AIMING HIGH: WHY THE UK SHOULD AIM TO BE TOBACCO-FREE

A REPORT BY CANCER RESEARCH UK AND THE UK HEALTH FORUM

TECHNICAL SUMMARY

CANCER RESEARCH UK

UK HEALTH FORUM PREVENTION FIRST

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The following scenarios from this report were used in the accompanying Tobacco Policy Report:

- Scenario 5 **–** This scenario was used to estimate the tobacco attributable fraction of smoking-related diseases in the baseline scenario
- ‘Tobacco-free society’ (TFS) policy scenario – This scenario was used to estimate the impact of the tobacco-free society policy on health and costs

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About the UK Health Forum

The UK Health Forum is a charitable alliance of professional and public interest organisations working to reduce the risk of avoidable non-communicable diseases (NCDs) by developing evidence-based public health policy and supporting its implementation through advocacy and information.

Working with and through our members, we are a centre of expertise in policy research and development, epidemiological and economic modelling of NCDs, and information provision.

UK Health Forum is a registered charity 803286.

About Cancer Research UK

Cancer Research UK is the world's largest independent cancer charity dedicated to saving lives through research. We support research into all aspects of cancer through the work of over 4,000 scientists, doctors and nurses. In 2013/14, we spent £386 million on research institutes, hospitals and universities across the UK – including a £35 million contribution we made to the Francis Crick Institute. We receive no funding from the Government for our research.

Cancer Research UK is a registered charity in England and Wales (1089464), Scotland (SC041666) and the Isle of Man (1103), Royal Patron, Her Majesty the Queen.

This project has been commissioned by the Cancer Research UK Policy Research Centre for Cancer Prevention. To learn more about this research centre, please click here.

Executive summary

KEY STATISTICS

EVEN IF CURRENT TRENDS OF DECREASING SMOKING PREVALENCE WERE TO CONTINUE:

- Tobacco could still cause 1.35 million new cases of disease over the next twenty years[2]. This includes 580,600 cases of cancer.
- A radical upgrade in prevention would be needed to achieve our tobacco-free ambition by 2035 for the UK. If current trends were to continue, smoking prevalence could decrease from 18% and 17% among men and women in 2015 to 10% in 2035 – missing our ambition.
- The poorest in society would increasingly bear the disease burden caused by smoking over the next twenty years. 2.4% of men and 2.6% of women from the least deprived income quintile are predicted to smoke in 2035, compared to 15.7% of men and 14.3% of women from the most deprived income quintile. The prevalence of smokers is projected to drop most markedly among the highest two income groups.
- Tobacco-related diseases could cost an additional £3.6 billion per year in 2035. This includes £542 million in direct NHS costs and £3.03 billion in indirect societal costs.

ACHIEVING A TOBACCO-FREE UK WOULD DRAMATICALLY IMPROVE THE NATION'S HEALTH:

- Compared to the current trend of decline, achieving a tobacco-free UK by 2035 could avoid around new 97,500 cases of disease, including around 36,000 cancers over the next 20 years.
- In the year 2035 alone, this is equivalent to avoiding around 12,355 new cases of disease across the UK, including around 5,100 cancers.
- Achieving a tobacco-free ambition would avoid around £615 million in costs in the year 2035 alone. These include £67 million in direct NHS costs, and £548 million in indirect societal costs.

[2] Values are derived by estimating the avoidable costs and diseases resulting from a 100% reduction in the prevalence of smoking below the predicted trend. This difference provides an estimate of the total directly attributable impact of smoking over the period of 2015 and 2035.

Smoking is still the biggest preventable cause of cancer in the UK, and the biggest cause of premature mortality and health inequalities. The single best thing a smoker can do for their health is quit. And the best thing a Government can do for the health of the country is to reduce the number of people who smoke.

Tobacco control policy has been successful in supporting individuals to quit and to reduce uptake. Smoking prevalence in the UK has decreased over the past 35 years, largely as a result of a range of evidence-based tobacco control policies including comprehensive restrictions on tobacco marketing, the tobacco duty escalator and smoke-free workplaces.

But it is not a given that smoking rates will continue to decrease. Latest data from the Office for National Statistics (ONS) points to smoking rates having stalled across the UK in 2014[i], whilst the Smoking Toolkit Study for England shows that smoking rates in England did not decline in 2015 – the first time since the survey started in 2007[ii].

The report by Action on Smoking and Health (ASH) 'Smoking Still Kills'[iii], endorsed by Cancer Research UK and the UK Health Forum, sets a clear plan of action that the Government should follow over the next five years to maintain progress on tackling tobacco. In the Department of Health's new Tobacco Control Strategy for England, we want to see a comprehensive approach which protects people from the lethal grip of tobacco. This approach must include an ambition for a 'tobacco-free' UK by 2035, where less than 5% of the population smoke across all socio-economic groups – a core recommendation of the Smoking Still Kills report.

We believe that quantifying the impact of further tobacco interventions is an important lever for change. This study uses a state of the art simulation model to measure dynamic changes in smoking prevalence over time by age, gender, sex and socio-economic status. It tested the impact of achieving a tobacco-free UK on the future burden of smoking-related diseases and cost savings to the NHS and society.

It should be noted the assumptions in this report are based on a continued decline in smoking. In recent years there have been substantial reductions to public health funding for Stop Smoking Services and mass media quit campaigns in particular, which could seriously jeopardise the progress that has been made. This has the potential to make the baseline assumptions in the report optimistic.

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Introduction

Tobacco is the leading cause of death in the UK (1). This is despite a halving of smoking prevalence over the past 35 years with around 18% of the UK population smoking. While progress in reducing smoking rates has been made over recent years, it is clear that more is required to reduce tobacco consumption.

