Europe Economics

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

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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 that the data so far published indicate no statistically significant impact in the sorts of models we have used:

- No statistically significant impacts on prevalence in the UK.
- No statistically significant impacts on consumption in the UK or in France.

We also note that at the time of the impact assessment accompanying TPD2 it was anticipated that there would be an impact by this point. In the government's TPD2 impact assessment of 2015 it provides estimates of projected prevalence levels and projected reductions associated with TPD2. [1] 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.

No such impact is yet identifiable in the data.

[1] 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

1 Introduction

In February 2014 the European Union agreed a revised Tobacco Products Directive[2], 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 around the same time France and the UK have adopted additional measures imposing standardised packing of tobacco products ("plain packs" which we refer to as "PP" requirements). Such measures involve precise restrictions with regards 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 2017, the data so far published indicate no statistically significant impact, in the sorts of models we have used, between TPD2+PP requirements and tobacco consumption in France or the UK. Similarly, again in the models we have used, those data indicate no statistically significant relationship between the presence of TPD2+PP requirements and smoking prevalence 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.

[2] 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 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 Jan 2008 — Aug 2017, whilst price data is available only for the period Jan 2012 — Aug 2017.

The data is provided 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).[3]
- 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 from.

For the UK, our analysis also incorporates information on smoking and vaping prevalence. The underlying hypothesis is that the emergence of electronic cigarettes may have affected the dynamics of the tobacco market in the UK and should therefore be incorporated in the analysis of our variables of interest for testing (namely downtrading and smoking prevalence).[4] Data on smoking and vaping prevalence in the UK were obtained from the Smoking Toolkit Study (STS).[5] The STS includes up-to-date data tracking national smoking and vaping patterns, as well as cessation-related behaviours.

2.3 Measuring TPD2 and plain-packaging requirements

In France and the UK, the TPD2 directive and plain-packaging requirements ("TPD2+PP") 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.

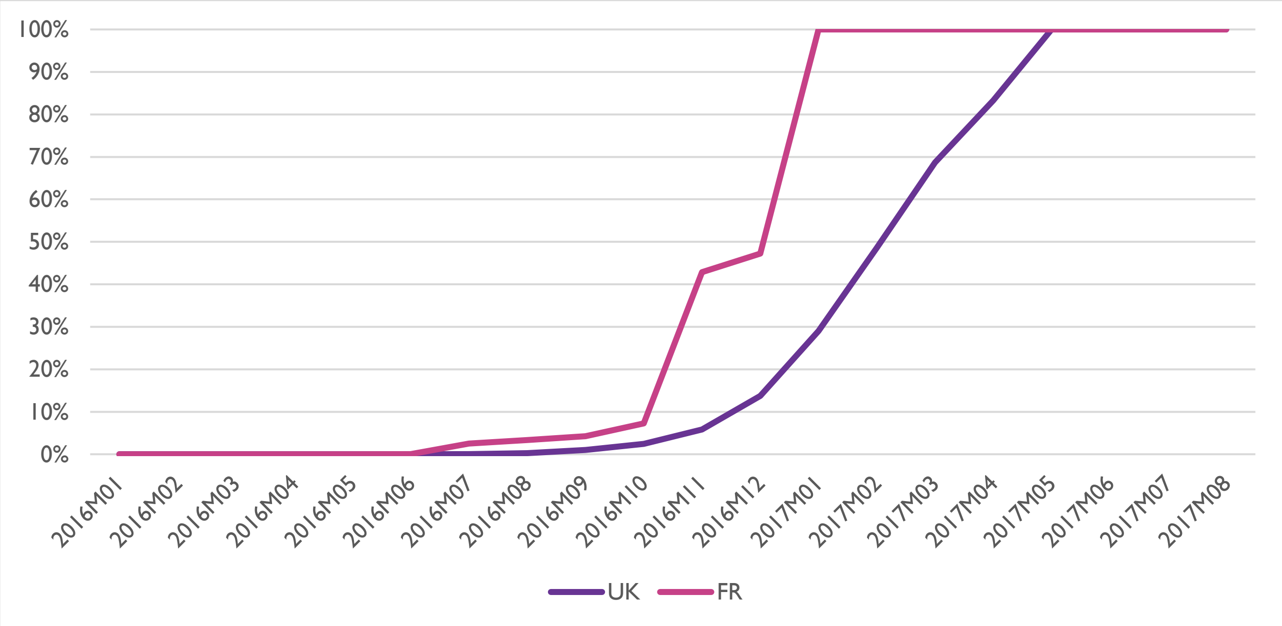
[3] For RYO/MYO products the raw data provides also a sticks-equivalent conversion.

[4] We emphasize that our models do not *assume* that the growth of vaping has led to a reduction in tobacco prevalence or consumption. Rather, vaping is included as a potential explanatory variable for the statistics to inform us of its impact.

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

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. These are illustrated in the chart below.

Figure 2.1: TPD2/PP Penetration (whole market)



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 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 are introduced together (as of May 2016). 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.

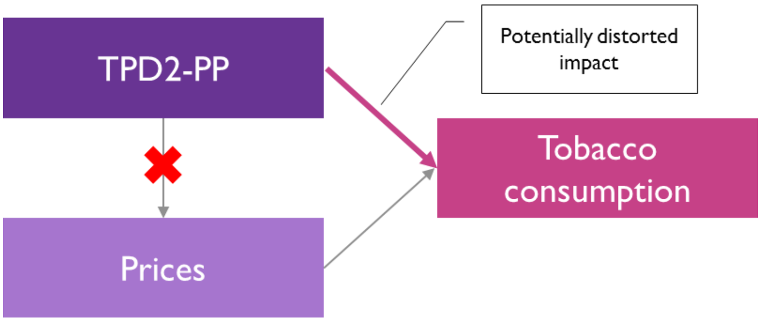
A further point to note here is that the use of time series relationships automatically accounts for seasonal effects in our data (where they exist). For example if the value of a variable in a particular month of the year is always, say, elevated, then it will have some relationship to its value one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

Figure 2.2: Distorted impact found in a model where prices are controlled for but the measure has an impact on prices themselves

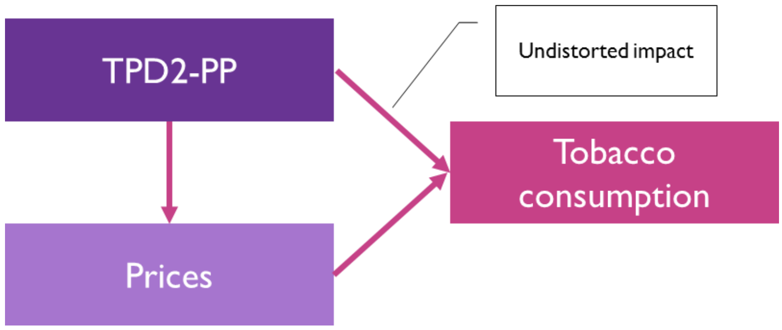


We can correct for this by what are commonly referred to as econometric "simultaneous equations" techniques. In our simultaneous equations models we estimate the impact of the measure (here, TPD2 and plain packs) upon prices and consumption (or other relevant variables in other models, such as prevalence) 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 2.3: 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 indicates 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

