the introduction of TPD2 and plain packs has been associated with an increase in consumption).

We also note that at the time of the impact assessment accompanying TPD2 it was anticipated that there would be an impact in the form of reduced consumption by this point. In the UK government's TPD2 impact assessment of 2015 it provides estimates of projected prevalence levels and projected reductions associated with TPD2. [2] These were for a reduction of 1.9 per cent in both smoking prevalence and smoking consumption over 5 years, applied linearly implying a reduction of 0.38 per cent in the 1st year, equivalent to 0.08 percentage points reduction in prevalence in the first year (2016) if prevalence would have been 19.7 per cent.

Furthermore, in the impact assessment on plain packaging it estimated the extent to which smoking prevalence would fall as a consequence of standardised packaging.[3] That suggested that in 2016 prevalence would be 0.37 percentage points lower as a consequence of standardised packaging, and in 2017 prevalence would be 0.74 percentage points lower as a consequence of standardised packaging.

None of these effects, for either TPD2 or standardised packaging, is yet identifiable in the data.

[1] We have publically available data with sufficient frequency to model prevalence impacts for the UK, but not for France

[2] See paragraphs 73-74 of Tobacco Products Directive (TPD) IA No: 3131, 29/06/2015, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/440994/TPD_IA.pdf

[3] See Table 2 p45 of https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/403493/Impact_assessment.pdf

1 Introduction

In February 2014, the European Union agreed a revised Tobacco Products Directive[4], often referred to as "TPD2". As well as introducing various other measures, such as restrictions on the advertising of electronic cigarettes and other vaping devices, TPD2 introduced a series of additional restrictions on the packaging of tobacco products, such as:

- making 20 the minimum number of cigarettes per cigarette pack, and 30 grams the minimum weight for roll-your-own tobacco packs;
- updating health warnings and requiring that combined (picture and text) health warnings cover 65 per cent of the front and back of cigarette and roll-your-own tobacco packages; and
- banning certain descriptors on packaging of tobacco products (such as "natural" and "organic").

At the same time as implementing TPD2, France and the UK introduced additional measures imposing standardised packaging of tobacco products ("plain packs" which we refer to as "PP" requirements). Such measures involve precise restrictions with regard to:

- the banning of all brand elements with the exception of the name which has to appear in a standardized font and size;
- the material, size, shape and opening mechanism of packaging;
- the colour of packaging and cigarettes; and
- the font, colour, size, case and alignment of text on packs.

Europe Economics was commissioned by Japan Tobacco International to assess any impacts yet discernible from TPD2 and plain packs upon tobacco consumption in France and the UK, and smoking prevalence in the UK.

Our analysis indicates that, based on data up to and including August 2018, there has been no statistically significant relationship, in the sorts of models we have used, between TPD2 and plain packs (hereafter frequently referred to as "TPD2+PP") requirements and smoking prevalence in the UK. Similarly, again in the models we have used, those data indicates no statistically significant relationship between the presence of TPD2+PP requirements and tobacco consumption in France. However, in some of the models employed we found a statistically significant and positive relationship between TPD2+PP requirements and tobacco consumption in the UK.

This report is structured as follows.

- Section 2 describes the data used for the analysis and intuitively explains our modelling approach.
- Section 3 sets out the analysis on tobacco consumption in France and the UK.
- Section 4 presents the analysis on the prevalence of smoking in the UK.
- A technical appendix is included at the end of this report, setting out various mathematical points in more detail, for reference.

[4] Directive 2014/40/EU ec.europa.eu/health/sites/health/files/tobacco/docs/dir_201440_en.pdf

2 Data and modelling approach

2.1 Introduction

In this section we describe the data sources the analysis relies upon and provide an intuitive description of the modelling approach adopted.

2.2 Primary data sources

The raw data underpinning the analysis has been provided by JTI (and sourced from Nielsen and IRI) and consist of monthly retail prices and numbers of sticks for each tobacco product sold in France and the UK. The volume of sticks data covers the period January 2008 — August 2018, whilst price data is available only from January 2012.

The data is available at a high level of disaggregation — information on the number of sticks sold and retail prices is provided at the product level (i.e. for each separate sub-brand and package size). In this respect, for the purpose of the analysis, the data has been aggregated so as to obtain:

- The number of sticks sold for the whole tobacco market (consisting of cigarettes, roll-your-own products, and make-your-own products).[5]
- The average price of tobacco products which has been calculated as the weighted average price across all products, whereby the weights are proportional to the number of sticks sold. These average prices have then been expressed in a "20 sticks" equivalent form.

2.3 Measuring TPD2 and plain-packaging requirements

In France and the UK, the TPD2 and plain-packaging requirements were adopted in May 2016. Following that transposition there was a transition period at the end of which all tobacco products sold needed to be compliant with the new regulation. The deadlines after which all products were obliged to comply with TPD2+PP requirements were: January 2017 for France; and May 2017 for the UK. This means that, during the implementation period, TPD2+PP products were sold next to products with the "old" branded packaging format. Therefore, for the purpose of the analysis, the degree of implementation of TPD2+PP requirements can be interpreted in terms of the penetration rate of TPD2+PP compliant products in the market.

For France and the UK we have fairly detailed information on the evolution of the actual penetration rate of TPD2+PP products within each tobacco brand and, therefore we have accurate information on the penetration of TPD2-PP products.

2.4 Modelling approach

The class of models we rely upon in this report are so-called "time series" models, in which we first attempt to infer the underlying evolution through time of the variables we are interested in (e.g. prevalence, consumption,) and then consider whether (and if so to what extent) the introduction of TPD2 and plain packs disturbed that underlying evolution path. Such models answer the question "What would have happened had TPD2 and/or plain packs not been introduced?" roughly as "The variables we are interested in

[5] For RYO/MYO products the raw data provides also a sticks-equivalent conversion.

would have continued to evolve through time in the ways they had done prior to the introduction of TPD2 and/or plain packs."

More detail on time series models

The most well-known "time series" relationship is probably a trend. Suppose that in country X the consumption of cigarettes fell steadily by 0.5 percentage points each year for 20 years before TPD2 and plain packs were introduced. Then (assuming, naïvely, for the purposes of illustration, that no other factors were found to be relevant) it might be reasonable to assume that if TPD2 and plain packs had not been introduced, the consumption of cigarettes in country X would have continued to drop by 0.5 percentage points each year. If in fact the consumption of cigarettes fell consistently by 0.75 percentage points each year after TPD2 and plain packs were introduced, we might (again assuming naïvely that no other factors were found to be relevant) infer that the introduction of TPD2 and plain packs had been correlated with an acceleration of 0.25 percentage points each year in the decline in cigarette consumption.

Trends are only one form of time series relationship. Others include lags (the value of a variable in any one year is some multiple of its value in the year before) and moving averages (which can take a number of forms — e.g. a moving average, over three periods, of the variation of a variable from its trend value). In a time series model we use our data to describe, as closely as possible, the evolution through time of the variable(s) we are interested in via such time series relationships. The impact of a measure such as TPD2 and plain packs is, then, the way in which it leads to changes in the evolution of the variable(s) of interest relative to these time series relationships.

One important point to note here is that in this sort of time series model it is not possible to disentangle the impacts of two measures introduced at the same time. For example, in France and the UK TPD2 and plain packs were introduced together (as of May 2016[6]). All that the model can do is to say whether the time series relationships were disturbed from May 2016 onwards. It cannot say why or what proportion of any impacts should be attributed to different things that happened at that same date.

A further point to note here is that the use of time series relationships automatically accounts for seasonal effects in our data (where they exist). For example if the value of a variable in a particular month of the year is always, say, elevated, then it will have some relationship to its value one year before, which the time series tests will automatically incorporate.

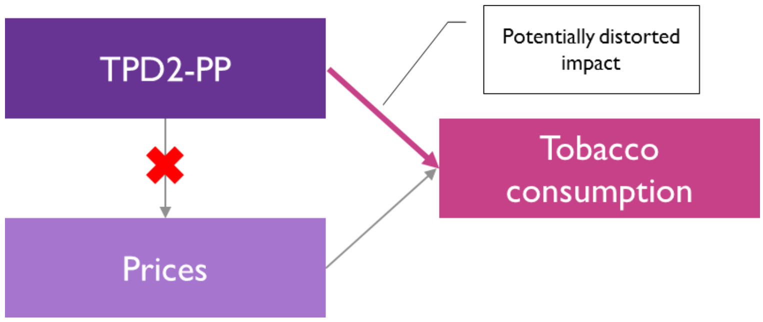
Pure time series versus simultaneous equations models

Our time series models infer time series relationships whilst controlling for prices. For example, consider a model such as the impact of TPD2 and plain packs upon consumption of tobacco products. It is natural to suppose that the average price of tobacco products might affect their consumption. So it is natural that such relative prices feature in the model.

But now suppose that as well as having a direct impact on tobacco consumption, measures such as TPD2 and plain packs also affected tobacco prices. Then there would be two routes by which impacts would occur: the direct one and the indirect one. If the model controls for price changes it will miss part of the impact — the impact that arises indirectly by causing the prices themselves to change. Such a distortion is illustrated below:

[6] May 2016 corresponds to the manufacturing deadline

Figure 2.1: Distorted impact found in a model where prices are controlled for but the measure has an impact on prices themselves

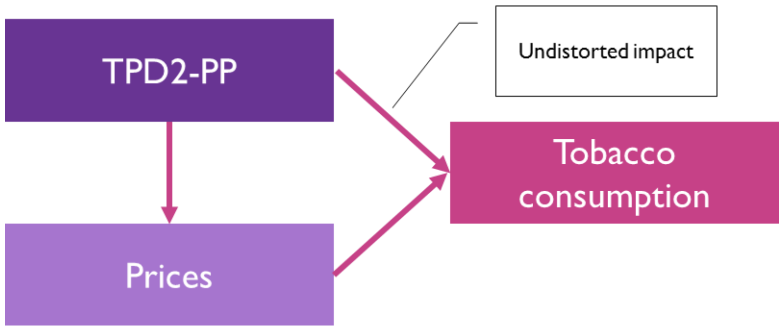


We can correct for this by what are commonly referred to as econometric "simultaneous equations" techniques. In our simultaneous equations models we estimate the impact of the measure (here, TPD2 and plain packs) upon prices and consumption (or other relevant variables in other models, such as prevalence) at the same time as measuring the direct impact of the measure upon consumption (or other variables). Doing so allows us to capture both impacts:

- The direct impact of TPD2+PP on consumption; and
- The indirect impact of TPD2+PP on consumption, which is enabled by the direct impact of TPD2+PP on prices.

These are further illustrated in the figure below:

Figure 2.2: Undistorted impact found in a model where impacts on prices and via prices are estimated simultaneously with direct impacts



3 Impacts on Consumption

3.1 Introduction

In this section we first provide an overview of smoking consumption in the UK and France. We then present a series of statistic models: to make ideas concrete we start by illustrating ideas using simple (indeed, in some senses naïve) models and then we move to more sophisticated ones.

3.2 Tobacco consumption in the UK and France

The following charts indicate the total number of sticks (these include both cigarette and RYO/MYO products) sold to consumers in the UK and France.