Tobacco predisposes individuals to a range of health conditions – chiefly cancers, coronary heart disease (CHD), stroke and chronic obstructive pulmonary disease (COPD). These non-communicable diseases (NCDs) are major causes of morbidity and mortality in the UK. A recent report estimates that the lifetime risk of developing cancer of those born in 1960 is approximately 54% for males and 48% for females (2), with old age and behavioural factors contributing to the increase in lifetime risk of cancers (3). It has been estimated that 80% of all deaths in people under the age of 75 years in England in 2012 were attributable to NCDs, of which cancers accounted for the greatest contribution at 42% (4). Yet, it has been estimated that at least 80% of all CHDs, strokes and type 2 diabetes are preventable (5) and more than 4 in 10 cases of cancer are preventable (6) by reducing adverse behavioural risk factors.

The burden of NCDs is evident not only among the affected individuals and their families, but also across health systems and the wider society, due to increased pressures on productivity and scarce resources (7). It is estimated that the global economic burden of NCDs will amount to more than £20 trillion by 2030, representing 48% of the projected global GDP (7). A report by the International Monetary Fund, 2011 identified "*health care costs as the main source of fiscal pressure for middle- and high-income countries, and projects that, unless action is taken, the impact of increasing health expenditures in these countries could dwarf the impact of the current economic crisis*", as cited in (8). The pervasive and costly nature of NCDs, alongside significant increases in life expectancy (9), has resulted in urgency among policy makers and health authorities to establish preventative public health interventions that are both effective and cost-effective.

Non-fiscal policies in the UK such as the ban on tobacco advertising and the creation of the stop-smoking services are helping the National Health Service (NHS) to save £380 million per year (10). The public health evidence on standardised packaging for tobacco products, another non-fiscal policy measure, has been independently reviewed (11) and recently been passed as legislation in the UK (12).

Understanding how trends in smoking prevalence will change over time and the resultant impact on tobacco related disease and cost burden is necessary for policy planning and decision-making. Computer simulation models are a useful way by which to test the impact of policy interventions on scenarios, and present the effects of these interventions in terms of changes in key parameters, such as mortality cases and costs incurred by the public purse. These models are able to identify where a society may be heading should current trends continue, giving policy makers unprecedented opportunities to act to modify the course of events (13).

Project aims

To evaluate the effect of smoking prevalence on the future burden of NCDs, Cancer Research UK (CRUK) commissioned the UK Health Forum (UKHF) to project trends in smoking prevalence from the year 2015 to the year 2035, evaluate the impact of smoking on the epidemiology of NCDs – namely CHD, stroke, COPD and a range of cancers, and provide an economic case for investment in public health interventions. Projections and simulations were made possible by adapting a predictive microsimulation model originally developed for the Foresight: Tackling Obesities Future Choices report (14). The key quantitative outputs are summarised in Table 1 below:

Table 1 Output data

Output data from the projection programme

1. Projection of the prevalence of smoking from 2015 to 2035, stratified by sex and 10-year age groups
2. Projection of the prevalence of smoking from 2015 to 2035, stratified by sex and income quintiles

Output data from the microsimulation programme

3. Projection of the prevalence and incidence rates of smoking related diseases from 2015 to 2035
4. Impact of the agreed intervention scenarios on the incidence and prevalence of smoking-related diseases
5. Impact of the agreed intervention scenarios on the costs incurred by the NHS and wider society

Methodology

Data collection

Table 2 provides a summary of the key parameters that were required for input into the UKHF model and for which data were collected. The information sources from which data were extracted for inclusion in the model have been summarised in Appendix 1.

Table 2 Input data

Risk factor data
1. Historical and current prevalence of smoker status (never smoker, ex-smoker and smoker), reported by age, sex and income quintile
Disease data
2. Most recent incidence, mortality and survival of the diseases of interest, reported by age and sex
3. Relative risk of acquiring the diseases of interest, reported by age and sex, where available
Demographic data
4. Most recent and projected UK population, reported by age and sex
5. Most recent mortality and fertility rates of the UK population
Health economic data
6. Mean utility weights of the diseases of interest prior to treatment intervention
7. Most recent direct NHS costs associated with the diseases of interest
8. Most recent indirect societal cost associated with the diseases of interest

Risk factor data

Smoking prevalence data were extracted from the General Household Survey (GHS)/General Lifestyle Survey (GLS) (15), following issue by special license from the UK Data Service for years 2000 to 2012. It is to be noted that some modules from these surveys were merged with the Opinions and Lifestyle Survey in 2012 (16). Smoking was categorised according to current smokers, ex-smokers and never smokers. To note, where non-smokers were included in our analyses, this refers to a combined group of never and ex-smokers.

Socioeconomic status

Socioeconomic data for smoking were presented by income quintiles. Gross income quintile data were extracted from GHS for years 2000 to 2011. It was not possible to include 2012 data for smoking prevalence by socioeconomic status due to a lack of equivalent gross income quintile data in the 2012 GHS dataset.

Disease data

Overview

CRUK commissioned the UKHF to investigate certain diseases, the full list of which is outlined in Table 3. The following disease data inputs were required to run the model: incidence, mortality and survival rates, stratified by age and sex; smoking-related relative risks; and time lag period between risk factor and disease.

Following discussion with the CRUK Statistical Information team, cancers were classified as tobacco-related (17) based upon published literature that supports this disease association. We note that oral cancer was defined as cancer of the oral cavity and pharynx (which includes cancers of the nasopharynx, oropharynx and hypopharynx) in keeping with the definition used by CRUK (18).

Table 3 Diseases of interest

Cancers linked to smoking

1. Cervical cancer
2. Gastric (stomach) cancer
3. Hepatic (liver) cancer
4. Laryngeal cancer
5. Leukaemia
6. Lung cancer
7. Nasal cavity and paranasal sinuses
8. Oral and pharyngeal cancer
9. Ovarian cancer
10. Bladder cancer
11. Oesophageal cancer
12. Pancreatic cancer
13. Colorectal (bowel) cancer
14. Renal (kidney) and ureteral cancer

Other diseases linked to smoking

15. Chronic Obstructive Pulmonary Disease (COPD)
16. Coronary Heart Disease (CHD)
17. Stroke

Incidence and mortality

Incidence and mortality data for cancers of interest were collected from the CRUK statistical information repository. Data for the other NCDs – namely CHD, COPD, and stroke – were identified from the published literature through searches of Science Direct and PubMed databases, and supplemented with searches of Google Scholar and relevant organisational websites. The most recent incidence and mortality data were included if they were presented as a proportion of the population, and stratified by age and sex.

