

### ‘The Smoking Pipe’: A model of the annual inflow and outflow of cigarette smokers in England in 2014

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#### Abstract

**Background and aims:** Developing effective tobacco control policies may be helped by estimating factors contributing to change in the numbers of smokers in the population from one year to the next and modelling what would happen if factors were to change. ‘The Smoking Pipe’ aims to do this for England.

**Methods:** Data from the Smoking Toolkit Study (STS) and several other sources were used. The STS involves monthly household surveys of representative samples of the adult population of England. An Excel spreadsheet was constructed using the data to model the change in prevalence from 2013 to 2014 and contributors to that change. The predicted prevalence change was compared with the observed change.

**Results:** The total inflow into the population of smokers was estimated to be 335,230, mostly made up of people taking up regular smoking post 16 years. The total outflow was 683,932 people, mostly made up of smokers stopping. Take-up at age 16 or earlier, relapse of long-term ex-smokers, and migration made small but important contributions to prevalence change. The predicted prevalence reduction was 0.8% which was similar to the reduction observed. Use of aids to cessation accounted for approximately a third of the prevalence reduction. A 20% increase in the rate of quit attempts *or* quit success would have increased the prevalence reduction to above 1%.

**Conclusions:** The number of smokers aged 16+ in England fell by approximately 350,000 in 2014 to an estimated 8.1 million, the fall being mostly driven by smoking cessation. Use of aids to cessation accounted for almost one third of the prevalence reduction.

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**Data access:** The Excel spreadsheet and accompanying notes are included as a supplementary file with this paper.

**Commentaries:** Readers are invited to comment on this article including presenting results of additional data analyses by going to: [www.smokinginbritain.co.uk](http://www.smokinginbritain.co.uk).

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## Introduction

Like some other countries, the English government aims to reduce cigarette smoking to negligible levels as quickly as possible subject to political and commercial constraints (1). To this end, since 1998 it has developed a succession of tobacco control strategies combining a range of policies that aim to reduce the take up of smoking and increase the rate of cessation. Both take-up and cessation have an important part to play, and it is useful when considering future policies to be able to estimate how far existing policies have achieved their goals, and what impact on overall prevalence would be achieved by improving performance. Questions have also been raised about the extent to which migration may also influence smoking prevalence so it is useful to model this.

While there are several widely used models of the effects of tobacco control interventions on prevalence such as SimSmoke (2), there is value in having a simple, easily understood model that uses available population level data in a country to model major factors contributing to observed changes in prevalence in the smoking population. This paper reports a model of the extent to which different factors contribute to the annual inflow and outflow of people into ‘The Smoking Pipe’ in England, a metaphorical pipe containing smokers at a given point in time. This model can then be used to predict what would happen if policies were more or less successful in either reducing take-up of smoking, increasing cessation, or preventing relapse.

Specific questions that the model aims to answer are:

1. How far does the prevalence reduction predicted by the model from 2013 to 2014 match the observed reduction?
2. What effect does a) take-up of smoking at 16 or younger, b) take-up of smoking post 16, c) relapse back to smoking among previous ex-smokers, d) migration, and e) smoking cessation have on prevalence?
3. How far do smoking cessation aids and services contribute to smoking prevalence reduction?
4. What would have been the effect on smoking prevalence of:
  - a. reducing take-up of smoking by a 20%?
  - b. increasing the quit attempt rate by 20%?
  - c. increasing the success rate of quit attempts by 20%?

## Methods

Table 1 shows the parameters entered directly into the model. The number of the entry corresponds to the explanation and comment in the numbered list following the table.

*Table 1: Parameters directly entered into the model*

1. Numbers of people in England aged 16+ at the start of 2014	43,834,096
2. Proportion of people aged 16+ at the start of the year who smoked	0.193
3. Proportion of 16 year olds who smoked in 2014	0.076
4. Number of 16 year olds at the start of 2014	632,294
5. Proportion of people age 16 to 25 estimated to take up smoking	0.021