Figure 3.1: Number of sticks (millions) sold in the UK

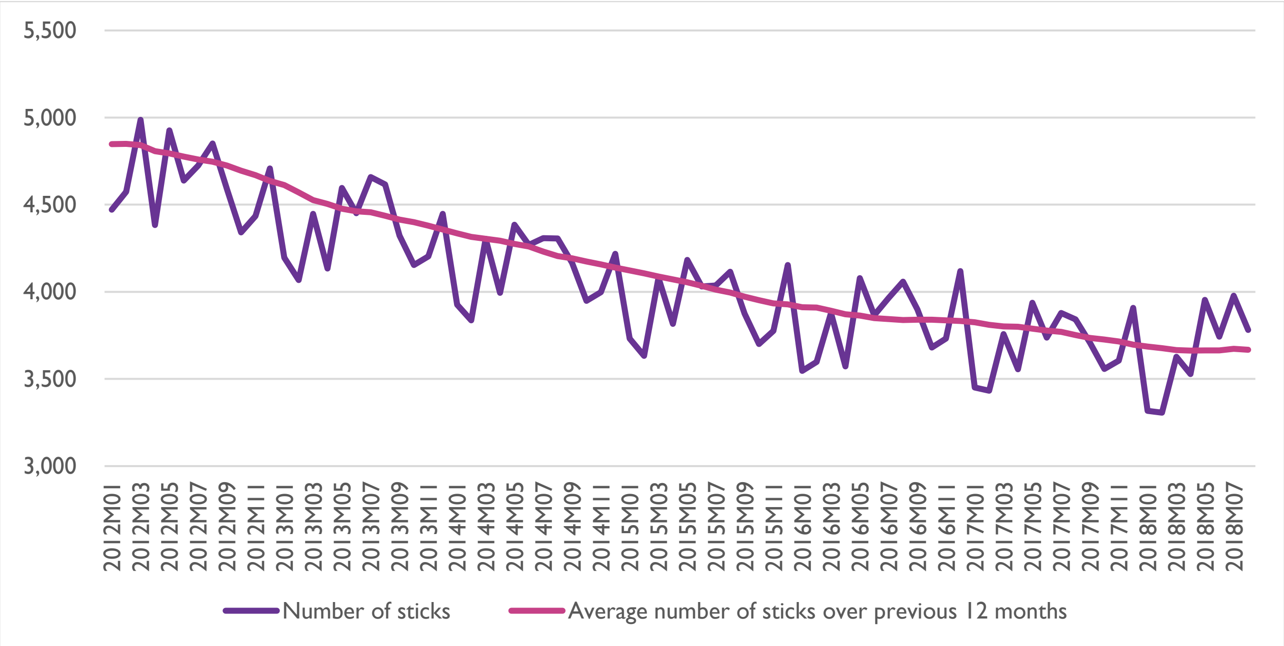
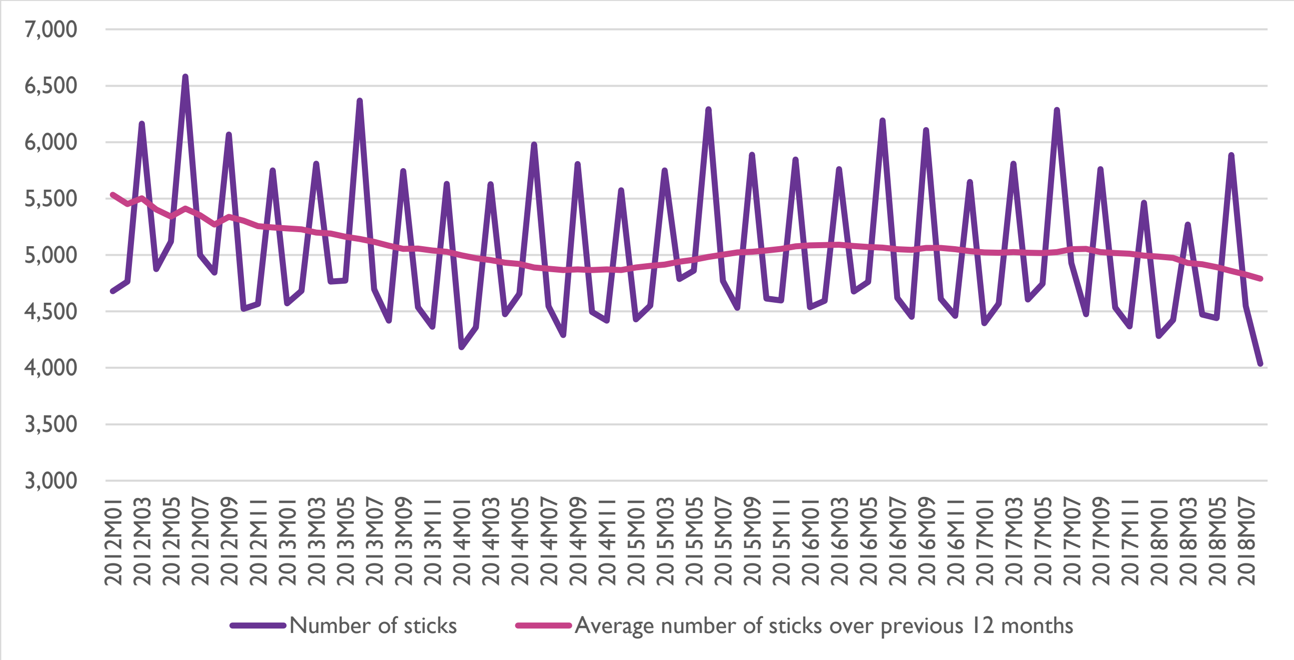


Figure 3.2: Number of sticks (millions) sold in France



We can notice from Figure 3.1 that in the UK there has been a declining trend in the number of sticks sold since 2012, with perhaps some suggestion of a flattening in the rate of fall since mid-2016. In France the sales of sticks decreased up to 2014 (albeit on a declining trend less pronounced than in the UK), but somewhat stabilised afterwards.

3.3 Simple trend model

We begin with a very simple "naïve trend analysis". In such a test we try to explain the evolution of tobacco consumption with merely a simple linear trend, and test whether there was a break in the series after the transposition of the TPD2+PP regulation. More specifically, we have tested for the following types of breaks:

- A break in absolute consumption levels;
- A break in consumption trend;
- A break in, both absolute consumption levels and consumption trend.

Such a model would not itself demonstrate whether the results of later, more advanced models were correct or not, but they would help us to understand to what extent results for later, more sophisticated models with extra control variables were a matter of those extra control variables

- validating (i.e. producing similar results to);
- reinforcing (i.e. producing results with the same sign but with larger coefficients than);
- removing (i.e. eliminating results that were there before in)
- reversing (i.e. producing results in the opposite direction to); or
- adding to (i.e. producing results that were not initially there for)

For France we ran a model with a single linear trend but in such model the trend was not statistically significant. This suggests that tobacco consumption in France is better described as fluctuating around a constant mean rather than following a single linear trend. Furthermore, none of the tests described above indicates the presence of a statistically significant break in a naïve trend analysis of the consumption series for France.

In contrast, the analysis for the UK suggests that tobacco consumption can be described — in statistically significant terms — as following a declining trend. The break tests we conducted suggest that the consumption series for the UK can be described either as having a break in its level (resulting in a higher level thereafter — i.e. *more* tobacco consumption, not less) at around May 2016 or as having a break in trend (resulting in a lower rate of decrease in tobacco consumption — i.e. more tobacco consumption, not less) after May 2016.

Table 3.1: Results of a naïve trend model with a break in the level of consumption (UK)

	Coefficient	Std. Error	Prob.
Constant	5,500,000,000	139,000,000	0.0000
Trend	-17,726,307	1,865,292	0.0000
Dummy *(break in levels)*	242,000,000	90,307,016	0.0091

Table 3.2: Results of a naïve trend model with a break in consumption trend (UK)

	Coefficient	Std. Error	Prob.
Constant	5,550,000,000	142,000,000	0.0000
Trend	-18,409,010	1,925,269	0.0000
Trend * dummy (*break in trend*)	2,448,565	825,274	0.0040

We also checked whether there might be a break affecting both consumption levels and consumption trend simultaneously. In such a model we find that the only break statistically significant is that affecting trend consumption.

Table 3.3: Results of a naïve trend model with a break in consumption level and trend (UK)

	Coefficient	Std. Error	Prob.
Constant	5,610,000,000	146,000,000	0.0000
Trend	-19,147,176	1,969,282	0.0000
Dummy (*break in levels*)	-886,000,000	581,000,000	0.1313
Trend * dummy (*break in trend*)	10,530,141	5,361,027	0.0532

More specifically, the results of Table 3.1 indicate that the introduction of TPD2+PP is associated (in this simple model) with a permanent increase in consumption of around 240 million sticks. Similarly, the results of Table 3.2 indicate that, whilst before the introduction of TPD2+PP, the monthly reduction in number of sticks sold in the UK was, on average, of the order of 18 million (the coefficient of the trend variable in Table 3.2), since May 2016 the average monthly reduction is of the order of approximately 16 million (the coefficient of the coefficient of the trend variable in Table 3.2 plus that of the trend-times-dummy variable, i.e. -18.4m+2.4m = -16m).

Thus **in this simple model, the introduction of TPD2+PP results in higher tobacco consumption**. We shall now explore to what extent this basic result from the data is validated, reinforced, removed, reversed or added to in more sophisticated models. We shall see that for our preferred class of time-series models the result is removed (i.e. there is no impact), but in some of our cross-check time-series models and in our simultaneous equations model for the UK it is validated (i.e. the result that TPD2+PP is associated with an increase in consumption in the UK is repeated).[7]

3.4 More sophisticated tests

As noted, the naïve trend model does not take into account certain statistical properties of the data. For example, a statistical inspection of the data indicates that tobacco consumption has a strong seasonal component (i.e. tobacco consumption higher in certain months of the year) and the simple trend model does not account for this. Moreover, the introduction of TPD2+PP regulation is modelled with a crude dummy variable, which does not reflect the fact that the penetration of TPD2+PP compliant products in the market has increased gradually over the implementation period. Finally, the model does not account for other economic variables (such as prices or household income) that may also affect consumption.

We have therefore implemented more sophisticated tests to model the evolution of tobacco consumption. The first class of such tests includes pure-time series models, the second class includes simultaneous equation models tests. These are presented in turns below.

3.4.1 Time-series models

The time-series models we use aim to explain monthly percentage changes in the number of sticks sold by time series components, monthly percentage changes in *prices* and the *penetration of TPD2+PP products* in the market. The models also include *monthly dummy variables* to account for seasonal patterns in the data.

If we were conducting tests over a large number of years, as well as adjusting for prices, it would be important to adjust, also, for household income. Our data is, however, relatively high frequency (monthly) but over only a few years (less than six). That means both that adjusting for household income is less crucial (it is less likely to be statistically significant over a short time period), less available (GDP data is available quarterly, not monthly, not available for the last two data points in our series and GDP per capita data is less reliable than GDP data at very short time periods because population estimates tend not to be reliable at very high frequency), and less straightforwardly interpreted (it is not clear that monthly fluctuations in GDP per capita would, even in theory, be expected to drive fluctuations in consumption insofar as such fluctuations reflected annual income stream volatility (e.g. self-employment revenue streams, bonuses, etc). Nonetheless, we have cross-checked the results that follow using models that allowed for the presence of GDP per capita, also.[8] None of the results below changed materially.

In all the models we have tested there is a strong seasonal pattern to consumption. More formally, monthly dummies are strongly significant and account for a sizable portion of the variation in the data, or, in other words, information on the specific calendar month is a very strong predictor of the tobacco consumption taking place in that month.

Finally, in addition to seasonal patterns, changes in prices and, changes in the penetration of TPD2+PP compliant products, there might be other factors that are important in explaining the evolution of consumption behaviour. When data evolves through time, it is common to model them using a class of what are referred to as “autoregressive–integrated–moving–average” (ARIMA) processes. Such a process attempts to describe the behaviour of variables by exploiting any systematic relationship between a variable’s current value and its past values.

7 Specifically, we find an increase of around 90m in the level of number of sticks sold in the UK. That compares with the increase of around 200m we found in Table 3.1. We regard these are broadly similar impacts, in this context.

8 GDP per capita is not statistically significant in any our benchmark consumption model and prevalence model.

Two key components in ARIMA processes are the "autoregressive" (AR) term and the moving average (MA) term.[9] The "autoregressive" term describes how the present value of the variable depends on its previous value at some point in the past (say the previous month, or three months ago, or twelve months ago). The moving average term describes how the noisy fluctuations around the current values of the variable depend on the noisy fluctuations observed in the past.[10] ARIMA models are particularly useful because they can provide an accurate description of a time-series variable by using only the information contained in the variables itself, i.e. without the need for additional control variables. However, in our setting the purpose of including an ARIMA process is that of capturing residual patterns in consumption data that cannot be explained by the other explanatory variables included in the model (namely seasonal dummies, prices and TPD-2 penetration). Among the available range of ARIMA models, the "best" ARIMA model (i.e. the one with the correct orders for the AR and MA terms) can be selected algorithmically based on standard statistical tests.[11]

We present below the results for the time series model that our algorithm indicated should be our preferred time series model for both the UK and France (for presentational purposes the results for the monthly seasonal dummies are omitted from the tables).