As morbidity and mortality data for CHD were incomplete or unavailable, myocardial infarction (MI) data were used as a proxy for CHD. This was deemed appropriate considering MI is one of the major sub-classification of diseases that falls within the category of CHD. It was acknowledged that these figures would underestimate CHD cases in the population.

Survival

Where available, one-year and five-year cancer survival rates for England were obtained from the Office for National Statistics (ONS) (19). These data were presented as a proportion of the disease prevalence, by age and sex, and were classified by anatomical site using codes in the International Classification of Diseases, 10th Revision (ICD-10).

ONS survival data were not available for AML, CML and oropharyngeal cancer. Survival data for 'all leukaemias', obtained from the ONS (20), was used as a proxy measure for AML and CML; oral and pharyngeal cancer were calculated in the microsimulation programme using the latest incidence and mortality data, based on DISMOD-II equations (20). Only male survival data for laryngeal cancer was available from the ONS; survival rates of males were used as a proxy measure for female survival data. Survival rates for CHD, COPD and stroke were calculated in the microsimulation programme using the latest incidence and mortality data since one-year survival data for these diseases were not available.

Evidence exists demonstrating that only certain morphological subtypes of particular cancers are associated with exposure to tobacco smoking. The International Agency for Research on Cancer (IARC) monographs (17) highlighted that the following subtypes of cancers are associated with exposure to tobacco smoking: myeloid leukaemias, oesophageal adenocarcinoma and squamous cell carcinomas, and mucinous ovarian cancer. Survival data were only available for overall cancer categories. That is, only survival data for 'all leukaemias' could be used for myeloid leukaemia and for the latter two cancers, survival data were only available for 'all oesophageal cancers' and 'all ovarian cancers'.

Relative risks

Relative risks (RR) for cancers were collected from various data sources that were identified in the CRUK statistical information repository. Where RR data for certain diseases were not available through CRUK, a literature search was undertaken to collect RR data. A set of criteria, outlined in Table 4, were used to review studies for inclusion where several RR datasets where available for a particular disease. As a general observation, most RR data that were not available in the CRUK statistical information repository were, instead, obtained from the Dynamic Model for Health Impact Assessment (DYNAMO-HIA) (21); these repositories provided granular sets of RR data as required for input into the microsimulation programme. The full list of the input data sources are outlined in Appendix 1A.

Smoking RR data was not available for CML, thus odds ratios for CML was used instead as a proxy for RR, given that CML is a rare disease.

Limited evidence exists on the relative risks of smoking and the development of disease in the case of cancers of the nasal cavity and paranasal sinus. Given that the microsimulation model is not able to run without relevant relative risk data, it was thus agreed with CRUK that cancers of the nasal cavity and paranasal sinus would be excluded from our analysis. Refer to Appendix 2 for further details.

The ex-smoker RRs are assumed to decrease over time since smoking cessation. The ex-smoker RR was computed using a decay function method developed by Hoogenveen and colleagues (22). This function uses the current smoker RR for each disease as the starting point and then models the decline in relative risk of disease for an ex-smoker over time. The regression coefficients required to implement this function in the programme were available for all diseases except the following 6 cancers: AML, bowel cancer, cervical cancer, CML, and liver cancer. Regression coefficients for lung cancer were used as proxy data for the 6 diseases for which this data were not available. Further technical details of the method used are presented in Appendix 2.

Table 4 Inclusion criteria for source of RR data

Criteria	Preference
1. Type of RR data	RR of acquiring disease preferred over RR of death due to death
2. Size of study	Larger studies preferred over smaller ones
3. Study design	Average RR data derived from meta-analysis preferred over types of study design
4. Year of study	More recent data preferred over older ones
5. Granularity of data	RR data stratified by smoker status, age and sex preferred over single RR data

Time lags

A literature review was undertaken to identify data on the latent period, or time lag, between 'exposure' to the behavioural risk factor and the appropriate increase in risk of cancers. Time lag data were only available for several cancers (23, 24). The relative risk data used in the model have time lag components inherent in them since they are an average of risk across time. Given the lack of availability of time lag data, and the nature of the relative risk data used in the model, it was not deemed appropriate to and 'force fit' time lag data into the model.

Demographic data

National population distribution data, stratified by age and sex, were used in conjunction with national mortality distribution data. Principal projections data were obtained from the ONS as were mortality distribution data (25), and were pre-processed to render them into a form acceptable to the model. Migration of individuals into and out of the country was also modelled. Mortality distributions were used to compute the probability of death for the diseases of interest as well as other unspecified causes of death. Total fertility rates (TFR), stratified by the mothers' age, was used to project increases in the population over time. Further technical details of the method used are presented in Appendix 2.

Health economic data

Utility weights

Several techniques exist for estimating utility weights. For this project, utility weights were represented by EQ-5D scores (26), based on recommendations in the NICE guidelines (27). To enable comparisons between diseases and to maintain consistency, utility weight figures derived using other elicitation techniques were excluded from the project. US-based community scores were used to derive health-related utility weights for the UK population since UK scores were not available. Furthermore, utility weights for the specific cancers described above were not available in this data source and from a literature search that was conducted. To address these gaps in the data, utility weights were identified from the same data source for conditions that were considered to be suitable proxy measures.

Utility weights for CHD and stroke were derived from an analysis previously undertaken by UKHF (28). Utility weights for cancers were obtained from a catalogue of UK-specific EQ-5D scores that were based on the ICD-9 disease classification (29). Utility weights for AML, CML, and pancreatic cancer were not available in this data source and therefore, EQ-5D scores for conditions that we considered to be the next best alternative were used instead. For AML and CML – 'leukaemia of unspecified cell-type' was used. No other utility weights were identified that we considered to be suitable alternatives to those selected above. For pancreatic cancer, utility weight was obtained from a study conducted by Romanus and colleagues (30).