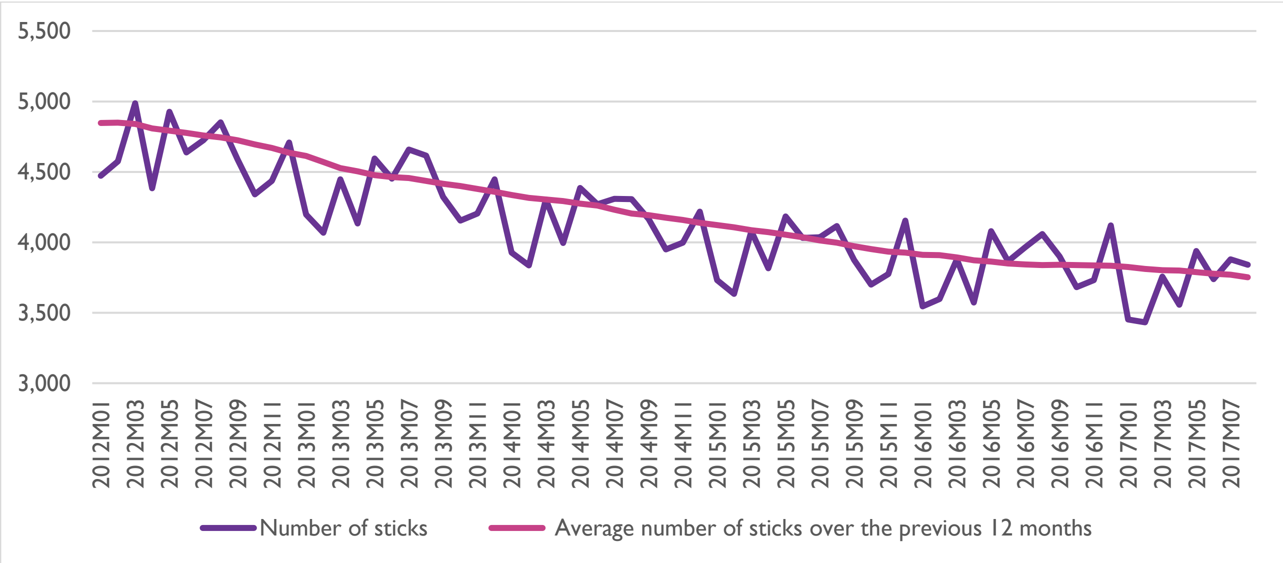
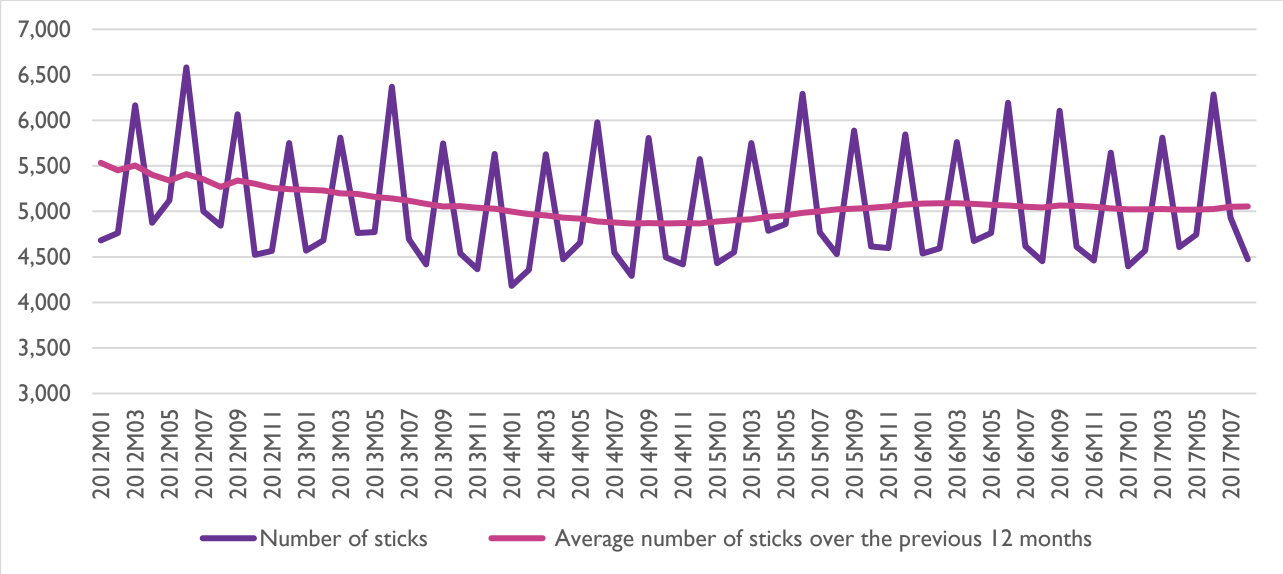


Figure 3.2: Number of sticks (millions) sold in France



We can notice from Figure 2.1 that in the UK there has been a declining trend in the number of RMC 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)

the results of simple trend analysis.

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	5,600,000,000	141,000,000	0.0000
Trend	-19,045,013	1,897,574	0.0000
Dummy *(break in levels)*	242,000,000	87,804,627	0.0076

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

	Coefficient	Std. Error	Prob.
Constant	5,600,000,000	1.41E+08	0.0000
Trend	-19,121,538	1,910,859	0.0000
Trend * dummy (*break in trend*)	2,298,611	829,214	0.0073

We also checked whether there might be a break affecting both consumption levels and consumption trend simultaneously. We do not find such a break to be statistically significant. So there is either a rise in tobacco consumption levels, or a fall in the rate of decrease, but not both.

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	144,000,000	0.0000
Trend	-19,147,176	1,938,408	0.0000
Dummy *(break in levels)*	-140,000,000	1,220,000,000	0.9089
Trend * dummy (*break in trend*)	3,621,667	11,541,262	0.7547

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 19 million (the coefficient of the trend variable in Table 3.2), since May 2016 the average monthly reduction is of the order of approximately 17 million (the coefficient of the coefficient of the trend variable in Table 3.2 plus that of the trend-times-dummy variable, i.e. -19.1m+2.3m = -16.8m).

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 models the result is removed (i.e. there is no impact), but in some of our cross-check models 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).[6]

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 implantation 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 (five). 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.[7] 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 evolve through time, it is common to model them using a class of what are referred to as "autoregressive–integrated–moving–average" (ARIMA) process. 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.

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6 Specifically, we find an increase of around 100m in the level of number of sticks sold in the UK. That compares with the increase of 200m we found in **Table 3.1**. We regard these are broadly similar impacts, in this context.

7 GDP per capita is statistically significant in the preferred consumption model and prevalence model for the UK, but leaves the results intact. In the preferred consumption model for France GDP per capita is not statistically significant.

Two key components in ARIMA processes are the "autoregressive" (AR) term and the moving average (MA) term.[8] 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.[9] 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.[10]

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	-0.853	0.355	0.0203
Penetration of TPD+PP products in the market	-0.003	0.003	0.3395
AR(1)	-0.344	0.225	0.1333
AR(2)	0.226	0.251	0.3727
AR(3)	0.198	0.129	0.1338
MA(1)	-0.442	0.215	0.0454
MA(2)	-0.557	0.234	0.0216

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	-0.782	0.126	0.0000
Penetration of TPD-PP products in the market	-0.001	0.002	0.6589
AR(1)	0.311	0.119	0.0128
AR(12)	-0.605	0.110	0.0000
MA(1)	-0.972	0.018	0.0000

8 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).

9 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.

10 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 component is appropriate.

The results presented in Table 3.4 and Table 3.5 indicate that, whilst higher prices are statistically and significantly associated with lower consumption levels in both France and the UK, the introduction of TPD2+PP requirements do not appear to have any statistical association with the number of sticks sold.