Table 3.4: Pure time-series model of tobacco consumption for the UK

	Coeff.	Std. Error	P-value
% Change in the average price of tobacco products	0.613745	0.473779	0.2002
Penetration of TPD+PP products in the market	0.002827	0.003044	0.3567
AR(1)	-0.461341	0.116211	0.0002
AR(2)	-0.022110	0.105778	0.8352
AR(3)	0.127886	0.102316	0.2163

Table 3.5: Pure time-series model of tobacco consumption for France

	Coeff.	Std. Error	P-value
% Change in the average price of tobacco products	-0.372984	0.184427	0.0473
Penetration of TPD2-PP products in the market	-0.001445	0.002932	0.6239
MA(1)	-0.626522	0.091738	0.0000

The results presented in Table 3.4 and Table 3.5 indicate that the introduction of TPD2+PP requirements do not appear to have any statistical association with the number of sticks sold.

9 The other element, the "I" in ARIMA, which stands for "Integrated", in this context means the model is calculated in first differences (i.e. in changes in values, rather than in levels). If the variable of interest is expressed in levels then the process is referred to as ARMA process.

10 Within the broad class of ARIMA models, a specific model is characterised by an order for the autoregressive components (p), and an order for the moving average component (q). The order simply indicates the lag of the relationship linking current values to past values, so, for example, an autoregressive term of order two AR(2) indicates that the current value of a variable depends on the variables' value observed two periods earlier.

11 For example, the Akaike Information Criterion (AIC) or the Schwarz Bayesian Information Criterion (BIC). For the purpose of selecting the best ARIMA process we used the BIC statistic, applied iteratively across possible ARIMA models to an order of up to 3 so as to identify those that perform best. We then inspect the correlogram of the residuals of the preferred model in order to decide whether the inclusions of additional AR components (such as, e.g. an AR(12) term to capture residual seasonal patterns) is appropriate.

A shortcoming of the time-series models of Table 3.4 Table 3.5 is that the price variables are not statistically significant despite abundant empirical evidence suggesting that that tobacco consumption is indeed sensitive to price changes. This is mainly due to the fact that models in which the dependent variable are expressed in differences (or, in our case, in percentage differences) are less likely to identify a statistically significant relationship between variables than models expressed in levels. In other words, if we find a statistically significant relationship in a model in difference we can be quite certain that such a relationship exists. However, if we fail to find such relationship to be statistically significant in differences, we might still be able to find it to be significant in a model expressed in levels (even though the risk of the statistical relationship being spurious is higher).

For these reason we have also employed alternative models (presented in details in Section 6.2.3) where the dependent variables are expressed in levels as opposed to percentage changes. Such an approach still requires some transformation of the dependent variable (i.e. de-trending and adjusting for seasonality) to ensure stationarity so as to allow the variables to be analysed in a meaningful way. Under the alternative modelling approach we find that an increase in the price of tobacco products is statistically associated with a decrease in consumption of tobacco products in both France and the UK, as expected.[12]. Furthermore, under this alternative modelling approach we find that the introduction of TPD2+PP products in the UK is also associated with an increase in tobacco consumption in the UK.

3.4.2 Simultaneous equation model

A simultaneous equation model is made up of two different equations that are estimated simultaneously. The first is a consumption equation the number of sticks sold are explained by price, *penetration of TPD2+PP products* in the market and an appropriate time series process. The second equation is a price equation where prices are modelled by a time-series process and the p*enetration of TPD2+PP products*. Therefore, in a simultaneous equation model, the potential impact of TPD2+PP on consumption can be broken down into two different components:

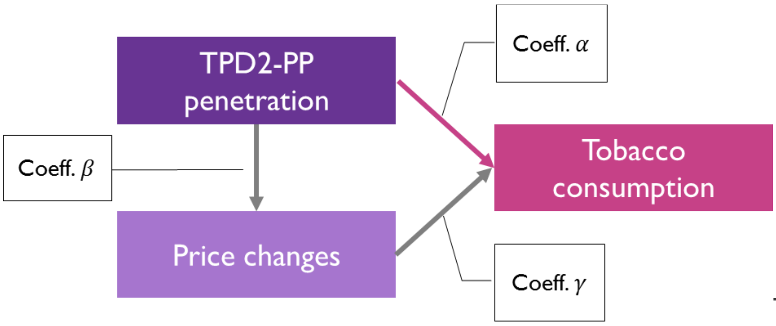
- A direct impact of TPD2+PP on consumption (through the consumption equation)
- An indirect impact of TPD2+PP on consumptions that feeds through the price channel, i.e. TPD2+PP has an impact on prices (through the price equation), and prices in turns affect consumptions (through the consumption equation).

Since a moving average (MA) cannot be estimated within a simultaneous equation framework, the selection of an appropriate ARMA process for the two equations has been restricted to include only autoregressive components.

A stylised representation of our modelling approach is presented in the figure below.

[12] The price coefficients of these models imply an own-price elasticities of around -0.21 (for the UK) and -0.32 (for France). These values are consistent with empirical literature findings that the demand for cigarettes is relatively inelastic.

Figure 3.3: Simultaneous equations approach to time series estimation of impacts on consumption



The coefficients α, β and γ are, respectively, the coefficient for the direct impact of TPD2+PP on consumption, the coefficient for the impact of TPD2+PP on prices, and the coefficient for the impact of prices on consumption. The following table, sets out the relevant conditions and calculation steps followed in order to calculate the aggregate TPD2+PP effect and to identify its constituent elements (i.e. direct and indirect, indirect only, direct only).

Table 3.6: Identifying and calculating the aggregate TPD2/PP penetration effect

Coefficient condition	Identification of aggregate effect of TPD2+PP penetration	Calculation of aggregate effect of TPD2+PP penetration
α, β, and γ are all statistically significant	Both direct and indirect effect	$\alpha + \beta \times \gamma$
β and γ are statistically significant	Only indirect effect	$\beta \times \gamma$
α *is* statistically significant	Only direct effect	α

Source: Europe Economics

The results of the simultaneous equation model are reported below (more details are provided in Section 6.3).

Table 3.7: Results of simultaneous equations time series model of impact of TPD2+PP on tobacco consumption in the UK and France

	Direct impact of TPD2+PP (α)	Indirect impact of TPD2+PP (β)	Price impact (γ)	Overall impact of TPD2+PP
UK	Positive*	Statistically insignificant	Negative***	Positive*
FR	Statistically insignificant	Statistically insignificant	Negative***	No impact

Note: * = "Significant at 90% confidence level"; ** = "Significant at 95% confidence level"; *** = "Significant at 99% confidence level".

As we can see from Table 3.7, the model estimates suggest that:

- **There is a statistically significant and positive (direct) impact of TPD2+PP on tobacco consumption in the UK**. The magnitude of the impact is in the order of a 0.2 per cent increase in the number of sticks consumed (see Table 6.25 for details). We can also see that the introduction of TPD2+PP products is associated with a statistically significant decrease in price, however, since β is not statistically significant (i.e. is not statistically distinguishable from zero), that means $\beta \times \gamma$ is not statistically distinguishable from zero.
- There is a statistically significant negative relationship between the price of tobacco products and smoking consumption in France (i.e. γ is statistically significant). But since β is not statistically significant (i.e. is not

statistically distinguishable from zero), that means $\beta \times \gamma$ is not statistically distinguishable from zero. **Thus there is no overall impact of TPD2+PP in France**.

4 Time-series smoking prevalence model for the UK

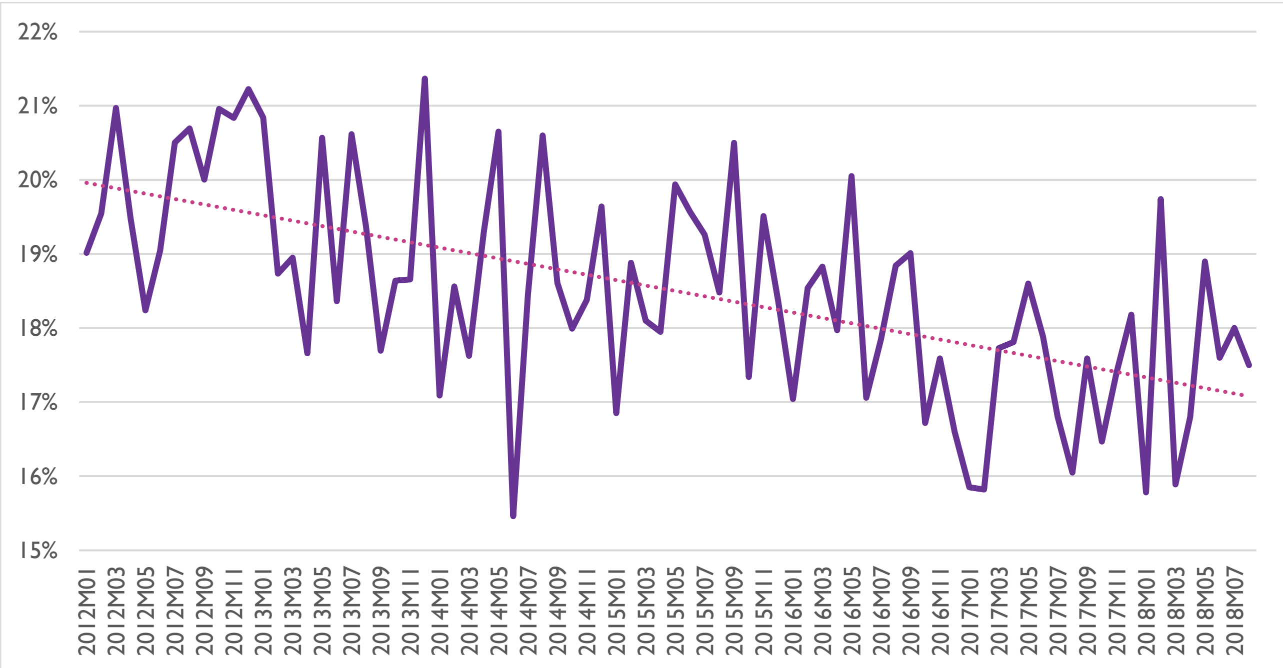
4.1 Introduction

We have publically available data with sufficient frequency to model prevalence impacts for the UK, but not for France. The data on smoking prevalence for England is reported on a monthly basis by the Smoking Toolkit Study (STS).[13] We use such data as a proxy for smoking prevalence in the UK as a whole. In this section we first provide an overview of monthly smoking prevalence in England, and we then then present the results of our statistical analysis. Like for the analysis on tobacco consumption, we first conduct a simple trend analysis and we then employ more sophisticated models.

4.2 Smoking prevalence England

As we can see from Figure 4.1smoking prevalence in England has decreased steadily since 2012. Moreover, the rate of decline in prevalence appears to follow a linear trend.

Figure 4.1: Smoking prevalence in England



4.3 Simple trend model

A simple trend model confirms the visual patterns observed in Figure 4.1, i.e. the evolution of smoking prevalence can be described – in statistically significant terms – as following a declining linear trend. We have

[13] See http://www.smokinginengland.info/latest-statistics/

then conducted number of tests to determine whether the series has a break (in levels, in trend, or both) in May 2016, but none of the tests suggests the presence of a statistically significant break.

4.4 More sophisticated tests

We present below the results of the pure-time series analysis and those of a simultaneous equation model

4.4.1 Time-series models

In our time-series analysis we explain model monthly changes in prevalence with monthly percentage changes in *prices* and the *penetration of TPD2+PP products* in the market. Seasonal patterns in smoking prevalence are much less marked than those observed for smoking consumption. As a result, the time-series model that our algorithm indicates should be preferred does not include monthly dummies.[14]

The results of the pure-time series analysis are reported below and indicate that there is no statistically significant association between prevalence and the introduction of TPD2 and PP requirements.

Table 4.1: Pure time-series model of smoking prevalence in the UK

	Coeff.	Std. Error	P-value
% Change in the average price of tobacco products	0.562285	0.239172	0.0220
Penetration of TPD-PP products in the market	0.001342	0.001362	0.3283
C	-0.002433	0.000986	0.0164
AR(1)	-0.788151	0.120529	0.0000
AR(2)	-0.413365	0.100689	0.0001
AR(12)	0.180347	0.112078	0.1128

4.4.2 Simultaneous equation model

The simultaneous equation model we present here is similar to that presented in Section 3.4.2, and attempts to identify two separate impacts:

- A direct impact of TPD2+PP on smoking prevalence;
- An indirect impact of TPD2+PP on smoking prevalence.

The results are reported below and suggest that there is a statically significant association between the introduction of TPD2+PP products and the price of tobacco. However, since there is no statistically significant association between prices and smoking prevalence, the overall impact of TPD2+PP requirements on smoking prevalence in the UK is not statistically significant.