Direct NHS costs

Direct NHS costs were based on healthcare expenditure data obtained from the NHS England programme budgeting cost database (31). Diseases were categorised into groups and so they had to be disaggregated in order to acquire costs for specific diseases. The total NHS healthcare expenditure figures for each disease were divided by the incidence or prevalence data, as applicable, of the disease to obtain an estimate of the average healthcare cost incurred per individual. Expenditure figures included both healthcare and social care costs incurred by the NHS (31). For healthcare costs, this was comprised of prevention and health promotion costs; primary care costs (primary care and prescriptions); secondary care (inpatient: elective and day-case, inpatient: non-elective, outpatient and other secondary care); urgent care/emergency care costs (ambulance and Accident and Emergency); community care costs; and cost of care provided in other settings. Social care costs were comprised of non-health and social care costs.

In the NHS budget cost database, where only total costs for a group of cancers were available, so costs for a specific cancer within that group were estimated in the following manner: the incidence of oesophageal cancers, for example, was divided by the total incidence of gastro-intestinal cancers. This ratio was multiplied by the total healthcare expenditure of gastro-intestinal cancers to obtain the total healthcare expenditure of oesophageal cancer. It was assumed that the average costs per patient for each disease within a group had equal weighting.

Please note that discounting the costs were outside the scope of this project, so any cost figures may represent slight overestimates of the true cost.

Indirect societal costs

A human capital approach (HCA) was taken to estimate the indirect societal costs associated with the smoking-related diseases (32, 33). The cancer literature to date has been dominated by the use of the HCA (34-37). This approach encompasses a societal perspective and estimates an individual's contribution to society by applying labour force earnings as a measure of productivity. It assumes full employment in competitive labour markets with minimum transaction costs. Firms are regarded as profit maximisers, employing workers until the marginal revenue product of labour equals the wage rate. Under these conditions, if a person leaves the labour market (e.g. due to illness), he or she will not be replaced and so an opportunity cost exists until the age of retirement.

Productivity loss attributable to premature mortality (termed premature mortality costs in this report) refers to the loss of potential earnings incurred when an adult dies prematurely. Lost earnings were based on data obtained from the ONS (38). Patients younger than 65 years of age were assumed to be economically active. The loss of earnings attributable to premature mortality due to the disease for those younger than 65 was calculated across their potential working life. These lost potential lifetime earnings were based on the multiplication of the mean net earnings of UK workers.

Productivity loss attributable to premature morbidity (termed premature morbidity costs in this report) refers to the loss of potential earnings incurred when an individual contracts a disease, which impacts their productivity. The productivity of an individual represents the amount of working time the individual actually spends working. These data were based on data obtained from the Annual Survey of Hours and Earnings (ASHE) (39) and the Labour Force Survey (LFS), which is available from the UK Data Service (15). The general principle in acquiring premature morbidity costs involves multiplying the average annual number of days off work (termed absenteeism) attributable to morbidity by the mean daily earnings. The number of days off work for a given disease was obtained using modelled outputs from a previous health economic modelling project overseen by the Centre for Health Economics at the University of York and the School of Health and Related Research (ScHARR) at Sheffield University (40).

Please note that discounting the costs were outside the scope of this project, so any cost figures may represent slight overestimates of the true cost.

The UKHF model

A dual-module modelling process written in C++ software, developed by the UK Foresight working group (14), was further refined and then utilised for this study. In this model, smoking was included as a single risk factor to determine future related disease burden. The future projections have been used to predict the burden of diseases from 2015 until 2035. Furthermore, the model can be updated to include new data as and when it becomes available.

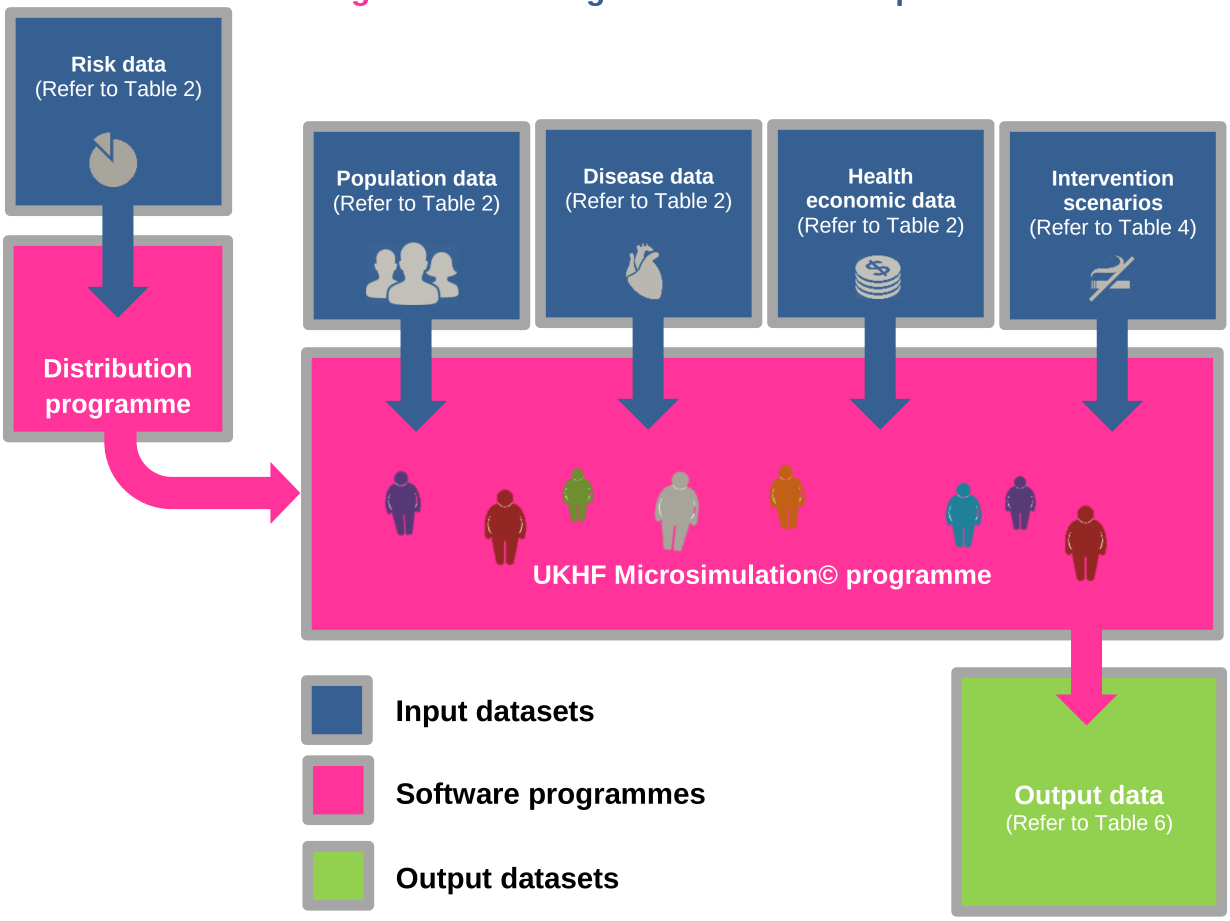
Module one uses a nonlinear multivariate, categorical regression model fitted to cross-sectional risk factor data to create longitudinal projections to 2035. The categories are defined by ten-year age groups and sex. Within each age and sex category of the population, the predicted proportions of each of the risk factor categories are constrained to sum to 100%.