3.4.2 Simultaneous equation model

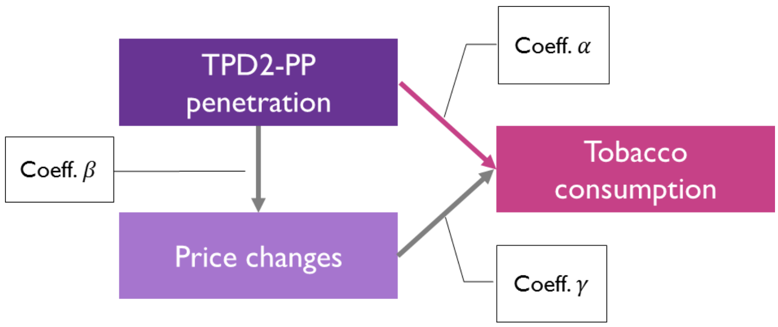
A simultaneous equation model is made up of two different equations that are estimated simultaneously. The first is a consumption equation similar to that presented in Section 2.4, where changes in the number of sticks sold are explained by *seasonal monthly* dummies, *percentage changes* in price, *penetration of TPD2+PP products* in the market and an appropriate time series process. The second equation is a price equation where changes in prices are modelled by a time-series process and the *penetration 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.

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.

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 change impact (γ)	Overall impact of TPD2/PP
UK	Statistically insignificant	Statistically insignificant	Statistically insignificant	No impact
FR	Statistically insignificant	Statistically insignificant	-0.06**	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 no statistically significant impact of TPD2 and PP on tobacco consumption either directly or indirectly via an impact on prices. The only statistically significant relationship is the negative association between price of tobacco products and the 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.

4 Time-series smoking prevalence model for the UK

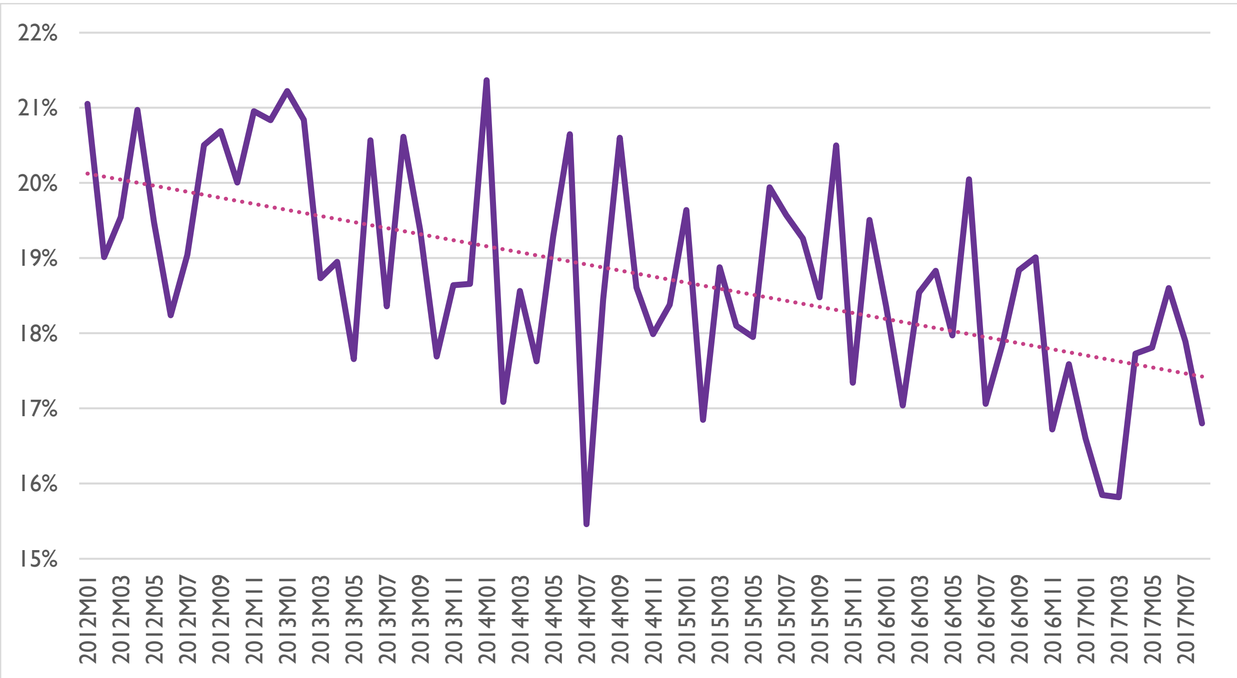
4.1 Introduction

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 Smoking Toolkit Study (STS).[11] We use such data as a proxy for the 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 employing more sophisticated models.

4.2 Smoking prevalence England

As we can see from Figure 4.1of smoking prevalence in England has decreases steadily since 2012. Moreover, the rate of decline in prevalence rate 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

[11] 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 our algorithm indicates should be preferred does not include monthly dummies.[12]

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	0.244	0.297	0.4157
Penetration of TPD-PP products in the market	0.311	0.209	0.1439
C	-0.155	0.097	0.1183
AR(1)	-0.800	0.119	0.0000
AR(2)	-0.608	0.168	0.0007
AR(3)	-0.340	0.109	0.0030
AR(12)	0.2411	0.113	0.0386

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 no statistically significant association (either directly or indirectly) between of TPD2+PP requirements and smoking prevalence in the UK.

[12] 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 note that our algorithm also considered the possibility that vaping might affect prevalence, but this was never statistically significant in a preferred model.

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

	Direct impact of TPD2+PP	Indirect impact of TPD2+PP	% Price change impact	Overall impact of TPD2/PP
UK	Statistically insignificant	Statistically insignificant	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 that there has as yet been no statistically significant impact in the sorts of models we have used:

- No statistically significant impacts on prevalence in the UK.
- No statistically significant impacts on consumption in the UK or in France.

These results remain provisional as the analysis is limited in time and it should be noted that they 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 government's TPD2 impact assessment of 2015 it 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.[13]

No such impact is yet identifiable in the data.

[13] 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

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 is 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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.20E+09	3.41E+08	15.24557	0.0000
Trend	-1982304.	4117631.	-0.481418	0.6318

R-squared	0.003499	Mean dependent var	5.04E+09
Adjusted R-squared	-0.011599	S.D. dependent var	6.63E+08

Table 6.2: Trend model of tobacco consumption for the UK

Dependent Variable: **Number of sticks (UK)**
Method: Least Squares
Sample: 2012M01 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.35E+09	1.12E+08	47.80068	0.0000
Trend	-15204327	1349832.	-11.26387	0.0000

R-squared	0.657809	Mean dependent var	4.12E+09
Adjusted R-squared	0.652624	S.D. dependent var	3.71E+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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.60E+09	1.41E+08	39.82594	0.0000
Trend	-19045013	1897574.	-10.03650	0.0000
Dummy	2.42E+08	87804627	2.754543	0.0076
R-squared	0.693578	Mean dependent var		4.12E+09
Adjusted R-squared	0.684150	S.D. dependent var		3.71E+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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.60E+09	1.41E+08	39.62268	0.0000
Trend	-19121538	1910859.	-10.00677	0.0000
Dummy*Trend	2298611.	829213.5	2.772037	0.0073
R-squared	0.693986	Mean dependent var		4.12E+09
Adjusted R-squared	0.684570	S.D. dependent var		3.71E+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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.61E+09	1.44E+08	39.06184	0.0000
Trend	-19147176	1938408.	-9.877784	0.0000
Dummy	-1.40E+08	1.22E+09	-0.114939	0.9089
Dummy*Trend	3621667.	11541262	0.313802	0.7547
R-squared	0.694049	Mean dependent var		4.12E+09
Adjusted R-squared	0.679707	S.D. dependent var		3.71E+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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.35E+09	4.52E+08	11.83771	0.0000
Trend	-4295360.	6104561.	-0.703631	0.4842
Dummy	1.46E+08	2.82E+08	0.515670	0.6078

R-squared	0.007559	Mean dependent var	5.04E+09
Adjusted R-squared	-0.022977	S.D. dependent var	6.63E+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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.35E+09	4.55E+08	11.75721	0.0000
Trend	-4291313.	6151783.	-0.697572	0.4879
Dummy*Trend	1354922.	2669554.	0.507546	0.6135