[14] We have also run models with monthly dummy variables but such models underperformed (in terms of BIC statistics output) the model without seasonal dummies that we present here. We also explored whether adding various indicators of vaping to our models had an effect but found that vaping proved not to be significant in any meaningful models.

Table 4.2: Results of simultaneous equations time series model of impact of TPD2 and PP on smoking prevalence in the UK

	Direct impact of TPD2+PP (α)	Indirect impact of TPD2+PP (β)	Price impact (γ)	Overall impact of TPD2+PP
UK	Statistically insignificant	Negative***	Statistically insignificant	No impact

Note: * = "Significant at 90% confidence level"; ** = "Significant at 95% confidence level"; *** = "Significant at 99% confidence level".

5 Conclusion

In this report we have considered the impacts of TPD2 and plain packs requirements, introduced in the UK and France between 2016 and 2017, upon tobacco consumption and prevalence, in three types of models: simple linear trend models, time series models and simultaneous equations models. We have found:

- No statistically significant impacts on prevalence in the UK in any of the models used.
- No statistically significant impacts on consumption in France in any of the models used.
- No statistically significant impact on consumption in the UK in our preferred time-series model, but a statistically significant and positive association between TPD2+PP and consumption in the simultaneous equation model.

We note that the analysis is limited in time and that the results are for the combined impact of TPD2 and plain packs rather than their individual impacts. It might be possible to attempt to disentangle the impacts of plain packs and TPD2 by using models that deployed other countries that introduced TPD2 but not plain pack requirements as controls, to explore the possibility that there was a statistically significant impact in one direction from TPD2 (e.g. a reduction in consumption) but an offsetting statistically significant impact in the opposite direction from plain packs requirements.

It is also possible that with additional time, the dynamic in the market might change and become more pronounced. We note, however, that at the time of the impact assessment accompanying TPD2 it was anticipated that there would be an impact by this point. In the UK government's TPD2 impact assessment of 2015 provides estimates of projected prevalence levels and projected reductions associated with TPD2. These were for a reduction of 1.9 per cent in both smoking prevalence and smoking consumption over 5 years, applied linearly implying a reduction of 0.38 per cent in the 1st year, equivalent to 0.08 percentage points reduction in prevalence in the first year (2016) if prevalence would have been 19.7 per cent.[15]

Furthermore, in the impact assessment on plain packaging it estimated the extent to which smoking prevalence would fall as a consequence of standardised packaging.[16] That suggested that in 2016 prevalence would be 0.37 percentage points lower as a consequence of standardised packaging, and in 2017 prevalence would be 0.74 percentage points lower as a consequence of standardised packaging.

No such impact is yet identifiable in the data.

[15] See paragraphs 73-74 of Tobacco Products Directive (TPD) IA No: 3131, 29/06/2015, https://www.bma.org.uk/-/media/files/pdfs/working%20for%20change/policy%20and%20lobbying/uk%20consultations/po-tobacco-products-directive-impact-assesment-2015-09-01.pdf

[16] See Table 2 p45 of https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/403493/Impact_assessment.pdf

6 Appendix

This section provides a more formal details on the statistical models employed. We also provide the results for a number of alternative models we have used as a cross-check.

6.1 Simple trend models for tobacco consumption (FR and UK) and smoking prevalence (UK).

6.1.1 Consumption

The estimation results of a simple trend model without break for tobacco consumption in France and the UK are provided respectively in Table 6.1 and Table 6.2. The result indicate that tobacco consumption in France does not appear to follow a trend, whilst in the UK it follows a negative trend.

Table 6.1: Trend model of tobacco consumption for France

Dependent Variable: **Number of sticks (FR)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.33E+09	2.85E+08	18.68786	0.0000
Trend	-3766245.	3185654.	-1.182252	0.2407

R-squared	0.017604	Mean dependent var	5.00E+09
Adjusted R-squared	0.005009	S.D. dependent var	6.60E+08

Table 6.2: Trend model of tobacco consumption for the UK

Dependent Variable: **Number of sticks (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.23E+09	97725990	53.52556	0.0000
Trend	-13603314	1091553.	-12.46235	0.0000

R-squared	0.665681	Mean dependent var	4.05E+09
Adjusted R-squared	0.661395	S.D. dependent var	3.87E+08

We report below the results of the trend models in which three types of breaks are introduced (namely a break in the level, a break in the trend, and a break in the level and the trend). The only break tests to be statistically significant (at the 99 or 95 per cent confidence level) are the break and in the level and the break in the trend for the UK.

Table 6.3: Trend model of tobacco consumption for the UK (break in level)

Dependent Variable: **Number of sticks (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.50E+09	1.39E+08	39.71998	0.0000
Trend	-17726307	1865292.	-9.503236	0.0000
Dummy	2.42E+08	90307016	2.675350	0.0091

R-squared	0.694115	Mean dependent var	4.05E+09
Adjusted R-squared	0.686169	S.D. dependent var	3.87E+08

Table 6.4: Trend model of tobacco consumption for the UK (break in trend)

Dependent Variable: **Number of sticks (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.55E+09	1.42E+08	38.99061	0.0000
Trend	-18409010	1925269.	-9.561787	0.0000
Dummy*Trend	2448565.	825273.8	2.966973	0.0040

R-squared	0.699980	Mean dependent var	4.05E+09
Adjusted R-squared	0.692188	S.D. dependent var	3.87E+08

Table 6.5: Trend model of tobacco consumption for the UK (break in level and trend)

Dependent Variable: **Number of sticks (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.61E+09	1.46E+08	38.44944	0.0000
Trend	-19147176	1969282.	-9.722922	0.0000
Dummy	-8.86E+08	5.81E+08	-1.525340	0.1313
Dummy*Trend	10530141	5361027.	1.964202	0.0532

R-squared	0.708892	Mean dependent var	4.05E+09
Adjusted R-squared	0.697401	S.D. dependent var	3.87E+08

Table 6.6: Trend model of tobacco consumption for France (break in level)

Dependent Variable: **Number of sticks (FR)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.48E+09	4.22E+08	12.98549	0.0000
Trend	-6049631.	5682450.	-1.064617	0.2904
Dummy	1.34E+08	2.75E+08	0.486361	0.6281

R-squared	0.020613	Mean dependent var	5.00E+09
Adjusted R-squared	-0.004826	S.D. dependent var	6.60E+08

Table 6.7: Trend model of tobacco consumption for France (break in trend)

Dependent Variable: **Number of sticks (FR)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.45E+09	4.38E+08	12.43207	0.0000
Trend	-5534320.	5926477.	-0.933830	0.3533
Dummy*Trend	900857.6	2540407.	0.354612	0.7239

R-squared	0.019206	Mean dependent var	5.00E+09
Adjusted R-squared	-0.006269	S.D. dependent var	6.60E+08

Table 6.8: Trend model of tobacco consumption for France (break in level and trend)

Dependent Variable: **Number of sticks (FR)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.35E+09	4.53E+08	11.79498	0.0000
Trend	-4199949.	6122451.	-0.685991	0.4948
Dummy	1.60E+09	1.81E+09	0.886895	0.3779
Dummy*Trend	-13708097	16667304	-0.822454	0.4134

R-squared	0.029253	Mean dependent var	5.00E+09
Adjusted R-squared	-0.009066	S.D. dependent var	6.60E+08

6.1.2 Prevalence

We provide here the same trend model and break test for UK smoking prevalence. The models show that smoking prevalence can be described as following a declining trend without any statistically significant breaks.

Table 6.9: Trend model of smoking prevalence (UK)

Dependent Variable: **Smoking prevalence (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	21.67302	0.516601	41.95315	0.0000
Trend	-0.036458	0.005770	-6.318260	0.0000
R-squared	0.338537	Mean dependent var		18.51944
Adjusted R-squared	0.330057	S.D. dependent var		1.456065

Table 6.10: Trend model of smoking prevalence (UK, break in level)

Dependent Variable: **Smoking prevalence (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	21.30587	0.763524	27.90463	0.0000
Trend	-0.030894	0.010280	-3.005286	0.0036
Dummy	-0.326027	0.497692	-0.655077	0.5144
R-squared	0.342203	Mean dependent var		18.51944
Adjusted R-squared	0.325117	S.D. dependent var		1.456065

Table 6.11: Trend model of smoking prevalence (UK, break in trend)

Dependent Variable: **Smoking prevalence (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	21.33312	0.792661	26.91331	0.0000
Trend	-0.031342	0.010721	-2.923369	0.0045
Dummy*trend	-0.002607	0.004596	-0.567208	0.5722
R-squared	0.341289	Mean dependent var		18.51944
Adjusted R-squared	0.324180	S.D. dependent var		1.456065

Table 6.12: Trend model of smoking prevalence (UK, break in level and trend)

Dependent Variable: **Smoking prevalence (UK)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	21.45976	0.822199	26.10044	0.0000
Trend	-0.033016	0.011105	-2.973060	0.0039
Dummy	-2.010894	3.276319	-0.613766	0.5412
Dummy*trend	0.015731	0.030232	0.520353	0.6043
R-squared	0.344538	Mean dependent var		18.51944
Adjusted R-squared	0.318665	S.D. dependent var		1.456065

6.2 Pure time-series models for tobacco consumption (FR and UK) and smoking prevalence (UK).

In Sections 6.2.1 and 6.2.2 we present the detailed results of our benchmark time-series models for tobacco consumption and smoking prevalence. In Section 6.2.3 we present the result we obtain with an alternative modelling approach.

6.2.1 Benchmark models for Consumption

In the table we provide the estimation results of the pure-time series models where the dependent variable is expressed in terms of percentage monthly change in consumption, and where seasonal dummy variables are included directly as regressors (these are the models we presented in Table 3.4 and Table 3.5).

Table 6.13: Pure time series-model of tobacco consumption (UK)

Dependent Variable: **%Change in number of sticks (UK)**
Method: Least Squares
Sample (adjusted): 2012M05 2018M08
Included observations: 76 after adjustments
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Jan dummy	-0.142489	0.009048	-15.74734	0.0000
Feb dummy	-0.009157	0.007084	-1.292645	0.2012
Mar dummy	0.095966	0.007958	12.05831	0.0000
Apr dummy	-0.064455	0.007967	-8.089936	0.0000
May dummy	0.104659	0.007661	13.66098	0.0000
Jun dummy	-0.041720	0.004543	-9.182356	0.0000
Jul dummy	0.022461	0.007684	2.923108	0.0049
Aug dummy	-0.000309	0.008395	-0.036776	0.9708
Sep dummy	-0.045053	0.007113	-6.333482	0.0000
Oct dummy	-0.048005	0.003477	-13.80623	0.0000
Nov dummy	0.012409	0.003259	3.808129	0.0003
Dec dummy	0.076881	0.010065	7.638625	0.0000
% change in price	0.613745	0.473779	1.295423	0.2002
TPD2+PP penetration	**0.002827**	**0.003044**	**0.928886**	**0.3567**
AR(1)	-0.461341	0.116211	-3.969848	0.0002
AR(2)	-0.022110	0.105778	-0.209022	0.8352
AR(3)	0.127886	0.102316	1.249911	0.2163

R-squared	0.962656	Mean dependent var	0.000615
Adjusted R-squared	0.952529	S.D. dependent var	0.071853
S.E. of regression	0.015655	Akaike info criterion	-5.281850
Sum squared resid	0.014460	Schwarz criterion	-4.760502
Log likelihood	217.7103	Hannan-Quinn criter.	-5.073494
Durbin-Watson stat	2.066227	Wald F-statistic	241.3010
Prob(Wald F-statistic)	0.000000		

Table 6.14: Pure time series-model of tobacco consumption (FR)

Dependent Variable: **%Change in number of sticks (FR)**
Method: Least Squares
Sample (adjusted): 2012M02 2018M08
Included observations: 79 after adjustments
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Jan dummy	-0.217886	0.006078	-35.84946	0.0000
Feb dummy	0.035649	0.009526	3.742303	0.0004
Mar dummy	0.258720	0.012876	20.09388	0.0000
Apr dummy	-0.185902	0.008693	-21.38510	0.0000
May dummy	0.022038	0.007871	2.799905	0.0068
Jun dummy	0.307335	0.007922	38.79365	0.0000
Jul dummy	-0.237398	0.006334	-37.47873	0.0000
Aug dummy	-0.062801	0.010931	-5.745013	0.0000
Sep dummy	0.313995	0.018297	17.16084	0.0000
Oct dummy	-0.220386	0.009148	-24.09070	0.0000
Nov dummy	-0.020686	0.007284	-2.839873	0.0060
Dec dummy	0.266267	0.005327	49.98834	0.0000
% Change in price	-0.372984	0.184427	-2.022388	0.0473
TPD2+PP penetration	**-0.001445**	**0.002932**	**-0.492708**	**0.6239**
MA(1)	-0.626522	0.091738	-6.829488	0.0000

R-squared	0.991324	Mean dependent var	0.019288
Adjusted R-squared	0.989427	S.D. dependent var	0.209687
S.E. of regression	0.021561	Akaike info criterion	-4.666636
Sum squared resid	0.029753	Schwarz criterion	-4.216741
Log likelihood	199.3321	Hannan-Quinn criter.	-4.486394
Durbin-Watson stat	1.918689	Wald F-statistic	1082.610
Prob(Wald F-statistic)	0.000000		

6.2.2 Benchmark model for Prevalence

In the table we provide the estimation results of the pure-time series models where the dependent variable is expressed in terms of monthly change in prevalence (this is the model we presented in Table 4.1).