Module two uses a microsimulation as a tool for predicting disease burden using longitudinal projections from module 1. A microsimulation is a computer model of any specified population which accurately reflects age profiles, births, deaths and health statistics to make future projections. The simulations specifically target the relationship between individuals' evolving risk factors and disease incidence. Risk factor distributions are determined by past and current trends and the model can simulate and compare the impact and cost of various public health interventions. Events compete to occur in each simulated life and a random component embedded in the models ensures that not all individuals at risk of an event may experience it. Individual life trajectories are simulated until death. Within the UKHF model, costs can be assigned to interventions associated with the life events that have been simulated to project a future trend in health spending.

The microsimulation also incorporates an economic module. The module employs Markov-type simulations of long-term health benefits, health care costs and cost-effectiveness of specified interventions. The model is used to project the differences in total costs over a specified time scale.

Figure 1 outlines a basic process map of the modelling and simulation component of the project. A wide set of input data, outlined in Table 2, were collected and utilised in order to obtain the output data, outlined in Table 1.

Figure 1 Modelling and simulation map



Building intervention scenarios

The microsimulation programme enables different intervention scenarios to be tested so that policy makers can assess the impact of public health interventions on the epidemiology and health economy of diseases relative to a baseline or 'no change' scenario. The agreed set of smoking scenarios to be modelled are summarised in Table 5 below:

Table 5 Scenarios and interventions

Scenarios/interventions	Details
Scenario 0 (Baseline scenario)	No change in smoker prevalence projections; maintain projections as predicted using GHS/GLS cohort data
Scenario 1	Reduction of baseline smoker prevalence projection by 1%
Scenario 2	Reduction of baseline smoker prevalence projection by 10%
Scenario 3	Reduction of baseline smoker prevalence projection by 20%
Scenario 4	Reduction of baseline smoker prevalence projection by 50%
Scenario 5	Reduction of baseline smoker prevalence projection by 100%
'Tobacco free society' (SFS)	Smoking prevalence reduces to 5% across all age groups and sex by 2035

Baseline scenario (Scenario 0)

A baseline scenario, based on the future projection of the current and historical trends of smoking prevalence using GLS/GHS data from 2000-2012, was modelled.

Hypothetical scenarios (Scenarios 1-5)

Five hypothetical scenarios, representing different versions of the future, were modelled to estimate the burden of smoking-related NCDs from 2015 to 2035. The following reductions in current smoking prevalence from the baseline trend were agreed with CRUK: 100%, 50%, 20%, 10% and 1%. These percentage figures represent the percentages of smokers in the model who were selected based on a probability (defined by the percentage chosen), and redefined as either an ex-smoker or never smoker. The probability of becoming either an ex-smoker or never smoker are dictated by the relative rates at which people give up and take up smoking. The take up rate was calculated from analysing the change in the proportion of never smokers from trend data in 2000 and 2012. Similarly, the giving up rate was calculated from changes in the numbers of ex-smokers. This is summarised in Table 6. This intervention is only applied to adults within the simulation and only occurs in the simulation start year. Once a smoker is redefined as either an ex-smoker or never smoker they are assumed to remain in a non-smoking state for the rest of the simulation.

There is likely to be a small amount of bias when modelling hypothetical scenarios. Individuals in the simulation who are also never smokers and were unaffected by the intervention will have a probability of taking up smoking defined by the smoking trajectories. In the start year of the simulation, if an individual is changed and becomes a never smoker, their smoking status will remain fixed for the entire simulation. The individuals that have not been affected by this scenario will follow the smoking projection as usual.

A number of points are made about this method. Firstly, if the individual was a smoker and contracted a smoking related disease before the start year of the intervention, the intervention has a probability of affecting their smoking status but not their disease state. Therefore, the intervention will not directly affect the prevalence of diseases in the model, but is likely to have indirect effects. Secondly, in cases where the intervention changes a smoker into a never smoker, these individuals will not smoke again and their smoking status remains fixed.

Table 6 Smoker transition rates

Scenario	Percentage reduction in smoker prevalence	Movement from smoker to never smoker category (Non-uptake)	Movement from smoker to ex-smoker category (Cessation)
1	1%	0.7%	0.3%
2	10%	7.5%	2.5%
3	20%	15.0%	5.0%
4	50%	37.5%	12.5%
5	100%	75.0%	25.0%

‘Tobacco free society’ policy scenario (Scenario TFS)

A scenario, where smoking prevalence drops to 5% across both sexes and across all age groups by 2035, was modelled. This is the level of smoking which the Action on Smoking and Health (ASH) report, *‘Smoking Still Kills’* (41) highlights as a ‘Tobacco free society’. The recommendations of this report are endorsed by Cancer Research UK and the UK Health Forum. Other countries such as New Zealand, Scotland and Ireland have adopted this target. In this report, this scenario was termed ‘Tobacco-free society’.