R-squared	0.007433	Mean dependent var	5.04E+09
Adjusted R-squared	-0.023108	S.D. dependent var	6.63E+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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.35E+09	4.62E+08	11.57192	0.0000
Trend	-4198566.	6240303.	-0.672814	0.5035
Dummy	5.08E+08	3.93E+09	0.129159	0.8976
Dummy*Trend	-3431366.	37154703	-0.092353	0.9267

R-squared	0.007692	Mean dependent var	5.04E+09
Adjusted R-squared	-0.038823	S.D. dependent var	6.63E+08

6.1.2 Prevalence

Finally 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 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 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	22.01904	0.608403	36.19151	0.0000
Trend	-0.040297	0.007343	-5.488098	0.0000

R-squared	0.313353	Mean dependent var	18.77510
Adjusted R-squared	0.302949	S.D. dependent var	1.423472

Dependent Variable: **Smoking prevalence (UK)**
Method: Least Squares
Date: 11/21/17 Time: 14:02
Sample: 2012M01 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	21.75079	0.806471	26.97035	0.0000
Trend	-0.036213	0.010886	-3.326514	0.0014
Dummy	-0.257186	0.503731	-0.510563	0.6114

R-squared	0.316095	Mean dependent var	18.77510
Adjusted R-squared	0.295052	S.D. dependent var	1.423472

Dependent Variable: **Smoking prevalence (UK)**
Method: Least Squares
Date: 11/21/17 Time: 14:02
Sample: 2012M01 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	21.71900	0.811594	26.76092	0.0000
Trend	-0.035737	0.010965	-3.259176	0.0018
Dummy*Trend	-0.002676	0.004758	-0.562359	0.5758

R-squared	0.316677	Mean dependent var	18.77510
Adjusted R-squared	0.295652	S.D. dependent var	1.423472

Dependent Variable: **Smoking prevalence (UK)**
Method: Least Squares
Date: 11/21/17 Time: 14:02
Sample: 2012M01 2017M08
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	21.65254	0.820577	26.38698	0.0000
Trend	-0.034858	0.011083	-3.145115	0.0025
Dummy	4.812869	6.982961	0.689230	0.4932
Dummy*Trend	-0.048039	0.065990	-0.727971	0.4693

R-squared	0.321712	Mean dependent var	18.77510
Adjusted R-squared	0.289917	S.D. dependent var	1.423472

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 preferred 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

Table 6.10: Pure time series-model of tobacco consumption (UK)

Dependent Variable: **%Change in number of sticks (UK)**
Method: Least Squares
Sample (adjusted): 2012M05 2017M08
Included observations: 64 after adjustments
Convergence achieved after 22 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Jan dummy	-11.88168	1.134776	-10.47051	0.0000
Feb dummy	-1.882840	0.887128	-2.122399	0.0393
Mar dummy	10.94947	1.046088	10.46707	0.0000
Apr dummy	-6.482104	0.696819	-9.302415	0.0000
May dummy	11.33563	0.817969	13.85825	0.0000
Jun dummy	-4.081629	0.481215	-8.481925	0.0000
Jul dummy	3.077330	1.002184	3.070625	0.0036
Aug dummy	0.865219	0.770582	1.122812	0.2675
Sep dummy	-4.525822	0.775342	-5.837197	0.0000
Oct dummy	-5.020536	0.554933	-9.047110	0.0000
Nov dummy	1.878206	0.368610	5.095371	0.0000
Dec dummy	7.385995	1.139673	6.480801	0.0000
% change in price	-0.853113	0.353680	-2.412103	0.0200
TPD2+PP penetration	**-0.002638**	**0.002730**	**-0.966380**	**0.3390**
AR(1)	-0.343725	0.224639	-1.530123	0.1330
AR(2)	0.225724	0.250418	0.901386	0.3722
AR(3)	0.197550	0.129326	1.527540	0.1336
MA(1)	-0.443491	0.214633	-2.066277	0.0446
MA(2)	-0.555654	0.233774	-2.376890	0.0218

R-squared	0.972512	Mean dependent var	0.044627
Adjusted R-squared	0.961517	S.D. dependent var	7.132992
S.E. of regression	1.399288	Akaike info criterion	3.751334
Sum squared resid	88.11031	Schwarz criterion	4.392252
Log likelihood	-101.0427	Hannan-Quinn criter.	4.003824
Durbin-Watson stat	1.962075	Wald F-statistic	172.2708
Prob(Wald F-statistic)	0.000000		

Table 6.11: Pure time series-model of tobacco consumption (FR)

Dependent Variable: **%Change in number of sticks (FR)**
Method: Least Squares
Date: 11/17/17 Time: 17:56
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 17 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.

Jan dummy	-0.230955	0.006354	-36.34520	0.0000
Feb dummy	0.033976	0.004788	7.095887	0.0000
Mar dummy	0.266615	0.003368	79.16514	0.0000
Apr dummy	-0.188187	0.005121	-36.75041	0.0000
May dummy	0.023034	0.003274	7.035746	0.0000
Jun dummy	0.311199	0.008507	36.58154	0.0000
Jul dummy	-0.245576	0.005825	-42.16204	0.0000
Aug dummy	-0.057018	0.005956	-9.573870	0.0000
Sep dummy	0.325113	0.007687	42.29196	0.0000
Oct dummy	-0.227999	0.005099	-44.71821	0.0000
Nov dummy	-0.020638	0.004501	-4.585158	0.0000
Dec dummy	0.282196	0.007989	35.32237	0.0000
% Change in price	-0.782411	0.125536	-6.232572	0.0000
TPD2+PP penetration	**-0.000802**	**0.001804**	**-0.444905**	**0.6589**
AR(12)	-0.605147	0.109540	-5.524453	0.0000
AR(1)	0.311365	0.119155	2.613108	0.0128
MA(1)	-0.972843	0.018013	-54.00813	0.0000

R-squared	0.996129	Mean dependent var	0.021298
Adjusted R-squared	0.994499	S.D. dependent var	0.213161
S.E. of regression	0.015809	Akaike info criterion	-5.207978
Sum squared resid	0.009498	Schwarz criterion	-4.587530
Log likelihood	160.2194	Hannan-Quinn criter.	-4.968046
Durbin-Watson stat	1.832369	Wald F-statistic	9704.347
Prob(Wald F-statistic)	0.000000		

6.2.2 Benchmark models for Prevalence

Table 6.12: Pure time series-model of smoking prevalence (UK)

Dependent Variable: **Changes in prevalence (UK)**
Method: Least Squares
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 14 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price	0.243294	0.293681	0.828429	0.4114
TPD2+PP penetration	**-0.031494**	**0.174570**	**-0.180409**	**0.8576**
C	-0.088166	0.074690	-1.180436	0.2434
AR(12)	0.282771	0.125278	2.257157	0.0284
MA(1)	-0.999582	0.089587	-11.15769	0.0000

R-squared	0.596263	Mean dependent var	-0.080443
Adjusted R-squared	0.563964	S.D. dependent var	1.826879
S.E. of regression	1.206344	Akaike info criterion	3.299573
Sum squared resid	72.76328	Schwarz criterion	3.482058
Log likelihood	-85.73827	Hannan-Quinn criter.	3.370142
F-statistic	18.46073	Durbin-Watson stat	2.189984
Prob(F-statistic)	0.000000	Wald F-statistic	4.566011
Prob(Wald F-statistic)	0.015090		

6.2.3 Alternative modelling approaches.

The time-series modelling approach used to produce the results set out in Section 6.2.1 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 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 sporous is higher).