Table 6.15: Pure time series-model of smoking prevalence (UK)

Dependent Variable: **Changes in prevalence (UK)**
Method: Least Squares
Sample (adjusted): 2013M02 2018M08
Included observations: 67 after adjustments
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price	0.562285	0.239172	2.350965	0.0220
TPD2+PP penetration	**0.001342**	**0.001362**	**0.985472**	**0.3283**
C	-0.002433	0.000986	-2.467775	0.0164
AR(1)	-0.788151	0.120529	-6.539106	0.0000
AR(2)	-0.413365	0.100689	-4.105352	0.0001
AR(12)	0.180347	0.112078	1.609128	0.1128

R-squared	0.486396	Mean dependent var	-0.000498
Adjusted R-squared	0.444297	S.D. dependent var	0.018649
S.E. of regression	0.013902	Akaike info criterion	-5.628323
Sum squared resid	0.011789	Schwarz criterion	-5.430888
Log likelihood	194.5488	Hannan-Quinn criter.	-5.550198
F-statistic	11.55369	Durbin-Watson stat	2.170663
Prob(F-statistic)	0.000000	Wald F-statistic	3.059924
Prob(Wald F-statistic)	0.054151		

6.2.3 Alternative modelling approaches

The time-series modelling approach used to produce the results set out in Sections 6.2.1 and 6.2.2 relies on expressing the dependent variable (tobacco consumption and prevalence) in terms of percentage change. This transformation ensures that dependent variables are stationary and can therefore be modelled meaningfully. We then control for seasonal patterns in the data with the use of dummy variables. It is however important to stress that models in which the dependent variable are expressed in differences (or, in our case, in percentage differences) are less likely to find a statistically significant relationship between variables than models expressed in levels. In other words, if we find a statistically significant relationship in a model in difference we can be fairly confident that such a relationship has not simply been created from the way that we constructed the tests. However, when no such relationship is statistically significant in differences, there could still be a chance that such a relationship exists in levels — though we would need to be very careful in claiming we had discovered it, given the risk of spurious discovery.

To make doubly sure that our key findings in this report are correct, we have therefore analysed a number of alternative models where the dependent variables are expressed in levels, as opposed to percentage changes, but with other required adjustments to ensure the dependent variable is stationary and thus reduce the risk of spurious correlations.

Specifically, in many cases we find that the dependent variables are trend-stationary, i.e. the variables themselves are non-stationary because they follow a linear trend, but their fluctuations around the trend are stationary. Furthermore, since deviations from the trend have a seasonal component, we can de-seasonalise them with the use dummy variables. Therefore, after being de-trended and de-seasonalised, the variables can be analysed in a meaningful way.

One advantage of this approach is that it reduce the risk of what is called “over-differencing”. Most time series models (and in particular the form of time series models we use here) work best when they have been rendered “stationary”, i.e. normalised such that the mean, variance, autocorrelation, etc. of the normalised series are all constant over time. In a number of time series setting, differencing (i.e. considering changes in rather than the levels of variables) is a useful and common technique to render an otherwise "non-stationary" series stationary. However, as noted above there is some risk that in the process of differencing we erase the correlation between variables that the time series model is seeking to identify (i.e. we "over-difference"). The alternative approach we set out here, where instead of differencing we use levels adjusted for trends and seasonal patterns, checks for the sorts of correlations that over-differencing might have erased.

A disadvantage of this approach is that this approach is more complex and requires more judgement to execute (e.g. in determining which approach to take to detrending or seasonalising). Furthermore, our approach in the main body is slightly more demanding of the data than the alternative set out here, and thus is appropriate in testing the robustness of a perhaps-counterintuitive or at least unintended result such as that in our simple trend model — namely that TPD2+PP is associated with higher consumption. If, on the other hand, our simple trend model had identified that TPD2+PP was associated with a reduction in consumption, there might have been more of a case for considering our alternative approach as an intermediate step — i.e. we would shift from simple model to normalised levels model to differenced model and see how robust that correlation was to more and more demanding tests.

More specifically, we have carried out the following variable transformations:

- We have de-trended and de-seasonalised the number of sticks in the UK and smoking prevalence in the UK (the variables have been de-trended because the models presented above suggest that these variables follow a linear trend)
- We have de-seasonalised the number of sticks in France (the variable has not been de-trended because the analysis presented above suggests that there is no statistically significant trend)

The dependent variables after such adjustments are reported in the figures below.

Figure 6.1: Number of sticks (millions) de-trended and seasonally adjusted (France and UK)

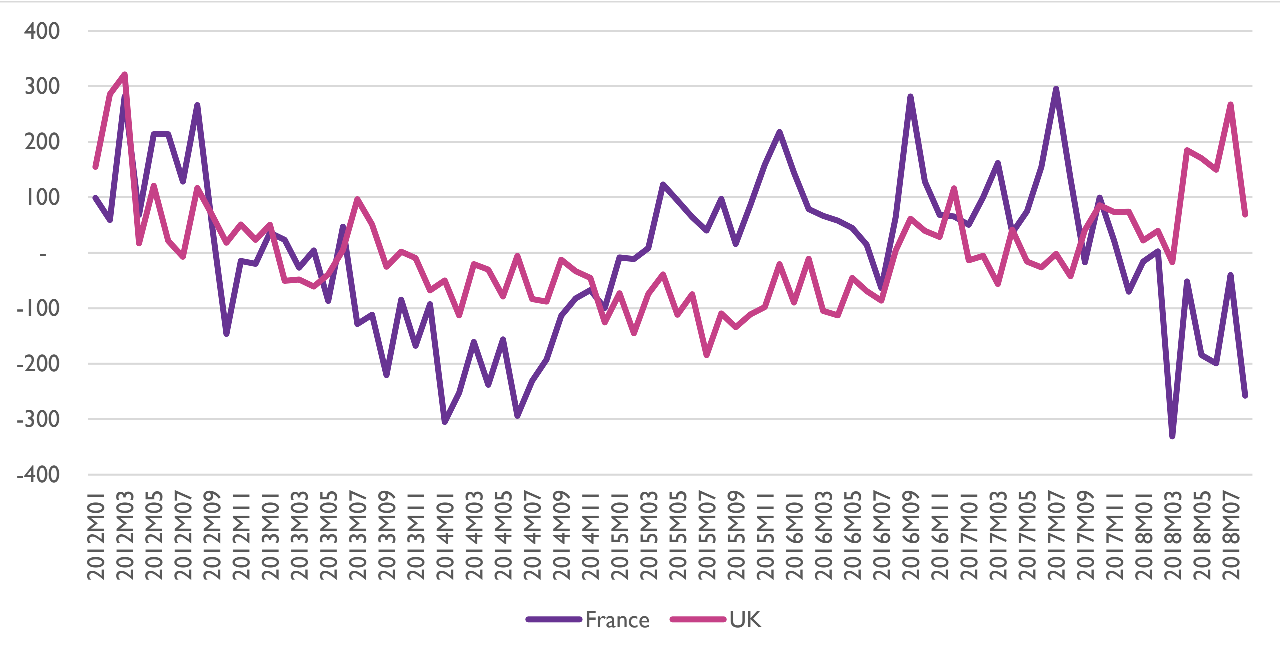
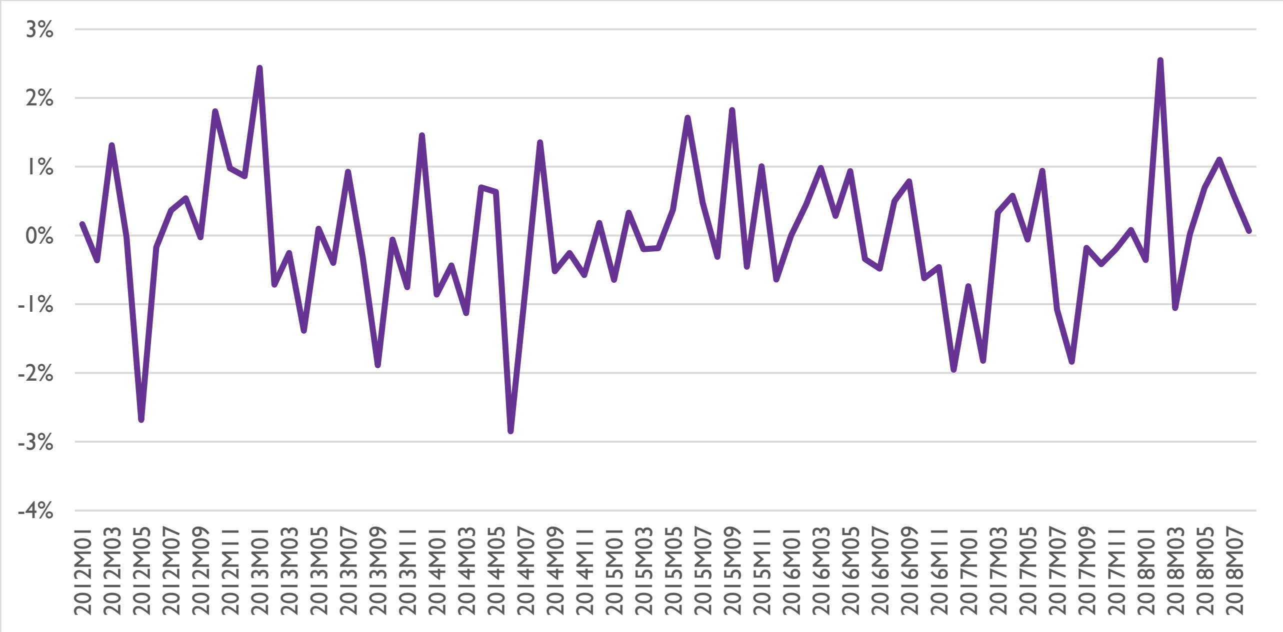


Figure 6.2: Smoking prevalence de-trended and seasonally adjusted (UK)



In order to be able to model the series of Figure 6.1 and Figure 6.2 the underlying series need to be stationary. We have conducted two widely used methods — the Augmented Dickey-Fuller (ADF) test, and the Phillips-Perron (PP) test — in order to test for the stationarity of the de-seasonalised and de-trended series. The results of these tests are reported below.

Table 6.16: Stationarity tests of de-seasonalised & de-trended tobacco consumption for the UK

		t-Statistics	P-value
Augmented Dickey-Fuller test statistic		**-3.220298**	**0.0225**
Test critical values:	*1% level*	-3.516676	
	5% level	-2.899115	
	10% level	-2.586866	
Phillips-Perron test statistic		**-3.815375**	**0.0041**
Test critical values:	*1% level*	-3.515536	
	5% level	-2.898623	
	10% level	-2.586605	

Table 6.17: Stationarity test of de-seasonalised & de-trended tobacco consumption in France

		t-Statistics	P-value
Augmented Dickey-Fuller test statistic		**-2.470617**	**0.1266**
Test critical values:	*1% level*	-3.517847	
	5% level	-2.899619	
	10% level	-2.587134	
Phillips-Perron test statistic		**-3.410822**	**0.0135**
Test critical values:	*1% level*	-3.516676	
	5% level	-2.899115	
	10% level	-2.586866	

Table 6.18: Stationarity test of de-seasonalised & de-trended smoking prevalence in England

		t-Statistics	P-value
Augmented Dickey-Fuller test statistic		**-8.559670**	**0.0000**
Test critical values:	*1% level*	*-3.515536*	
	5% level	*-2.898623*	
	10% level	*-2.586605*	
Phillips-Perron test statistic		**-8.559670**	**0.0000**
Test critical values:	*1% level*	*-3.515536*	
	5% level	*-2.898623*	
	10% level	*-2.586605*	

Both the ADF and PP tests confirm that, after de-trending and seasonal adjustments, the tobacco consumption series for the UK and the smoking prevalence series are stationary. For tobacco consumption in France the results are less conclusive. The PP test suggests that the de-seasonalised and de-trended series is stationary (at the 95 per cent confidence leave), but the ADF test fails to reject the hypothesis of non-stationarity at the 90 per cent confidence level (the non-stationary hypothesis can only be rejected at the 87 per cent confidence level). In what follows we will treat the de-trended and seasonally adjusted series of tobacco consumption in France as stationary.