Results

Future trends in smoking prevalence: baseline scenario

Table 7 presents the projected prevalence of smokers and non-smokers (consisting of never and ex-smokers) for adults ages 18 to 100 years. For males and females combined, the prevalence of smokers is predicted to decrease from 17% in 2015 to 10% in 2035.

Table 7 Prevalence of smokers (18-100 year olds): baseline scenario

Year	Male				Female				Both			
	Non-smoker	95% CL	Smoker	95% CL	Non-smoker	95% CL	Smoker	95% CL	Non-smoker	95% CL	Smoker	95% CL
2015	0.82	0.01	0.18	0.01	0.83	0.01	0.17	0.01	0.83	0.01	0.17	0.01
2016	0.82	0.01	0.18	0.01	0.84	0.01	0.16	0.01	0.83	0.01	0.17	0.01
2017	0.83	0.01	0.17	0.01	0.84	0.01	0.16	0.01	0.84	0.01	0.16	0.01
2018	0.83	0.01	0.17	0.01	0.85	0.01	0.15	0.01	0.84	0.01	0.16	0.01
2019	0.84	0.01	0.16	0.01	0.85	0.01	0.15	0.01	0.84	0.01	0.16	0.01
2020	0.84	0.01	0.16	0.01	0.85	0.01	0.15	0.01	0.85	0.01	0.15	0.01
2021	0.85	0.01	0.15	0.01	0.86	0.01	0.14	0.01	0.85	0.01	0.15	0.01
2022	0.85	0.01	0.15	0.01	0.86	0.01	0.14	0.01	0.86	0.01	0.14	0.01
2023	0.85	0.01	0.15	0.01	0.86	0.01	0.14	0.01	0.86	0.01	0.14	0.01
2024	0.86	0.02	0.14	0.02	0.87	0.01	0.13	0.01	0.86	0.01	0.14	0.01
2025	0.86	0.02	0.14	0.02	0.87	0.01	0.13	0.01	0.87	0.02	0.13	0.02
2026	0.87	0.02	0.13	0.02	0.87	0.02	0.13	0.02	0.87	0.02	0.13	0.02
2027	0.87	0.02	0.13	0.02	0.88	0.02	0.12	0.02	0.87	0.02	0.13	0.02
2028	0.87	0.02	0.13	0.02	0.88	0.02	0.12	0.02	0.88	0.02	0.12	0.02
2029	0.88	0.02	0.12	0.02	0.88	0.02	0.12	0.02	0.88	0.02	0.12	0.02
2030	0.88	0.02	0.12	0.02	0.89	0.02	0.11	0.02	0.88	0.02	0.12	0.02
2031	0.88	0.02	0.12	0.02	0.89	0.02	0.11	0.02	0.89	0.02	0.11	0.02
2032	0.89	0.02	0.11	0.02	0.89	0.02	0.11	0.02	0.89	0.02	0.11	0.02
2033	0.89	0.02	0.11	0.02	0.90	0.02	0.10	0.02	0.89	0.02	0.11	0.02
2034	0.89	0.03	0.11	0.03	0.90	0.02	0.10	0.02	0.90	0.02	0.10	0.02
2035	0.90	0.03	0.10	0.03	0.90	0.02	0.10	0.02	0.90	0.03	0.10	0.03

Males

Table 7 shows that the prevalence of male smokers is projected to decrease from the current level of 18% to 10% by 2035. This is accompanied by a clear increase in the prevalence of non-smokers.

Figure 2 to Figure 8 present the breakdown of the aforementioned projection by 10-year age groups. The prevalence of male smokers is projected to decrease among all age groups. The prevalence of male smokers is projected to drop most markedly among 18-29 year olds, decreasing from the current level of 24% to 11% by 2035. The oldest age group is projected to comprise the lowest proportion of smokers (2%) by 2035.

Females

Table 7 shows that the prevalence of female smokers is projected to decrease from the current level of 17% to 10% by 2035. This is accompanied by a clear increase in the prevalence of non-smokers.

Figure 9 and Figure 15 present the breakdown of the aforementioned projection by 10-year age groups. The prevalence of female smokers is projected to decrease among all age groups. The prevalence of female smokers is projected to drop most markedly among 18-29 year olds, decreasing from the current level of 25% to 15% by 2035. The oldest age group is projected to comprise the lowest proportion of smokers (4%) by 2035.