As a cross check we have therefore analysed a number of alternative models where the dependent variables are expressed in levels as opposed to percentage changes. Such modelling approach would still require some transformation of the dependent variable to ensure stationarity. 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, 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 — and the key reason we regard the approach we set out in the main body of this report as preferred — 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.

To being with, we report below the result of the unit root-test for the following (unadjusted) variables:

- Number of sticks in the UK.
- Prevalence in the UK.
- Number of sticks in France.

The tests confirms that tobacco consumption and smoking prevalence in the UK are non-stationary, but they are trend-stationary. However, tobacco consumption in France appears to be stationary (at the 95 percent confidence level) even without de-trending.

Table 6.13: ADF test for tobacco consumption in the UK

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic (Constant)	-1.797211	0.3789
Augmented Dickey-Fuller test statistic (Constant, Linear Trend)	-7.933299	0.0000

Table 6.14: Table 6.15: ADF test for smoking prevalence in the UK

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic (Constant)	-2.873546	0.0538
Augmented Dickey-Fuller test statistic (Constant, Linear Trend)	-8.434966	0.0000

Table 6.16: ADF test for tobacco consumption in France

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic (Constant)	-4.090260	0.0020
Augmented Dickey-Fuller test statistic (Constant, Linear Trend)	-4.079499	0.0108

Based on the unit-root tests conducted above 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.
- We have de-seasonalised the number of sticks in France.

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

Figure 6.1: Number of sticks (France and UK)

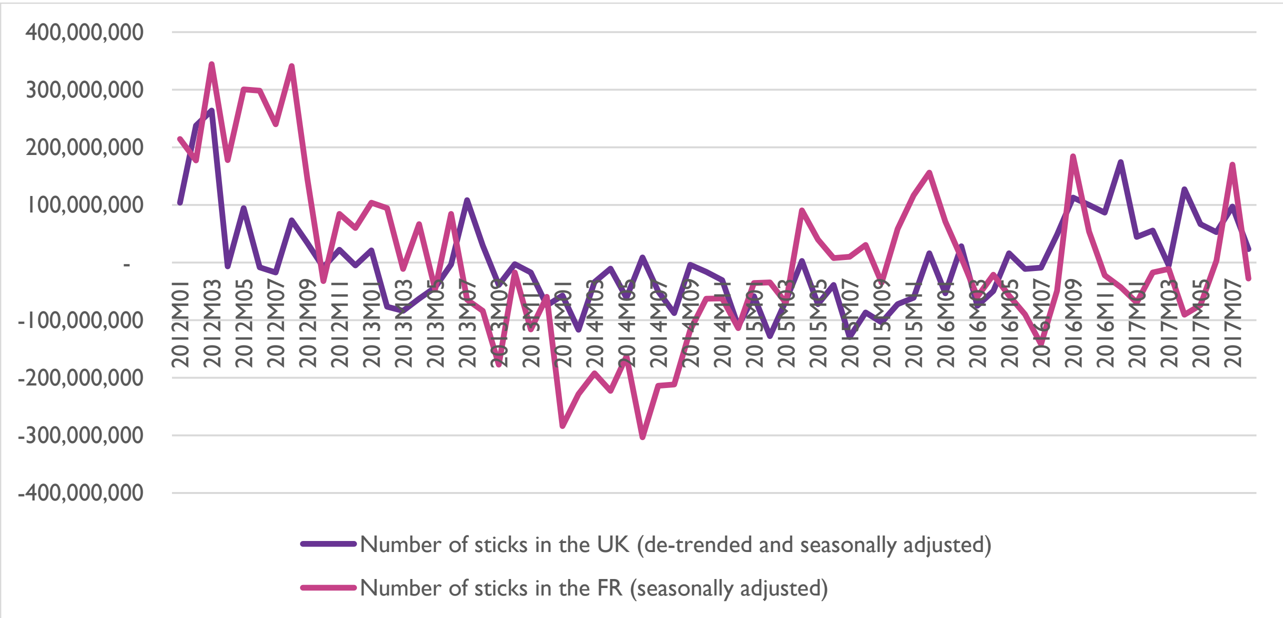
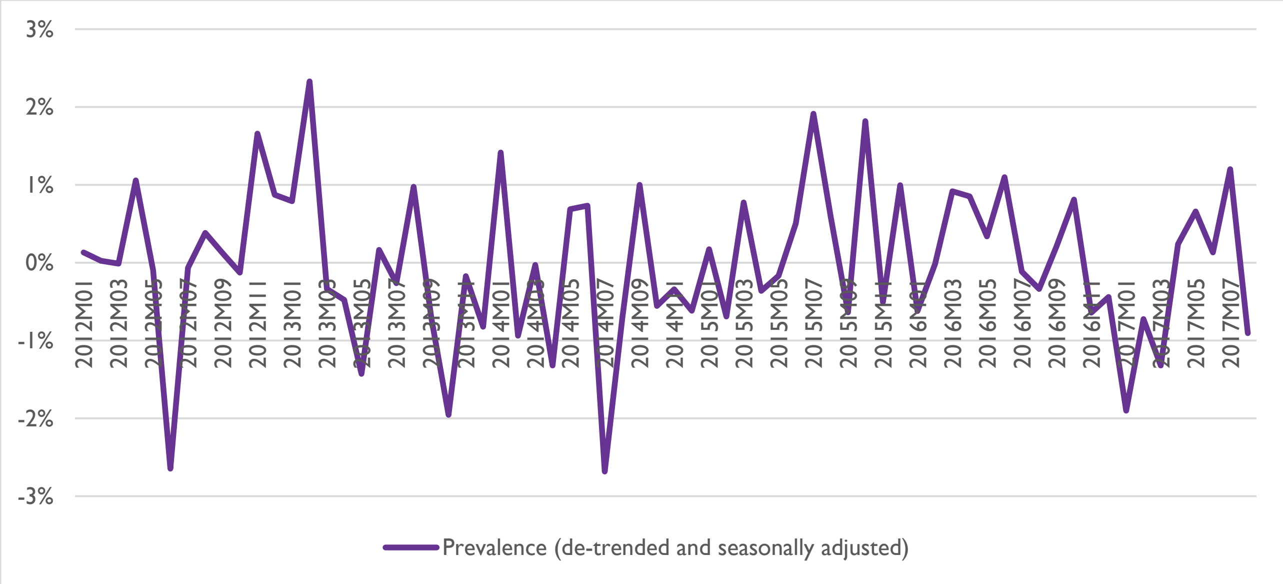


Figure 6.2: Smoking prevalence (UK)



We have then modelled the above adjusted variables with the following explanatory variables: percentage changes in the average price of cigarettes, penetration of TPD2+PP products, and an optimally selected ARMA process. The results of such models are reported below.