6. Number of people aged between 17 and 25 at the start of 2014	6,289,319
7. Total number of deaths during the year	450,605
8. Proportion of people dying during the year who were smokers	0.191
9. Number immigrating to UK each year	560,000
10. Number emigrating from UK each year	316,000
11. Proportion of smoking in accession immigrants	0.025
12. Proportion of smoking in accession émigrés	0.017
13. Proportion of smokers who tried to stop during the year ('attempters')	0.370
a. Proportion of attempters who used nicotine replacement therapy bought over the counter (NRT OTC)	0.165
b. Proportion of attempters who used a prescription medicine with limited behavioural support, or an e-cigarette bought from a shop	0.391
c. Proportion of attempters who used specialist behavioural support and a prescription medicine	0.032
d. Relative increase in success rate expected from NRT OTC compared with unaided cessation	1.0
e. Relative increase in success rate expected from prescription medicine or e-cigarette compared with unaided cessation	1.5
f. Relative increase in success rate expected from specialist behavioural support plus prescription medicine compared with unaided cessation	3.0
g. Proportion of unaided attempters who relapsed during the year	0.820
h. Proportion of NRT OTC users who relapsed during the year	0.861
i. Proportion of prescription medicine or e-cigarette users who relapsed during the year	0.779
j. Proportion of specialist service users who relapsed during the year	0.792
k. Overall proportion of smokers who tried to stop during the year who relapsed before the end of the year <sup>2</sup>	0.809
14. Proportion of 16+ population who stopped smoking in previous years (ex-smokers)	0.157
15. Proportion of ex-smokers at the start of the year who relapse during the year	0.010

### Sources and comments

1. Taken from mid-year 2014 population estimate from Office of National Statistics (see Sources). The figure was reduced by a ratio of half the estimated UK population growth for the year since mid 2013 ( $0.82\%/2=0.41\%$ ) to arrive at a figure for the start of 2014 (44013062/1.0041). NB: Figures are rounded here but exact figures are used in calculations.

2. The estimated cigarette smoking prevalence of people aged 16+ in 2013 in England from the Smoking Toolkit Study (see Sources). Surveys were carried out throughout the year.
3. The estimated cigarette smoking prevalence of people aged 16 in 2014 in England from the Smoking Toolkit Study. Used as a proxy for the proportion of 15 year old smokers who turned 16 in 2014.
4. Taken from mid-year 2014 population estimate of 634876 from Office of National Statistics (see Sources). This figure was divided by 1.0041 (half the annual population growth) to give an estimate for the figure at the start of 2014.
5. Data from Smoking Toolkit Study. In 2014, the percentage of people who had ever smoked cigarettes for a year or more increased at a rate of 2.1% per year of age between 16 and 25 (uptake after age 25 is negligible) as determined by a regression model for the years 2010-2014. This was used as a proxy for the take up at each age in the year 2014. The years 2010-2014 were used to create sample sizes large enough for reasonable stability. This measure would not be responsive to short-term fluctuation in the take up rate.
6. Taken from mid-year 2014 population estimate of 6,314,997 from Office of National Statistics which provides figures in age bands starting at age 15. The figure was divided by 1.0041 (half the annual population growth) to give an estimate for the figure at the start of 2014.
7. Taken from the 2014 figure provided by the Office of National Statistics filtered for ages 15+ (see Sources).
8. This is not the same as the number of smoking-related deaths. This is because many smokers die from causes other than smoking and many ex-smokers die as a result of having previously smoked. The proportion was obtained from the Department of Health for 2009 and is assumed to have remained the same. It was derived by estimating the standardised mortality ratio for smokers versus non-smokers at each age and weighting by the numbers in each age category to give a figure for the overall relative death rate for smokers and non-smokers and applying to the relative numbers of smokers and non-smokers.
9. Taken from Office of National Statistics figure for UK for year ending March 2014 (see Sources). A total of 560,000 people entered as long-term immigrants of whom 265,000 were from non-EU countries. We do not know how many end up in England and so just use the UK figures.
10. Taken from Office of national Statistics figure for year ending March 2014.
11. Smoking prevalence in EU countries is mostly typically higher than the UK. Cigarette smoking prevalence from non-EU countries that are the main source of immigration is probably similar. An upper estimate of the likely smoking prevalence among immigrants to the UK overall is 25%.
12. Emigration tends to occur in people from higher social grades and so the smoking prevalence is likely to be lower than the national average. A lower bound estimate of the prevalence is 17%.
13. Data from the Smoking Toolkit Study for 2014. This is the percentage throughout the year who reported that they had tried to stop at least once in the previous 12 months ('attempters').
  - a. The proportion of attempters who reported using NRT OTC in at least one quit attempt but not medicine on prescription, an e-cigarette or a specialist service.
  - b. The proportion of attempters who reported using a prescription medicine (NRT, varenicline or bupropion) in at least one quit attempt but did not report receiving individual counselling or group support in any quit attempt.