The table below provides the estimation results of the best time-series model for the de-trended and seasonally adjusted consumption series for the UK. In Figure 6.3 we compare the actual de-trended and seasonally adjusted consumption series with the one predicted by the model in Table 6.19. Because in this alternative estimation approach the dependent variable is expressed in levels (after de-trending seasonal adjustments), the price variable is also expressed in (log-transformed) levels.

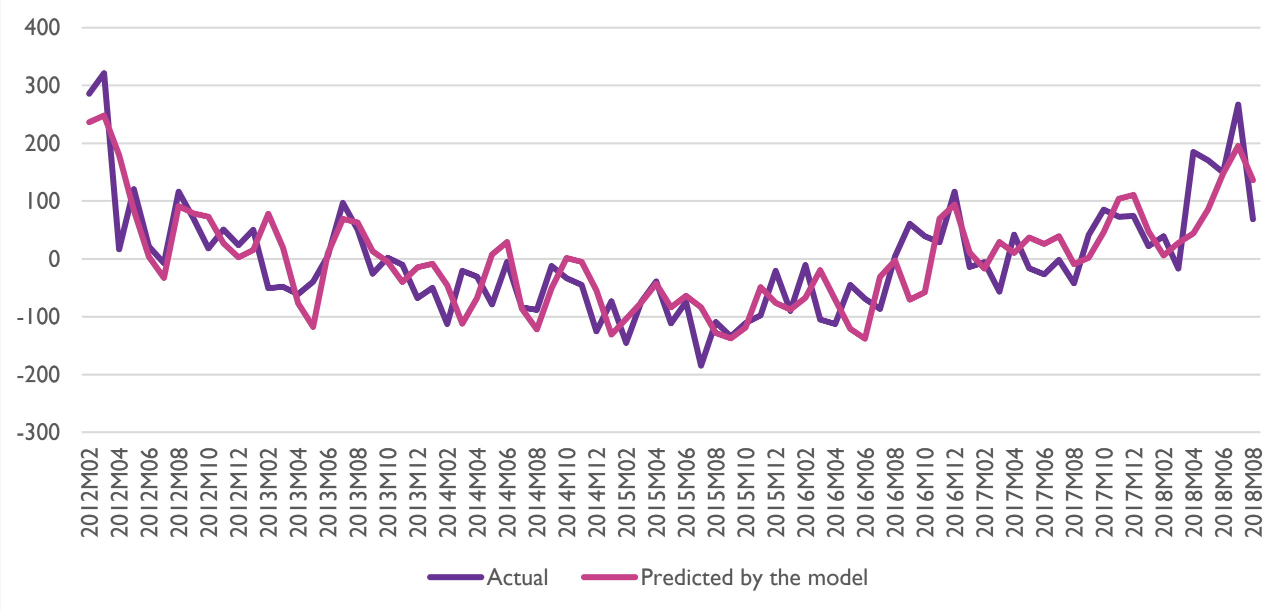
Table 6.19: Best pure time-series model of tobacco consumption (de-seasonalised & de-trended) for the UK

Dependent Variable: **No. of sticks (de-trended and seasonally adjusted)**
Method: Least Squares
Sample: 2012M02 2018M08
Included observations: 79
Convergence achieved after 14 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log-price	-8.47E+08	3.57E+08	-2.370789	0.0204
TPD2+PP penetration	**1.68E+08**	**51915500**	**3.227939**	**0.0019**
Constant	1.49E+09	6.39E+08	2.338472	0.0221
MA(1)	0.383881	0.066574	5.766234	0.0000
MA(2)	0.728874	0.044761	16.28371	0.0000
MA(3)	0.690663	0.065231	10.58788	0.0000

R-squared	0.643048	Mean dependent var	-1955718.
Adjusted R-squared	0.618599	S.D. dependent var	94988303
S.E. of regression	58662543	Akaike info criterion	38.68541
Sum squared resid	2.51E+17	Schwarz criterion	38.86537
Log likelihood	-1522.074	Hannan-Quinn criter.	38.75751
F-statistic	26.30186	Durbin-Watson stat	2.042398
Prob(F-statistic)	0.000000	Wald F-statistic	5.587345
Prob(Wald F-statistic)	0.005523		

Figure 6.3: Number of sticks (millions) sold in the UK, de-seasonalised and de-trended (actual and predicted by the model)



The pure time-series model indicates a positive impact of TPD2+PP on tobacco consumptions. The interpretation is that, full penetration of TPD2+PP products is associated with 168,000,000 extra sticks consumed. Since the average number of sticks consumed annually (since May 2016) is, 45,130 millions, this is an increase of around 0.4 per cent (on an annual basis).

The best pure time-series model for the de-trended and seasonally adjusted tobacco consumption series in France is provided in below. A comparisons between the actual series in the model-predicted series in provided in Figure 6.4.

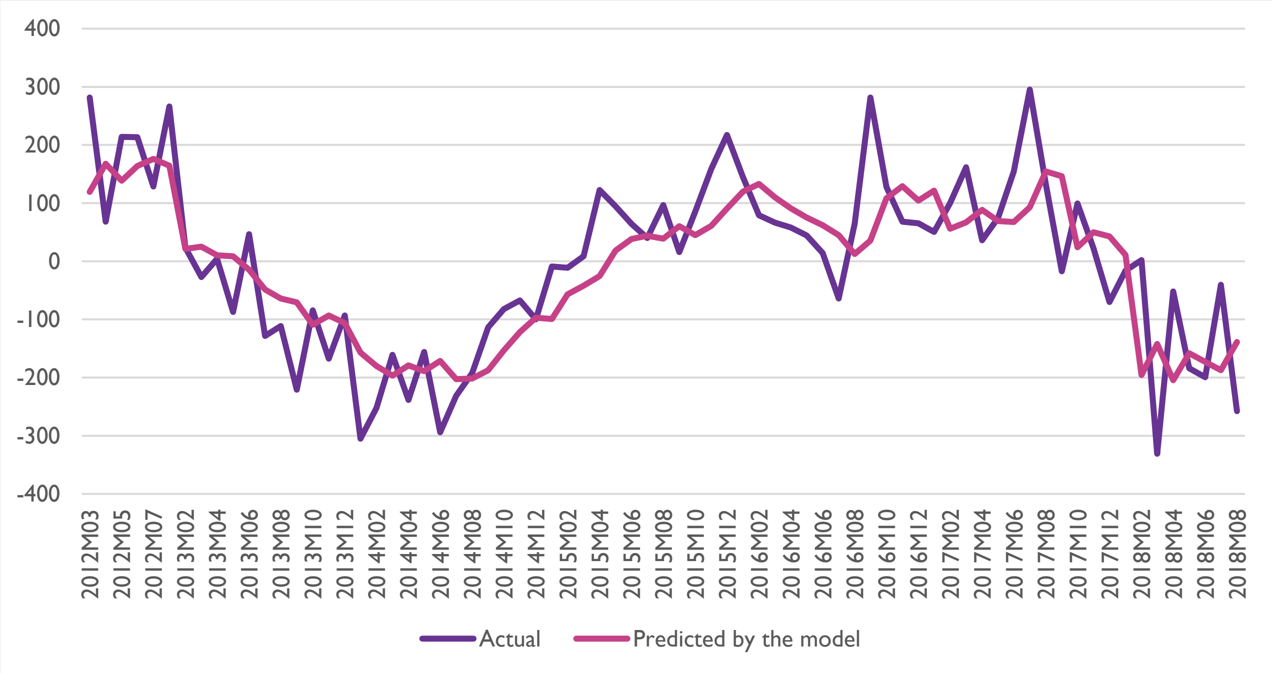
Table 6.20: Best pure time-series model of tobacco consumption (de-seasonalised & de-trended) in France

Dependent Variable: : **No. of sticks (de-trended and seasonally adjusted)**
Method: Least Squares
Sample: 2012M02 2018M08
Included observations: 79
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log-price	-1.58E+09	5.49E+08	-2.887262	0.0051
TPD2+PP penetration	**39709341**	**69389980**	**0.572263**	**0.5689**
Constant	2.86E+09	1.05E+09	2.711192	0.0083
AR(1)	0.963148	0.052568	18.32195	0.0000
MA(1)	-0.668637	0.127894	-5.228061	0.0000

R-squared	0.591624	Mean dependent var	-1250000.
Adjusted R-squared	0.569549	S.D. dependent var	1.44E+08
S.E. of regression	94366036	Akaike info criterion	39.62446
Sum squared resid	6.59E+17	Schwarz criterion	39.77443
Log likelihood	-1560.166	Hannan-Quinn criter.	39.68454
F-statistic	26.80135	Durbin-Watson stat	2.088202
Prob(F-statistic)	0.000000	Wald F-statistic	4.307278
Prob(Wald F-statistic)	0.017001		

Figure 6.4: Number of sticks (millions) sold in France, de-seasonalised and de-trended (actual and predicted by the model)



The pure time-series model indicates that the penetration of TPD2+PP products in France is not statistically associated any change in consumption.

An advantage of the models of Table 6.19 and Table 6.20 relative to those in Table 3.4 and Table 3.5 is that in in both these alternative models the price variable is statistically significant and has a negative relationship with consumption. The interpretation of the price coefficients of Table 6.19 and Table 6.20 is that a 1 per cent increase in the average price of tobacco products lead to a reduction of 8.47 million sticks in the UK and 15.8 million sticks in France[17]. Since the average number of sticks consumed per month in the UK and France are respectively 4,050 million and 5,010 million, the log-price coefficients of these alternative models imply an own-price elasticities of around -0.21 (for the UK) and -0.32 (for France). These values are consistent with empirical literature findings that the demand for cigarettes is relatively inelastic.

We finish by providing the estimation results for the de-trended and de-seasonalised smoking prevalence series. As

Table 6.21 indicates, the best time series model does not include any AR or MA terms and moreover, neither the price variable nor the TPD2+PP penetration variables are statistically significant. This implies that the evolution of smoking prevalence in England can be fully explained by a linear trend and seasonal patterns.

[17] In a model where the dependent variable (in this case number of sticks) is in level, and one of the repressor (in this case price) is in log-format, the interpretation of the coefficient for the variable expressed in log-format is that a 1 per cent increase in that variable lead to an increase in the dependent variable equal to the coefficient divided by 100.

Table 6.21: Pure time-series model of smoking prevalence (de-seasonalised & de-trended) in England

Dependent Variable: **Prevalence (de-trended and seasonally adjusted)**
Method: Least Squares
Sample: 2012M02 2018M08
Included observations: 79
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log-price	0.003898	0.024043	0.162138	0.8716
TPD2+PP penetration	-0.000223	0.003193	-0.069934	0.9444
Constant	-0.007030	0.043355	-0.162145	0.8716

R-squared	0.000418	Mean dependent var	-2.07E-05
Adjusted R-squared	-0.025887	S.D. dependent var	0.010199
S.E. of regression	0.010330	Akaike info criterion	-6.270222
Sum squared resid	0.008110	Schwarz criterion	-6.180243
Log likelihood	250.6738	Hannan-Quinn criter.	-6.234173
F-statistic	0.015895	Durbin-Watson stat	1.947539
Prob(F-statistic)	0.984234	Wald F-statistic	0.013637
Prob(Wald F-statistic)	0.986458		

6.3 Simultaneous equation models of tobacco consumption (FR and UK) and smoking prevalence (UK)

In Sections 6.3.1 we present the detailed results of our simultaneous-equation approach to estimate consumption in France and the UK, and in 6.3.2 we present the detailed results of our simultaneous-equation approach to estimate smoking prevalence.