Table 6.17: Alternative time-series model of tobacco consumption (UK)

Dependent Variable: **Number of sticks (UK) – de-trended and de-seasonalised**
Method: Least Squares
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 25 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price	-1.20E+09	1.36E+09	-0.881870	0.3823
TPD2+PP penetration	**1.05E+08**	**33879280**	**3.108016**	**0.0032**
C	-24196093	13080108	-1.849839	0.0706
AR(1)	0.881033	0.072432	12.16351	0.0000
AR(2)	-0.584877	0.109486	-5.342017	0.0000
AR(12)	-0.292297	0.075784	-3.856965	0.0003
MA(1)	-0.640215	0.054947	-11.65140	0.0000
MA(2)	0.970106	0.029148	33.28233	0.0000

R-squared	0.534687	Mean dependent var	-14640942
Adjusted R-squared	0.465385	S.D. dependent var	69626918
S.E. of regression	50909392	Akaike info criterion	38.46272
Sum squared resid	1.22E+17	Schwarz criterion	38.75469
Log likelihood	-1049.725	Hannan-Quinn criter.	38.57563
F-statistic	7.715313	Durbin-Watson stat	1.768091
Prob(F-statistic)	0.000003	Wald F-statistic	6.082837
Prob(Wald F-statistic)	0.004474		

Table 6.18: Alternative time-series model of tobacco consumption (FR)

Dependent Variable: **Number of sticks (FR) –de-seasonalised**
Method: Least Squares

Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 2 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price	1.48E+09	1.05E+09	1.414638	0.1634
TPD2+PP penetration	**35391179**	**43936200**	**0.805513**	**0.4243**
C	-52446992	22839261	-2.296352	0.0259
AR(1)	0.672015	0.085446	7.864783	0.0000
AR(12)	-0.145444	0.059326	-2.451583	0.0178

R-squared	0.503886	Mean dependent var	-44632861
Adjusted R-squared	0.464197	S.D. dependent var	1.08E+08
S.E. of regression	78939336	Akaike info criterion	39.29277
Sum squared resid	3.12E+17	Schwarz criterion	39.47525
Log likelihood	-1075.551	Hannan-Quinn criter.	39.36333
F-statistic	12.69581	Durbin-Watson stat	2.182962
Prob(F-statistic)	0.000000	Wald F-statistic	1.194752
Prob(Wald F-statistic)	0.311274		

Table 6.19: Alternative time-series model of smoking prevalence (UK)

Dependent Variable: **Smoking prevalence (UK) – de-trended and de-seasonalised**
Method: Least Squares
Sample (adjusted): 2012M02 2017M08
Included observations: 67 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed
bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price	-7.770281	20.33475	-0.382118	0.7036
TPD2+PP penetration	-0.141121	0.420876	-0.335303	0.7385
C	0.035668	0.155353	0.229592	0.8191

R-squared	0.003427	Mean dependent var	-0.002007
Adjusted R-squared	-0.027716	S.D. dependent var	0.994814
S.E. of regression	1.008506	Akaike info criterion	2.898560
Sum squared resid	65.09340	Schwarz criterion	2.997277
Log likelihood	-94.10176	Hannan-Quinn criter.	2.937623
F-statistic	0.110028	Durbin-Watson stat	1.946764
Prob(F-statistic)	0.895978	Wald F-statistic	0.090144
Prob(Wald F-statistic)	0.913916		

We see from Table 6.17, that under this alternative modelling approach the introduction of TPD2+PP in the UK is statistically associated (at the 95 per cent confidence level) with an increase in the number of sticks sold. In all other models the introduction of TPD2+PP remains statistically insignificant. We also note, in Table 6.19 that, after de-trending and de-seasonalising, there no time series structure explaining the evolution of smoking prevalent in the UK.

6.2.4

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

In Sections 6.3.1 and 6.3.2 we present the detailed results of our simultaneous-equation approach. In Section 6.3.3 we present the result we obtain when we model the consumption equation and the prevalence with the alternative approach described in 6.2.3, ie by using de-trended and de-seasonalised series.

6.3.1 Consumption

Below we first present estimation results for the two separate equations (consumption equation and the price equation) constituting the system model for the UK. We then provide the estimation output of the system as a whole (the coefficients of the systems are coded from C(1) to C(21)).

Table 6.20: Consumption equation (UK)

Dependent Variable: **%Change in number of sticks (UK)**
Method: Least Squares
Sample (adjusted): 2012M05 2017M08
Included observations: 64 after adjustments
Convergence achieved after 11 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Jan dummy – C(1)	-0.129707	0.012847	-10.09644	0.0000
Feb dummy – C(2)	-0.014292	0.009551	-1.496381	0.1412
Mar dummy – C(3)	0.102621	0.011478	8.940368	0.0000
Apr dummy – C(4)	-0.067798	0.006445	-10.51873	0.0000
May dummy – C(5)	0.108252	0.008165	13.25799	0.0000
Jun dummy – C(6)	-0.040937	0.005140	-7.964950	0.0000
Jul dummy – C(7)	0.023875	0.010011	2.384891	0.0212
Aug dummy – C(8)	0.007914	0.006808	1.162371	0.2510
Sep dummy – C(9)	-0.047890	0.007511	-6.376170	0.0000
Oct dummy – C(10)	-0.049283	0.004172	-11.81409	0.0000
Nov dummy – C(11)	0.015665	0.003060	5.118889	0.0000
Dec dummy – C(12)	0.076023	0.011796	6.444657	0.0000
% Change in price – C(13)	-0.023253	0.636968	-0.036506	0.9710
TPD2+PP penetration – C(14)	**-0.000703**	**0.003496**	**-0.200984**	**0.8416**
AR(1) – C(15)	-0.505837	0.112412	-4.499826	0.0000
AR(2) – C(16)	-0.126897	0.155517	-0.815973	0.4186
AR(3) – C(17)	0.061557	0.099467	0.618869	0.5390

R-squared	0.968019	Mean dependent var	0.000446
Adjusted R-squared	0.957132	S.D. dependent var	0.071330
S.E. of regression	0.014769	Akaike info criterion	-5.370121
Sum squared resid	0.010251	Schwarz criterion	-4.796667
Log likelihood	188.8439	Hannan-Quinn criter.	-5.144208
Durbin-Watson stat	2.098984	Wald F-statistic	321.1981
Prob(Wald F-statistic)	0.000000		

Inverted AR Roots	.22	-.36-.39i	-.36+.39i

Table 6.21: Price equation (UK)

Dependent Variable: **%Change in price (UK)**
Method: Least Squares
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 4 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TPD2+PP penetration – C(18)	**-0.000646**	**0.001148**	**-0.563310**	**0.5757**
C – C(19)	0.000993	0.001441	0.689420	0.4937
AR(1) – C(20)	-0.192167	0.087678	-2.191746	0.0330
AR(12) – C(21)	0.700237	0.074611	9.385222	0.0000

R-squared	0.746224	Mean dependent var	0.002454
Adjusted R-squared	0.731296	S.D. dependent var	0.005781
S.E. of regression	0.002997	Akaike info criterion	-8.712628
Sum squared resid	0.000458	Schwarz criterion	-8.566640
Log likelihood	243.5973	Hannan-Quinn criter.	-8.656173
F-statistic	49.98816	Durbin-Watson stat	1.760053
Prob(F-statistic)	0.000000	Wald F-statistic	0.317318
Prob(Wald F-statistic)	0.575692		

Inverted AR Roots	.96	.83-.48i	.83+.48i	.47-.84i
	.47+.84i	-.02-.97i	-.02+.97i	-.50+.84i
	-.50-.84i	-.86+.48i	-.86-.48i	-.99

Table 6.22: Simultaneous equation model of consumption (UK)

System (UK)
Estimation Method: Iterative Least Squares
Sample: 2012M05 2017M08
Included observations: 67
Total system (unbalanced) observations 119
Convergence achieved after 15 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.129707	0.011546	-11.23370	0.0000
C(2)	-0.014292	0.008334	-1.715036	0.0895
C(3)	0.102621	0.009285	11.05201	0.0000
C(4)	-0.067798	0.008034	-8.439080	0.0000
C(5)	0.108252	0.007947	13.62189	0.0000
C(6)	-0.040937	0.007101	-5.764998	0.0000
C(7)	0.023875	0.009725	2.454987	0.0159
C(8)	0.007914	0.006993	1.131649	0.2605
C(9)	-0.047890	0.007552	-6.341432	0.0000
C(10)	-0.049283	0.007546	-6.531261	0.0000
C(11)	0.015665	0.007866	1.991624	0.0492
C(12)	0.076023	0.007732	9.831942	0.0000
C(13)	-0.023261	0.655719	-0.035474	0.9718
C(14)	**-0.000703**	**0.005086**	**-0.138161**	**0.8904**
C(15)	-0.505837	0.141811	-3.566974	0.0006
C(16)	-0.126898	0.165013	-0.769016	0.4437
C(17)	0.061557	0.132164	0.465759	0.6424
C(18)	**-0.000646**	**0.001188**	**-0.544292**	**0.5875**
C(19)	0.000993	0.001127	0.881118	0.3804
C(20)	-0.192167	0.080750	-2.379787	0.0193

C(21)	0.700237	0.078014	8.975804	0.0000

For France, estimation results for the two separate system equations and for the system as a whole are reported below (the coefficients of the systems are coded from C(1) to C(18)).