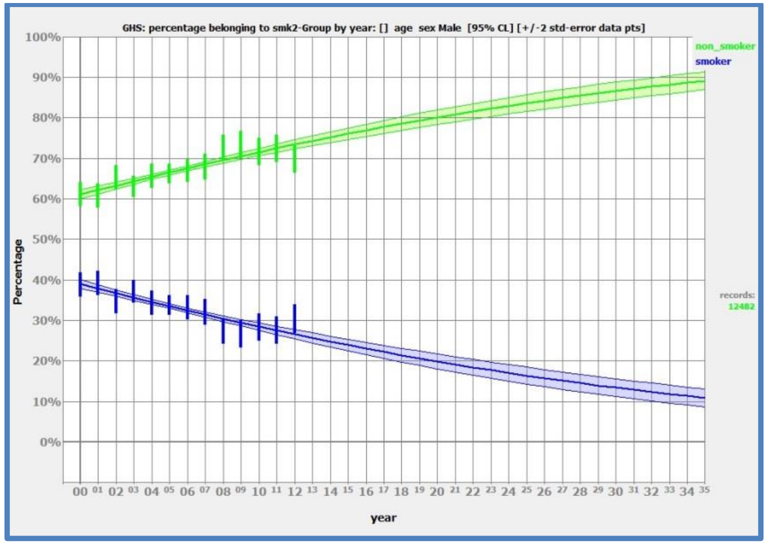


Figure 2. Projected smoking prevalence in 18-29 year old males

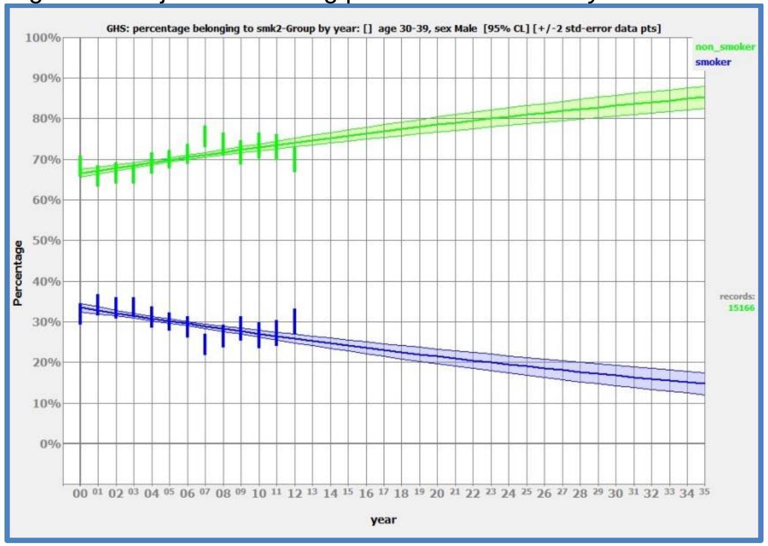


Figure 3. Projected smoking prevalence in 30-39 year old males

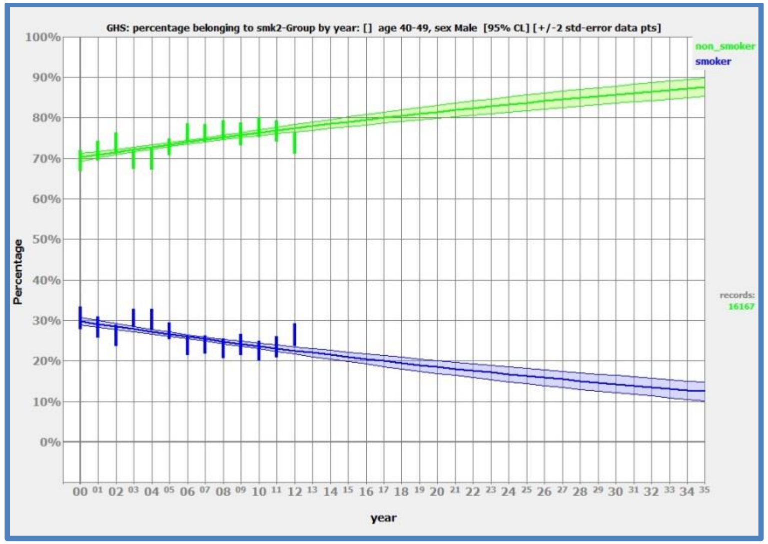


Figure 4. Projected smoking prevalence in 40-49 year old males

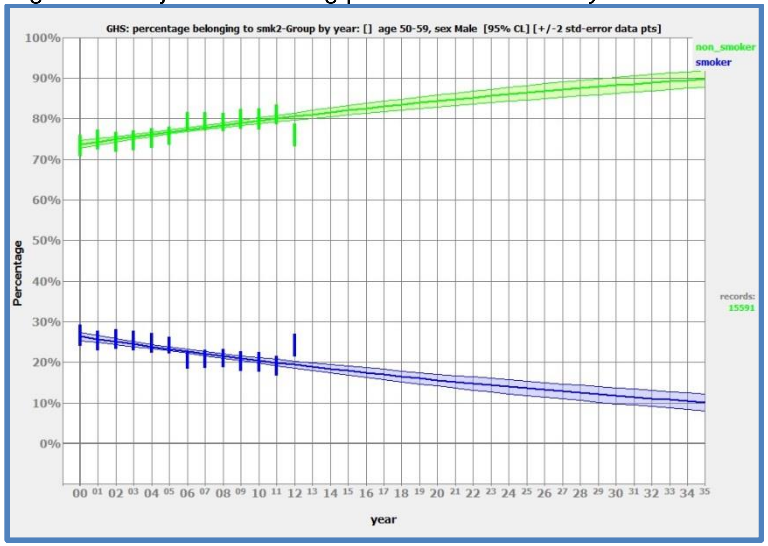


Figure 5. Projected smoking prevalence in 50-59 year old males

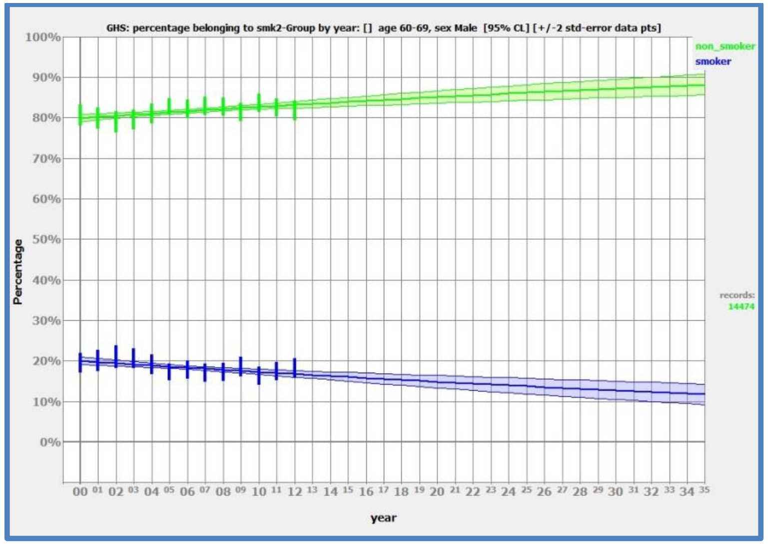