6.3.1 Consumption

The simultaneous equation approach requires first estimating two separate equations, one for consumption (or prevalence), and one for prices. These two equations are then re-estimated simultaneously as a single system. In order to be estimated, simultaneous equations models should not contain MA terms, therefore we have selected the best time-series from a set of AR-processes (as opposed to ARMA-processes).

We start by providing the best consumption equation and price equation for the UK.

Table 6.22: Consumption equation (UK)

Dependent Variable: **No. sticks (de-trended and seasonally adjusted)**
Method: Least Squares
Sample (adjusted): 2012M04 2018M08
Included observations: 77 after adjustments
HAC standard errors & covariance

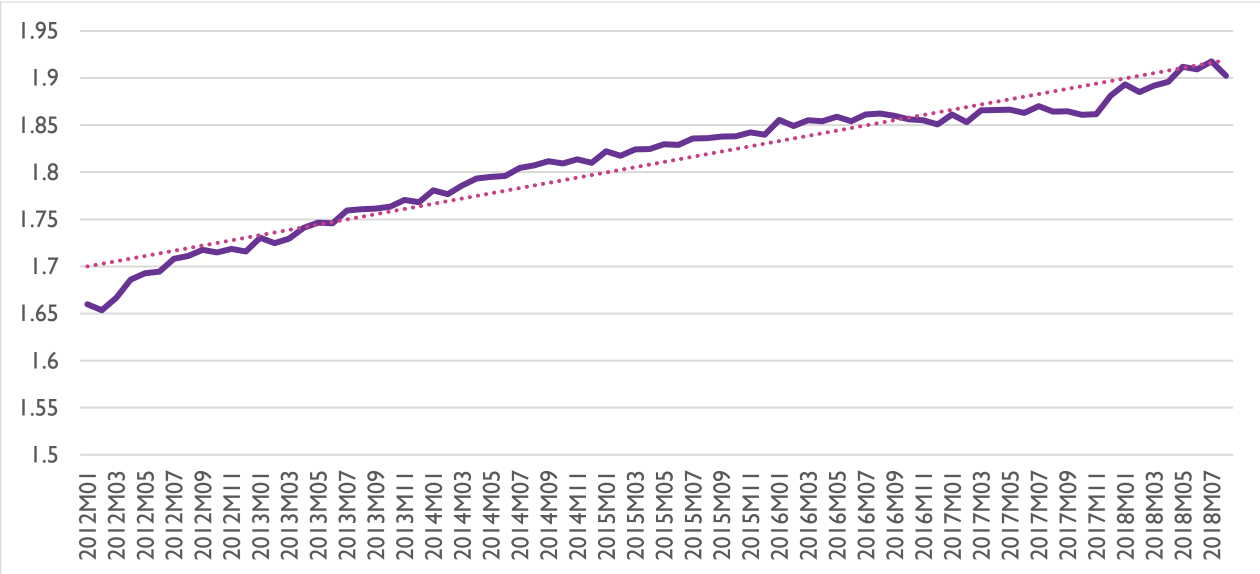
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log-price — C(1)	-5.06E+08	4.07E+08	-1.242796	0.2180
TPD2+PP penetration — C(2)	1.44E+08	51487697	2.793063	0.0067
Constant — C(3)	8.73E+08	7.30E+08	1.196796	0.2354
AR(1) — C(4)	0.262329	0.127667	2.054783	0.0436

AR(2) — C(5)	0.197113	0.084188	2.341351	0.0220
AR(3) — C(6)	0.019962	0.098683	0.202281	0.8403

R-squared	0.469023	Mean dependent var	-9889537.
Adjusted R-squared	0.431630	S.D. dependent var	82053172
S.E. of regression	61860156	Akaike info criterion	38.79337
Sum squared resid	2.72E+17	Schwarz criterion	38.97600
Log likelihood	-1487.545	Hannan-Quinn criter.	38.86642
F-statistic	12.54314	Durbin-Watson stat	1.715934
Prob(F-statistic)	0.000000	Wald F-statistic	3.910927
Prob(Wald F-statistic)	0.024475		

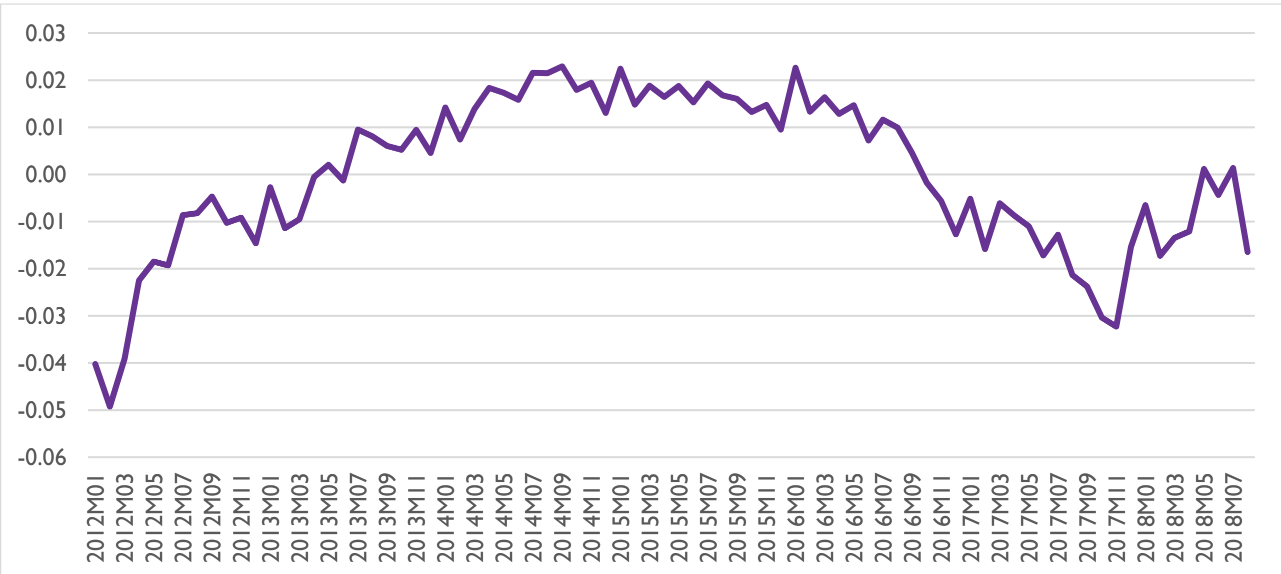
In order to estimate the price equations for the UK we have first applied a log-transformation to the average price of tobacco products in the UK. This is reported in Figure 6.5 below. As we can see the log-price appears to have increased linearly over most of the 2012-2018 period.

Figure 6.5: Log-price of tobacco products in the UK



The de-trended log-price series is reported below in Figure 6.6.

Figure 6.6: De-trended average log-price of tobacco product in the UK



The stationarity tests for the de-trended (log) price series are reported below. According to the ADF test the de-trended series is stationary (at the 95 percent confidence level), however according to the PP test we cannot reject the hypothesis of non-stationarity with a confidence of 90 per cent (the hypothesis of non-stationarity can be rejected only at the 88 per cent confidence level). In what follows we will treat the series as stationary. However, given that results of the two tests are not entirely conclusive, we also provide an alternative modelling approach (see Table 6.26) which would be the appropriate one to use in case of non-stationarity.

Table 6.23: Stationarity test of de-trended log-price of tobacco product in the UK

		t-Statistics	P-value
Augmented Dickey-Fuller test statistic		-3.015409	0.0378
Test critical values:	*1% level*	*-3.516676*	
	5% level	*-2.899115*	
	10% level	*-2.586866*	
Phillips-Perron test statistic		-2.507773	0.1175
Test critical values:	*1% level*	*-3.515536*	
	5% level	*-2.898623*	
	10% level	*-2.586605*	

The best time series model for the de-trended log-price series is reported below. As we can see the price equation suggests that there is a statistically significant association between the introduction of TPD2+PP products and a decrease in the price of tobacco products.

Table 6.24: Price equation (UK)

Dependent Variable: **Log-price (de-trended)**
Method: Least Squares
Sample (adjusted): 2012M03 2018M08
Included observations: 78 after adjustments
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TPD2+PP penetration — C(7)	-0.020549	0.006597	-3.114790	0.0026
Constant— C(8)	0.009847	0.003273	3.008218	0.0036
AR(1) — C(9)	0.491043	0.107792	4.555454	0.0000
AR(2) — C(10)	0.303426	0.112743	2.691307	0.0088

R-squared	0.854235	Mean dependent var	0.001147
Adjusted R-squared	0.848325	S.D. dependent var	0.015183
S.E. of regression	0.005913	Akaike info criterion	-7.373314
Sum squared resid	0.002588	Schwarz criterion	-7.252458
Log likelihood	291.5593	Hannan-Quinn criter.	-7.324933
F-statistic	144.5550	Durbin-Watson stat	1.927891
Prob(F-statistic)	0.000000	Wald F-statistic	9.701919
Prob(Wald F-statistic)	0.002619		

The consumption equation in Table 6.22 and the price equation in Table 6.24 are then estimated simultaneously, and the results of the simultaneous equation estimates are provided below (the coefficients of the systems are coded from C(1) to C(10)).

Table 6.25: Simultaneous equation model for tobacco consumption (UK)

Consumption system (UK)
Estimation Method: Iterative Least Squares
Sample: 2012M03 2018M08
Included observations: 80
Total system (unbalanced) observations 155

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	1.55E+08	4.84E+08	0.321295	0.7484
C(2)	**89679990**	**51018163**	**1.757805**	**0.0809**
C(3)	-3.22E+08	8.75E+08	-0.368157	0.7133
C(4)	0.249474	0.111819	2.231047	0.0272
C(5)	0.232501	0.118017	1.970055	0.0507
C(6)	0.094337	0.114252	0.825694	0.4103
C(7)	**-0.020549**	**0.006279**	**-3.272532**	**0.0013**
C(8)	0.009847	0.003926	2.508235	0.0132
C(9)	0.491043	0.108216	4.537639	0.0000
C(10)	0.303426	0.102509	2.959986	0.0036

From the estimation results of

Table 6.25 we can see that the direct impact of TPD2+PP penetration on tobacco consumption is statistically significant and positive (this this represented by coefficient C(2)). We also see that, whilst the penetration of TPD2+PP products is associated with a decrease in prices (coefficient C(7)), the price variable is no longer significantly associated with a change in consumption (coefficient (C(1)[18]) and, therefore, there is no indirect impact of TPD2+PP on consumption via the price channel. The coefficient C(2) suggests that full penetration of TPD2+PP products is associated with approximately 90 million extra sticks consumed. Since the average number of sticks consumed annually (since May 2016) is, 45,130 millions, this is an increase of around 0.2 per cent (on an annual basis).

Because the tests of Table 6.23 are not entirely conclusive on the stationarity of the de-trended log-price of tobacco, we have also run a simultaneous equations model where the price equation relates log-price only to TPD2+PP penetration and a constant. This alternative price equation is provided below.

Table 6.26: Alternative price equation (UK)

Dependent Variable: **Log-price (de-trended)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TPD2+PP penetration — C(7)	-0.019254	0.005156	-3.734497	0.0004
Constant — C(8)	0.004459	0.003813	1.169485	0.2458
R-squared	0.223756	Mean dependent var		5.93E-16

[18] In the system of

Table 6.25 the coefficient C(1) is the coefficient the log-price expressed as de-trended log price (which is the dependent variable of the price equation in Table 6.24, and is illustrated in Figure 6.6) plus the linear trend of the log price (the dotted line in Figure 6.5).

Adjusted R-squared	0.213804	S.D. dependent var	0.016649
S.E. of regression	0.014762	Akaike info criterion	-5.568847
Sum squared resid	0.016997	Schwarz criterion	-5.509297
Log likelihood	224.7539	Hannan-Quinn criter.	-5.544972
F-statistic	22.48384	Durbin-Watson stat	0.220305
Prob(F-statistic)	0.000009	Wald F-statistic	13.94646
Prob(Wald F-statistic)	0.000356		

The estimates of the simultaneous equation model with the alternative price equation of Table 6.26 are reported below and confirm the results of

Table 6.25.