Table 6.23: Consumption equation (FR)

Dependent Variable: %**Change in number of sticks (FR)**
Method: Least Squares
Sample (adjusted): 2012M03 2017M08
Included observations: 66 after adjustments
Convergence achieved after 9 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Jan dummy – C(1)	-0.227381	0.008510	-26.71946	0.0000
Feb dummy – C(2)	0.032137	0.006768	4.748507	0.0000
Mar dummy – C(3)	0.267953	0.009330	28.72091	0.0000
Apr dummy – C(4)	-0.192211	0.007576	-25.37172	0.0000
May dummy – C(5)	0.025326	0.006909	3.665796	0.0006
Jun dummy – C(6)	0.307333	0.010322	29.77432	0.0000
Jul dummy – C(7)	-0.243539	0.006484	-37.55881	0.0000
Aug dummy – C(8)	-0.056444	0.009873	-5.716893	0.0000
Sep dummy – C(9)	0.326064	0.017642	18.48181	0.0000
Oct dummy – C(10)	-0.233604	0.010837	-21.55628	0.0000
Nov dummy – C(11)	-0.017034	0.009446	-1.803236	0.0773
Dec dummy – C(12)	0.275462	0.008504	32.39371	0.0000
% Change in price – C(13)	-0.600980	0.421292	-1.426517	0.1598
TPD2+PP penetration – C(14)	0.004020	0.002946	1.364588	0.1784
AR(1) – C(15)	-0.435354	0.117535	-3.704021	0.0005

R-squared	0.992794	Mean dependent var	0.020938
Adjusted R-squared	0.990816	S.D. dependent var	0.213407
S.E. of regression	0.020451	Akaike info criterion	-4.744839
Sum squared resid	0.021331	Schwarz criterion	-4.247190
Log likelihood	171.5797	Hannan-Quinn criter.	-4.548194
Durbin-Watson stat	2.059488	Wald F-statistic	765.6594
Prob(Wald F-statistic)	0.000000		

Inverted AR Roots	-.44

Table 6.24: Price equation (FR)

Dependent Variable: %**Change in price (FR)**
Method: Least Squares
Sample (adjusted): 2012M11 2017M08
Included observations: 58 after adjustments
Convergence achieved after 4 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TPD2+PP penetration – C(16)	0.003093	0.002586	1.196242	0.2368
C – C(17)	0.000403	0.000985	0.409066	0.6841
AR(1) – C(18)	-0.210309	0.089010	-2.362770	0.0218
AR(9) – C(19)	0.309955	0.173792	1.783482	0.0801

R-squared	0.232445	Mean dependent var	0.001201

Adjusted R-squared	0.189803	S.D. dependent var	0.008584
S.E. of regression	0.007726	Akaike info criterion	-6.821955
Sum squared resid	0.003223	Schwarz criterion	-6.679856
Log likelihood	201.8367	Hannan-Quinn criter.	-6.766605
F-statistic	5.451080	Durbin-Watson stat	2.112697
Prob(F-statistic)	0.002393	Wald F-statistic	1.430994
Prob(Wald F-statistic)	0.236828		

Table 6.25: Simultaneous equation model of consumption (FR)

System (FR)
Estimation Method: Iterative Least Squares
Sample: 2012M03 2017M08
Included observations: 67
Total system (unbalanced) observations 121
Convergence achieved after 8 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.227381	0.010381	-21.90387	0.0000
C(2)	0.032137	0.010325	3.112666	0.0024
C(3)	0.267953	0.009492	28.23010	0.0000
C(4)	-0.192211	0.009364	-20.52683	0.0000
C(5)	0.025326	0.009329	2.714751	0.0078
C(6)	0.307333	0.009467	32.46353	0.0000
C(7)	-0.243539	0.009329	-26.10667	0.0000
C(8)	-0.056444	0.009349	-6.037307	0.0000
C(9)	0.326064	0.010476	31.12552	0.0000
C(10)	-0.233604	0.010204	-22.89266	0.0000
C(11)	-0.017034	0.010191	-1.671507	0.0976
C(12)	0.275462	0.010530	26.16012	0.0000
C(13)	-0.600979	0.242801	-2.475194	0.0149
C(14)	**0.004020**	**0.005583**	**0.720097**	**0.4731**
C(15)	-0.435355	0.132462	-3.286645	0.0014
C(16)	**0.003093**	**0.002497**	**1.238641**	**0.2182**
C(17)	0.000403	0.001246	0.323588	0.7469
C(18)	-0.210310	0.119637	-1.757890	0.0817
C(19)	0.309955	0.089476	3.464104	0.0008

6.3.2 Prevalence

The estimation results of the two equations constituting the prevalence system model for the UK are reported below together with the estimation output of the model as a whole.

Table 6.26: Prevalence equation (UK)

Dependent Variable: **Change in prevalence (UK)**
Method: Least Squares
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 15 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price – C(1)	24.39122	29.71090	0.820952	0.4157
TPD2+PP penetration – C(2)	0.311121	0.209438	1.485501	0.1439
C – C(3)	-0.155055	0.097487	-1.590525	0.1183

AR(1) – C(4)	-0.800223	0.119349	-6.704904	0.0000
AR(2) – C(5)	-0.608348	0.168030	-3.620484	0.0007
AR(3) – C(6)	-0.340353	0.108971	-3.123342	0.0030
AR(12) – C(7)	0.241178	0.113386	2.127054	0.0386

R-squared	0.490603	Mean dependent var	-0.080443
Adjusted R-squared	0.426928	S.D. dependent var	1.826879
S.E. of regression	1.382975	Akaike info criterion	3.604764
Sum squared resid	91.80573	Schwarz criterion	3.860243
Log likelihood	-92.13101	Hannan-Quinn criter.	3.703560
F-statistic	7.704845	Durbin-Watson stat	2.169288
Prob(F-statistic)	0.000008	Wald F-statistic	1.385540
Prob(Wald F-statistic)	0.260014		

Inverted AR Roots	.80	.68+.45i	.68-.45i	.35-.79i
	.35+.79i	-.06+.94i	-.06-.94i	-.47-.79i
	-.47+.79i	-.81-.43i	-.81+.43i	-.95

Table 6.27: Price equation (UK)

Dependent Variable: %**Change in price (UK)**
Method: Least Squares
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 4 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TPD2+PP penetration – C(8)	-0.000646	0.001148	-0.563310	0.5757
C – C(9)	0.000993	0.001441	0.689420	0.4937
AR(1) – C(10)	-0.192167	0.087678	-2.191746	0.0330
AR(12) – C(11)	0.700237	0.074611	9.385222	0.0000

R-squared	0.746224	Mean dependent var	0.002454
Adjusted R-squared	0.731296	S.D. dependent var	0.005781
S.E. of regression	0.002997	Akaike info criterion	-8.712628
Sum squared resid	0.000458	Schwarz criterion	-8.566640
Log likelihood	243.5973	Hannan-Quinn criter.	-8.656173
F-statistic	49.98816	Durbin-Watson stat	1.760053
Prob(F-statistic)	0.000000	Wald F-statistic	0.317318
Prob(Wald F-statistic)	0.575692		