- c. The proportion of attempters who reported using a prescription medicine as well as individual counselling or group support in at least one quit attempt.
  - d. Data from the Smoking Toolkit Study. The ratio of the proportion of those using NRT OTC in the most recent quit attempt who were currently abstinent compared with those using no cessation aid, after adjusting statistically for potential confounding variables such as level of cigarette dependence (3).
  - e. Data from the Smoking Toolkit Study. The ratio of the proportion of those using medicine on prescription in the most recent quit attempt, or an e-cigarette bought from a shop who were currently abstinent compared with those using no cessation aid, after adjusting statistically for potential confounding variables such as level of cigarette dependence (4).
  - f. Data from the Smoking Toolkit Study. The ratio of the proportion of those using individual counselling or group support and a prescription medicine in the most recent quit attempt who were currently abstinent compared with those using no cessation aid, after adjusting statistically for potential confounding variables such as level of cigarette dependence (3).
  - g. Data from the Smoking Toolkit Study. The proportion of those attempters using no aid to cessation in the most recent quit attempt who were currently not abstinent.
  - h. Data from the Smoking Toolkit Study. The proportion of those attempters using NRT OTC but no prescription medicine or counselling or group support in the most recent quit attempt who were currently not abstinent.
  - i. Data from the Smoking Toolkit Study. The proportion of those attempters using a prescription medicine or e-cigarette but no prescription medicine or counselling or group support in the most recent quit attempt who were currently not abstinent.
  - j. Data from the Smoking Toolkit Study. The proportion of those attempters using a individual counselling or groups support plus a prescription medicine in the most recent quit attempt who were currently not abstinent.
  - k. Data from the Smoking Toolkit Study. The overall proportion of those attempters who were currently not abstinent.
14. Data from the Smoking Toolkit Study. The proportion of people aged 16+ who stated that they had smoked for at least a year but had stopped at least a year ago.
15. Data from Stapleton (5) on relapse rates following 12 months of abstinence. The rate is highest in the first year and declines rapidly thereafter. The average number of years stopped was 20 and the lifetime risk of relapse for ex-smokers of more than a year is estimated at 20%, so the overall risk of relapse in ex-smokers at the start of 2014 was estimated at 1% in 2014.

Key derived outcomes are shown in Table 2. The computations used to derive these outcome are given in the spreadsheet as a supplementary file.

## Results

Table 2 shows the main outputs from the model. The net outflow was 348,703 with a resulting fall in smoking prevalence of 0.79% to a figure of 18.51%. This was similar to the observed reduction of 0.8% to a prevalence of 18.5% (see [www.smokinginengland.info](http://www.smokinginengland.info)).

Take-up of sustained regular smoking at 16 or younger had a small effect on prevalence because this age group is only a small proportion of the population. Migration and relapse to smoking by long-term ex-smokers have a somewhat larger effect but the largest contributor to inflow is take-up post 16. Cessation has the largest effect on prevalence of any parameter.

Use of smoking cessation aids and services accounts for approximately a third of the prevalence reduction (0.24% out of 0.79%).

Modelling the potential impact of a 20% reduction in take-up and a 20% increase in quit attempts and success of quit attempts indicates that the largest impact immediate would be achieved by an increase in quit attempts or quit success.

*Table 2: Derived parameters from The Smoking Pipe for 2014*

<b>Overall</b>	
16. Total inflow of smokers during 2014	335,230
17. Total outflow of smokers during 2014	683,932
18. Number of smokers aged 16+ at the start of 2014	8,459,980
19. Number of smokers aged 16+ at the end of 2014	8,111,278
20. Reduction in number of smokers during the year	348,703
21. Estimated number of people aged 16+ at the end of 2014	44,259,785
<b>Components of inflow</b>	
22. Number of new smokers aged 16+ during the year	180,130
a. New 16-year old smokers	48,054
b. Number taking up smoking post-16	132,076
23. Number of previous ex-smokers who relapsed to smoking during the year	68,820
24. Increase in number of smokers arising from migration during the year	86,280
<b>Components of outflow</b>	
25. Number of smokers who tried to stop and did not relapse during the year	597,867
a. Number of smokers who tried to stop during the year	3,130,193
b. Number of smokers who tried to stop but relapsed during the year	2,532,326
c. Number of smokers attempting to stop unaided	1,289,639
d. Number of smokers attempting to stop using NRT OTC	516,482
e. Number of smokers attempting to stop using prescription medicine or an e-cigarette but not counselling or group support	1,223,905
f. Number of smokers attempting to stop with counselling or group support and a prescription medicine	100,166
g. Number who stopped smoking unaided	232,135
h. Number who stopped smoking with NRT OTC	71,791
i. Number who stopped smoking with prescription medicine but not counselling or group support, or an e-cigarette	270,483
j. Number who stopped smoking with counselling or group support plus a medicine	20,835
k. Number of smokers estimated to have stopped because they used NRT OTC (recognising that there is no evidence for a benefit)	0
l. Number of smokers estimated to have stopped because they	90,161