Table 6.27: Alternative simultaneous equation model for tobacco consumption (UK)

Consumption system (UK)
Estimation Method: Iterative Least Squares
Sample: 2012M01 2018M08
Included observations: 80
Total system (unbalanced) observations 157

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	1.55E+08	4.84E+08	0.321302	0.7484
C(2)	**89679469**	**51018524**	**1.757783**	**0.0808**
C(3)	-3.22E+08	8.75E+08	-0.368163	0.7133
C(4)	0.249474	0.111819	2.231048	0.0272
C(5)	0.232501	0.118017	1.970059	0.0507
C(6)	0.094338	0.114252	0.825700	0.4103
C(7)	**-0.019254**	**0.004060**	**-4.741712**	**0.0000**
C(8)	0.004459	0.001900	2.347477	0.0202

We now report the estimation results for the simultaneous equation model of tobacco consumption in France. The best AR process to describe the number of sticks (de-trended and seasonally adjusted) consumed in France is provided in Table 6.28 below.

Table 6.28: Consumption equation (France)

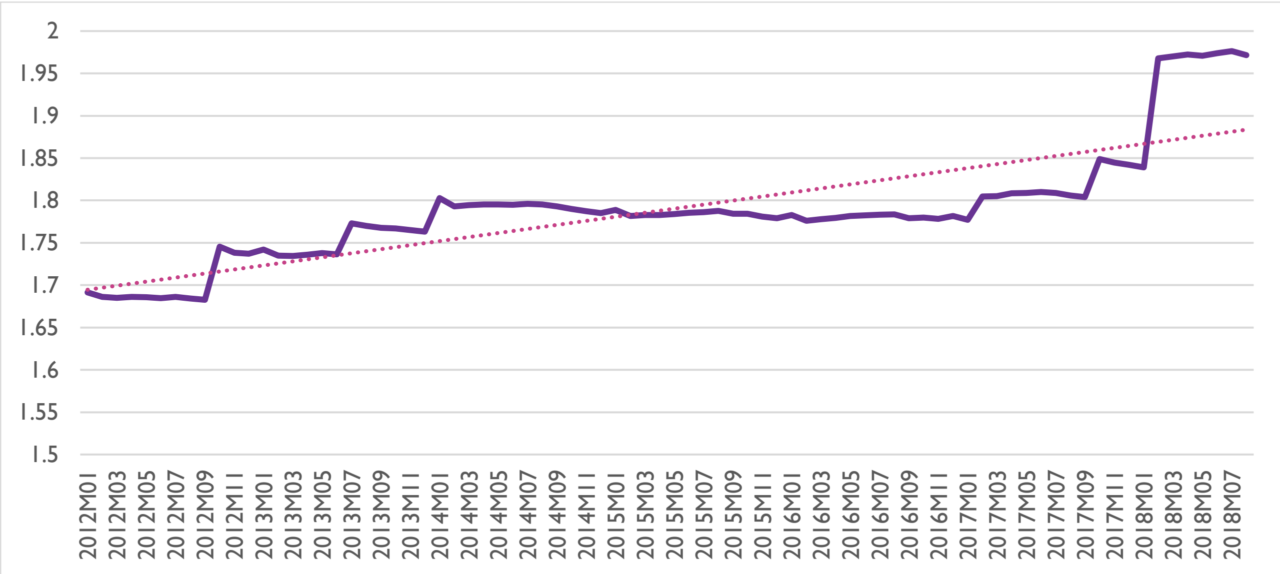
Dependent Variable: **No. sticks (de-trended and seasonally adjusted)**
Method: Least Squares
Sample (adjusted): 2012M04 2018M08
Included observations: 77 after adjustments
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log-price — C(1)	-1.61E+09	5.81E+08	-2.780209	0.0069
TPD2+PP penetration— C(2)	1.80E+08	1.17E+08	1.539698	0.1281
Constant — C(3)	2.84E+09	1.02E+09	2.771246	0.0071
AR(1) — C(4)	0.283979	0.137372	2.067228	0.0424
AR(2) — C(5)	0.238838	0.134793	1.771885	0.0807
AR(3) — C(6)	0.228661	0.089338	2.559520	0.0126

R-squared	0.577402	Mean dependent var	-5711967.
Adjusted R-squared	0.547641	S.D. dependent var	1.42E+08
S.E. of regression	95375056	Akaike info criterion	39.65925
Sum squared resid	6.46E+17	Schwarz criterion	39.84189
Log likelihood	-1520.881	Hannan-Quinn criter.	39.73230
F-statistic	19.40164	Durbin-Watson stat	1.934283
Prob(F-statistic)	0.000000	Wald F-statistic	4.106557
Prob(Wald F-statistic)	0.020529		

As we can see in Table 6.7, the evolution of tobacco prices in France is markedly different from the one observed in the UK. Differently from the smooth linear increase in price observed in the UK the average price of tobacco in France has increased in a stepwise fashion (with the biggest step increase observed in 2018). An implication of this is that the evolution of prices in France cannot be estimated through a time-series model. In fact even after de-trending and seasonally adjusting the price series, and including a dummy to control for the 2018 price increase (which we understand was the result of change in the tax regime), the price series remains highly non-stationary.

Figure 6.7: Log-price of tobacco products in France



The evolution of the log-price series for France after de-trending, de-seasonalising and controlling for the step increase observed in 2018 is reported in the chart below.

Figure 6.8: De-trended and de-seasonalised average log-price of tobacco products in France (with dummy to control for changes in taxation introduced in 2018)

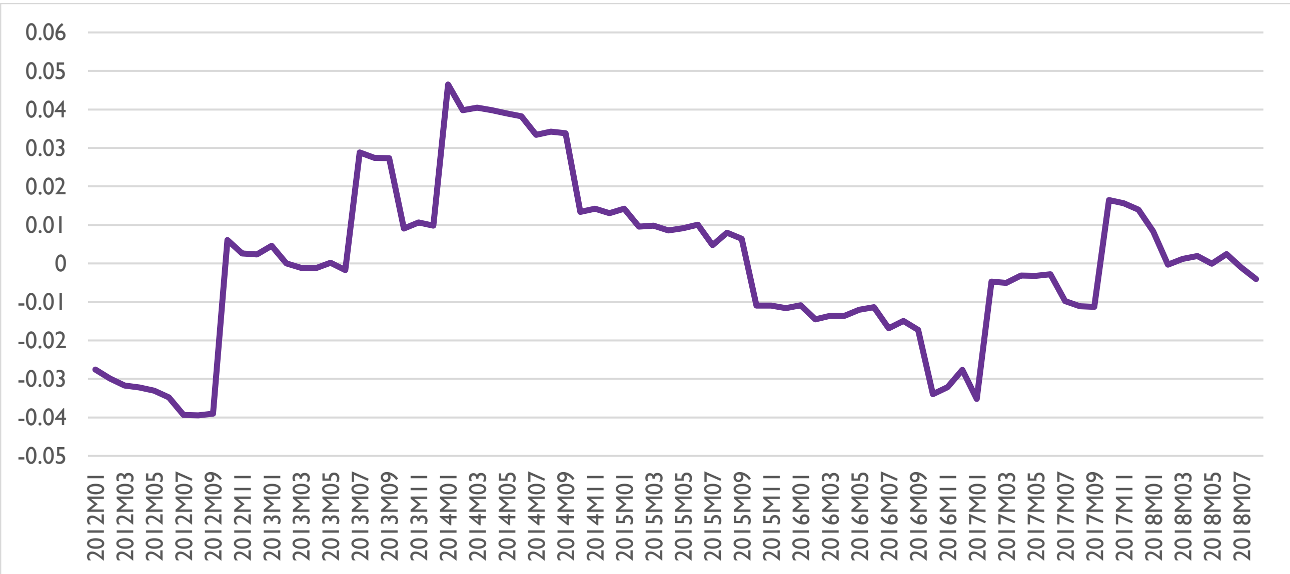


Table 6.29: Stationarity test of de-trended and de-seasonalised log-price of tobacco product in the France (with dummy to control for changes in taxation introduced in 2018)

		t-Statistics	P-value
Augmented Dickey-Fuller test statistic		-2.342340	0.1616
Test critical values:	*1% level*	*-3.515536*	
	5% level	*-2.898623*	
	10% level	*-2.586605*	
Phillips-Perron test statistic		-2.227931	0.1982
Test critical values:	*1% level*	*-3.515536*	
	5% level	*-2.898623*	
	10% level	*-2.586605*	

As we can see from the stationarity tests of Table 6.29 both the ADF and the PP tests fail to reject the hypothesis that the series is non-stationary. Since the price series for France cannot be modelled with an AR process, we use a simple model in which we explain the adjusted log-price (i.e. de-trended, de-seasonalised and adjusted to control for changes in taxation), simply by the penetration of TPD2+PP products. The estimation results of this simple model are reported below and suggest that the penetration of TPD2+PP products did not have any impact on price.

Table 6.30: Price equation (France)

Dependent Variable: **log-price (adjusted)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant — C(7)	0.001102	0.002788	0.395124	0.6938
TPD2+PP penetration — C(8)	-0.004189	0.005520	-0.758882	0.4502

R-squared	0.007329	Mean dependent var	-1.37E-16
Adjusted R-squared	-0.005397	S.D. dependent var	0.021234
S.E. of regression	0.021292	Akaike info criterion	-4.836324
Sum squared resid	0.035360	Schwarz criterion	-4.776774
Log likelihood	195.4530	Hannan-Quinn criter.	-4.812449
F-statistic	0.575902	Durbin-Watson stat	0.222888
Prob(F-statistic)	0.450210		

The estimation results of the simultaneous equation model based on the consumption equation of Table 6.28 and the price equation of Table 6.30 are reported below and indicate that the penetration of TPD2+PP products is not associated with any change in tobacco consumption in France.

Table 6.31: Simultaneous equation model for tobacco consumption (France)

Consumption system (France)
Estimation Method: Iterative Least Squares
Sample: 2012M01 2018M08
Included observations: 80
Total system (unbalanced) observations 156

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1311.056	466.9050	-2.807972	0.0057
C(2)	46.14882	96.48225	0.478314	0.6331
C(3)	2335.055	843.9479	2.766823	0.0064

C(4)	0.319801	0.116417	2.747038	0.0068
C(5)	0.242943	0.119321	2.036038	0.0435
C(6)	0.252271	0.117574	2.145635	0.0335
C(7)	0.001102	0.002788	0.395124	0.6933
C(8)	-0.004189	0.005520	-0.758882	0.4491

6.3.2 Prevalence

We finish by providing the estimation results of the simultaneous equation model for smoking prevalence in the UK.

The best time series model for the de-trended and seasonally adjusted prevalence series does not contain any AR terms and is provided below. The price equation is the same as in Table 6.24.

Table 6.32: Prevalence equation (UK)

Dependent Variable: **Prevalence (de-trended and seasonally adjusted)**
Method: Least Squares
Sample: 2012M01 2018M08
Included observations: 80
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log-price — C(1)	0.002626	0.022181	0.118379	0.9061
TPD2+PP penetration —C(2)	-0.000135	0.003149	-0.042749	0.9660
Constant — C(3)	-0.004720	0.039927	-0.118220	0.9062

R-squared	0.000212	Mean dependent var	1.43E-18
Adjusted R-squared	-0.025757	S.D. dependent var	0.010136
S.E. of regression	0.010266	Akaike info criterion	-6.283211
Sum squared resid	0.008115	Schwarz criterion	-6.193885
Log likelihood	254.3284	Hannan-Quinn criter.	-6.247397
F-statistic	0.008157	Durbin-Watson stat	1.949895
Prob(F-statistic)	0.991878	Wald F-statistic	0.007460
Prob(Wald F-statistic)	0.992569		

The estimate results of the simultaneous equation model are reported in the table below and indicate that the penetration of TPD2+PP products is not associated with any change in prevalence. We have also estimated a simultaneous equation model with the alternative price equation of Table 6.26, and the results are in line with those of Table 6.33.

Table 6.33: Simultaneous equation model for smoking prevalence (UK)

Prevalence system (UK)
Estimation Method: Iterative Least Squares
Sample: 2012M02 2018M08
Included observations: 80
Total system (unbalanced) observations 157

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.003898	0.022996	0.169524	0.8656
C(2)	-0.000223	0.003626	-0.061583	0.9510
C(3)	-0.007030	0.041150	-0.170833	0.8646
C(4)	-0.020549	0.006279	-3.272507	0.0013
C(5)	0.009847	0.003926	2.508220	0.0132
C(6)	0.491043	0.108216	4.537639	0.0000
C(7)	0.303426	0.102509	2.959988	0.0036