Inverted AR Roots	.96	.83-.48i	.83+.48i	.47-.84i
	.47+.84i	-.02-.97i	-.02+.97i	-.50+.84i
	-.50-.84i	-.86+.48i	-.86-.48i	-.99

Table 6.28: Simultaneous equation model of prevalence (UK)

System (UK)
Estimation Method: Iterative Least Squares
Sample: 2013M02 2017M08
Included observations: 67
Total system (balanced) observations 110
Convergence achieved after 12 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	24.39086	39.95897	0.610398	0.5430

C(2)	**0.311120**	**0.270258**	**1.151195**	**0.2524**
C(3)	-0.155054	0.135334	-1.145714	0.2547
C(4)	-0.800223	0.137375	-5.825118	0.0000
C(5)	-0.608349	0.163921	-3.711226	0.0003
C(6)	-0.340354	0.137449	-2.476216	0.0150
C(7)	0.241178	0.110446	2.183684	0.0313
C(8)	**-0.000646**	**0.001188**	**-0.544292**	**0.5875**
C(9)	0.000993	0.001127	0.881118	0.3804
C(10)	-0.192167	0.080750	-2.379787	0.0192
C(11)	0.700237	0.078014	8.975804	0.0000

6.3.3 Simultaneous equation under alternative approach.

The consumption equations for France and the UK under the alternative approach are reported below (notice that, for both countries, the adjusted consumption variables are best explained by the same AR structure, ie one with one AR(1) and one AR(12) term).

Table 6.29: Alternative consumption equation (UK)

Dependent Variable: **Number of sticks (de-trended and de-seasonalised)**
Method: Least Squares
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 2 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price – C(1)	-1.20E+09	1.29E+09	-0.933094	0.3553
TPD2+PP penetration – C(2)	**1.05E+08**	**29292335**	**3.594679**	**0.0007**
C – C(3)	-24195560	14706038	-1.645281	0.1062
AR(1) – C(4)	0.465818	0.145384	3.204064	0.0024
AR(12) – C(5)	-0.149243	0.088668	-1.683170	0.0986

R-squared	0.407000	Mean dependent var	-14640942
Adjusted R-squared	0.359560	S.D. dependent var	69626918
S.E. of regression	55720688	Akaike info criterion	38.59611
Sum squared resid	1.55E+17	Schwarz criterion	38.77859
Log likelihood	-1056.393	Hannan-Quinn criter.	38.66668
F-statistic	8.579251	Durbin-Watson stat	2.180760
Prob(F-statistic)	0.000024	Wald F-statistic	7.328286
Prob(Wald F-statistic)	0.001618		

Table 6.30: Alternative consumption equation (FR)

Dependent Variable: **Number of sticks (de-seasonalised)**
Method: Least Squares
Sample (adjusted): 2013M02 2017M08
Included observations: 55 after adjustments
Convergence achieved after 2 iterations
HAC standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
% Change in price – C(1)	1.48E+09	1.05E+09	1.414638	0.1634
TPD2+PP penetration – C(2)	35391179	43936200	0.805513	0.4243
C – C(3)	-52446992	22839261	-2.296352	0.0259

AR(1) – C(4)	0.672015	0.085446	7.864783	0.0000
AR(12) – C(5)	-0.145444	0.059326	-2.451583	0.0178

R-squared	0.503886	Mean dependent var	-44632861
Adjusted R-squared	0.464197	S.D. dependent var	1.08E+08
S.E. of regression	78939336	Akaike info criterion	39.29277
Sum squared resid	3.12E+17	Schwarz criterion	39.47525
Log likelihood	-1075.551	Hannan-Quinn criter.	39.36333
F-statistic	12.69581	Durbin-Watson stat	2.182962
Prob(F-statistic)	0.000000	Wald F-statistic	1.194752
Prob(Wald F-statistic)	0.311274		

The price equations for France and the UK are the same as in Table 6.21 and Table 6.24. However to facilitate the interpretation of the simultaneous equations models the coefficients of the price equations can be renumbered as follows:

Dependent variables and coefficients codes of price equation for the UK
TPD2+PP penetration – C(6)
C – C(7)
AR(1) – C(8)
AR(12) – C(9)
Dependent variables and coefficients codes of price equation for France
TPD2+PP penetration – C(6)
C – C(7)
AR(1) – C(8)
AR(9) – C(9)

The estimation output of the simultaneous equating models for consumptions are below.

Table 6.31: Alternative simultaneous equation model of consumption (UK)

System
Estimation Method: Iterative Least Squares
Sample: 2013M02 2017M08
Included observations: 67
Total system (balanced) observations 110
Convergence achieved after 4 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-3.22E+08	8.78E+08	-0.366962	0.7144
C(2)	**92892040**	**46207404**	**2.010328**	**0.0471**
C(3)	-24532019	12464725	-1.968115	0.0518
C(4)	0.490354	0.124495	3.938731	0.0002
C(5)	-0.152944	0.100923	-1.515453	0.1328
C(6)	**-0.000646**	**0.001188**	**-0.544296**	**0.5874**
C(7)	0.000993	0.001127	0.881163	0.3803
C(8)	-0.192167	0.080750	-2.379786	0.0192
C(9)	0.700237	0.078014	8.975804	0.0000

Table 6.32: Alternative simultaneous equation model of consumption (FR)

System:
Estimation Method: Iterative Least Squares
Sample: 2012M11 2017M08
Included observations: 67
Total system (unbalanced) observations 113
Convergence achieved after 6 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	2.25E+09	8.89E+08	2.528743	0.0129
C(2)	**15596221**	**73895746**	**0.211057**	**0.8333**
C(3)	-41315001	25360103	-1.629134	0.1063
C(4)	0.679995	0.098163	6.927215	0.0000
C(5)	-0.147897	0.071537	-2.067419	0.0412
C(6)	**0.003093**	**0.002497**	**1.238641**	**0.2183**
C(7)	0.000403	0.001246	0.323588	0.7469
C(8)	-0.210310	0.119637	-1.757890	0.0817
C(9)	0.309955	0.089476	3.464104	0.0008

The statistical significance of the coefficient C(2) in Table 6.31 confirms results we obtained with the alternative time-series model of Table 6.17:, in the UK the introduction of TPD2+PP is associated with an increase in tobacco consumption. However, the alternative simultaneous equation model for France indicates that there is is no statistically significant relationship between TPD2+PP and tobacco consumption.

Finally, the prevalence equations for the UK under the alternative approach is the same provided in Table 6.19, whilst the price equation is the same as in Table 6.21. For the same of interpretation of the simultaneous equation system the coefficients of the two equations (prevalence equation and price equation) are labelled as follows:

Dependent variables and coefficients codes of the prevalence equation for the UK
% Change in price – C(1)
TPD2+PP penetration – C(2)
C – C(3)
Dependent variables and coefficients codes of price equation for the UK
TPD2+PP penetration – C(4)
C – C(5)
AR(1) – C(6)
AR(9) – C(7)

As Table 6.33 shows there is no statistically significant relationship between prevalence and the introduction of TPD2+PP in the UK.

Table 6.33: Alternative simultaneous equation model of prevalence (UK)

System:
Estimation Method: Iterative Least Squares
Sample: 2012M02 2017M08
Included observations: 67
Total system (unbalanced) observations 122
Convergence achieved after 4 iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-7.770281	19.85453	-0.391361	0.6963
C(2)	**-0.141121**	**0.460649**	**-0.306353**	**0.7599**
C(3)	0.035668	0.147073	0.242516	0.8088
C(4)	**-0.000646**	**0.001188**	**-0.544292**	**0.5873**
C(5)	0.000993	0.001127	0.881118	0.3801
C(6)	-0.192167	0.080750	-2.379787	0.0190
C(7)	0.700237	0.078014	8.975804	0.0000