used a prescription medicine or e-cigarette but not counselling or group support	
m. Number of smokers estimated to have stopped because they used counselling or group support plus a medicine	13,890
n. Number of smokers estimated to have stopped because they used a cessation aid	104,051
26. Number of smokers who died	86,066
<b>Prevalence impact</b>	
27. Expected prevalence at the end of the year	18.51%
28. Expected drop in prevalence during the year	0.79%
29. Prevalence reduction attributable to use of aids to cessation	0.24%
30. Total contribution of take-up of smoking in 2014 to prevalence	0.41%
31. Contribution of take-up at 16 or younger to prevalence in 2014	0.11%
32. Contribution of relapse in previous ex-smokers to prevalence in 2014	0.16%
33. Contribution of cessation to prevalence reduction in 2014	1.36%
34. Contribution of migration to prevalence change in 2014	0.20%
35. Expected additional prevalence reduction from a 20% reduction in take up	0.08%
36. Expected additional prevalence reduction from a 20% increase in cessation attempts (from 37% to 44.4%)	0.27%
37. Expected additional prevalence reduction from a 20% increase in success of cessation attempts (from 19% to 22.8%)	0.27%

## Discussion

The Smoking Pipe Model predicted a reduction in prevalence of 0.8% from 19.3% to 18.5% which matched the observed reduction. The model indicated that the main source of inflow into the population of smokers was take-up post 16 while the main source of outflow was cessation. Migration, relapse of long-term ex-smokers and take-up at aged 16 or below played a smaller role in driving prevalence. For a given percentage change in key parameters, increasing quit attempts or quit success would have the largest immediate impact on prevalence.

The model produces a large number of outputs and different users may be interested in different ones. For example, it is interesting to note that use of aids to cessation accounted for almost a third of the reduction in prevalence. There has been discussion in the literature about whether use of cessation aids and services has enough of an impact on prevalence to make them worth investing in. This model clearly shows that in England they do, even though most national surveys would not have sufficient statistical power to detect the effect in any one year.

Another output of interest is the contribution to overall prevalence of take-up of smoking. It is clear that the numbers involved in any one year mean that the impact of interventions such as standard packaging, will take many years to accumulate an effect that can be detected in prevalence surveys. This does not mean these policies may not be extremely cost-effective, it just means that their impact will not be able to be detected using the standard survey methods for many years.

It is also important to note that, while the contribution of smoking uptake at age 16 and younger is small, many of those who take up regular smoking post 16 will have had their first experiences of smoking at a much younger age, and there is evidence that this early exposure is important in driving future regular smoking, even when there is a gap in smoking activity (6).

The model also makes clear the size of the task facing the tobacco industry in replenishing the pool of smokers who stop smoking or die. To stand still in terms of numbers, they would need to recruit more than half a million smokers each year.

The model allows users to examine what would happen if key parameters had been different. A 20% increase in quit attempts (from 37% to 44.4%) *or* quit success (from 19% to 22.8%) would have increased the prevalence reduction by 0.27 percentage points to more than 1%.

The model did not differentiate between prescription medicine use and electronic cigarette use. The reason was that, at a population level, the improvement in success rates from these two aids to cessation have thus far been similar (4). It is important to try to estimate, however, what the impact of these two types of aid to cessation are individually. Calculating the precise figure requires a number of assumptions and is beyond the scope of this paper, but, given that use of electronic cigarettes has markedly expanded use of this category of aid, the impact is likely to be tens of thousands of additional ex-smokers.

A major strength of the model is that it is wholly transparent and easy to see the impact of each of the assumptions and how they are being used. The model has a number of important limitations.

First, many of the parameters entered into the model are subject to a margin of error that could affect the output. With that in mind, it is perhaps surprising that the predicted prevalence reduction was so close to what was observed. This was not tautologous because the observed figure emerged directly from a survey question about current smoking status while the parameters in the model were derived from different questions and figures from other sources. Nevertheless, the close match between the predicted and observed prevalence reduction must be due to chance to some degree.

Secondly, the model uses a number of proxy parameters. For example, it uses the increase in ever-smoking prevalence as a function of age from 16 to 25 as a proxy for take up of smoking in the year at each age in that range. It would be better to have a more direct measure resulting from asking smokers at each age whether they took up smoking in the past 12 months.

Thirdly, some of the parameters entered into the model cover a slightly different time period than the start to end of 2014. This is because the surveys that generated these parameters accumulated respondents over the course of the year and asked about activities in the past 12 months. This did not make a substantial difference for 2014 because there had been little change from 2013. In future years, when there may be a large change in cessation rates, a different approach may be needed.

## Sources

Population: <http://www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/mid-2014/index.html>

Migration: <http://www.ons.gov.uk/ons/rel/migration1/migration-statistics-quarterly-report/august-2014/index.html>

Smoking prevalence, uptake and cessation: <http://www.smokinginengland.info>

## Supplementary file

Excel spreadsheet of The Smoking Pipe Model 2014

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