Figure 6. Projected smoking prevalence in 60-69 year old males

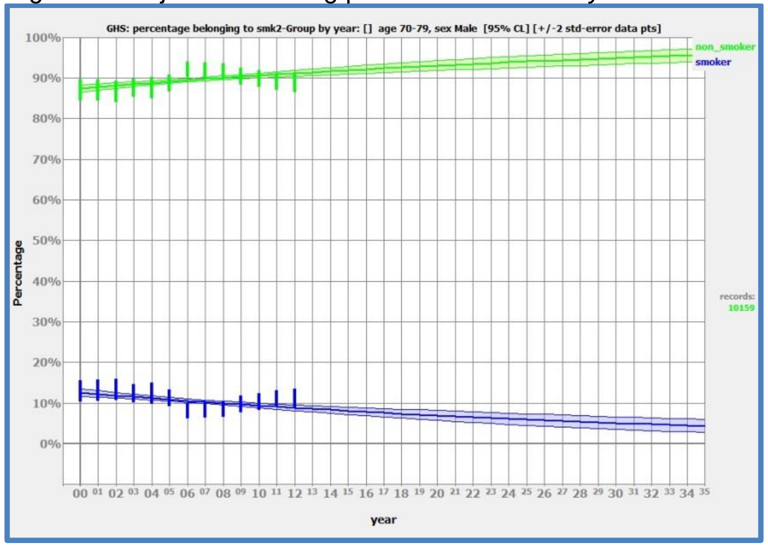


Figure 7. Projected smoking prevalence in 70-79 year old males

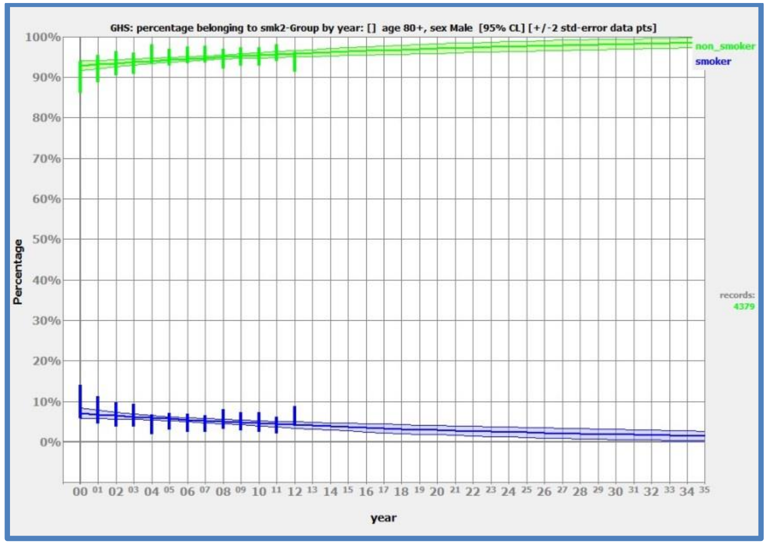


Figure 8. Projected smoking prevalence in 80+ year old males

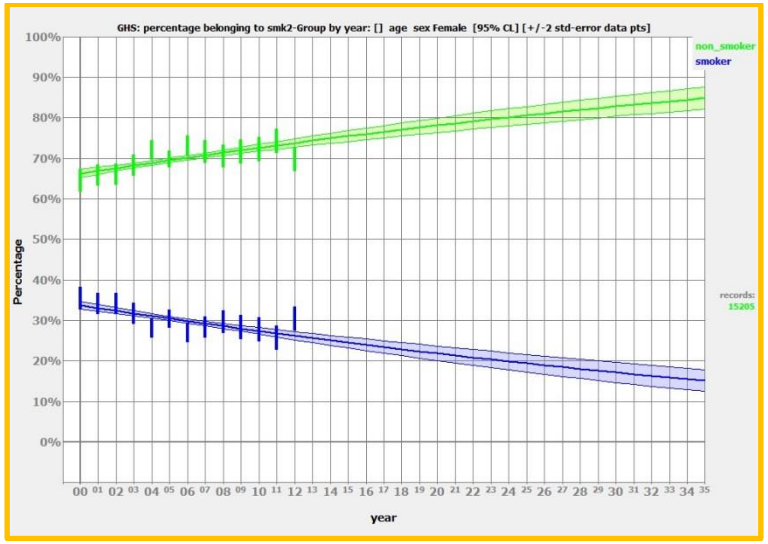


Figure 9. Projected smoking prevalence in 18-29 year old females

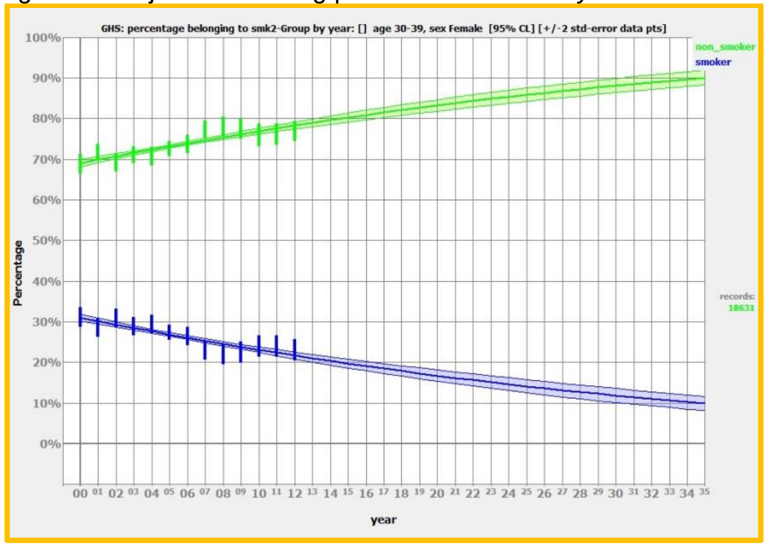


Figure 10. Projected smoking prevalence in 30-39 year old females

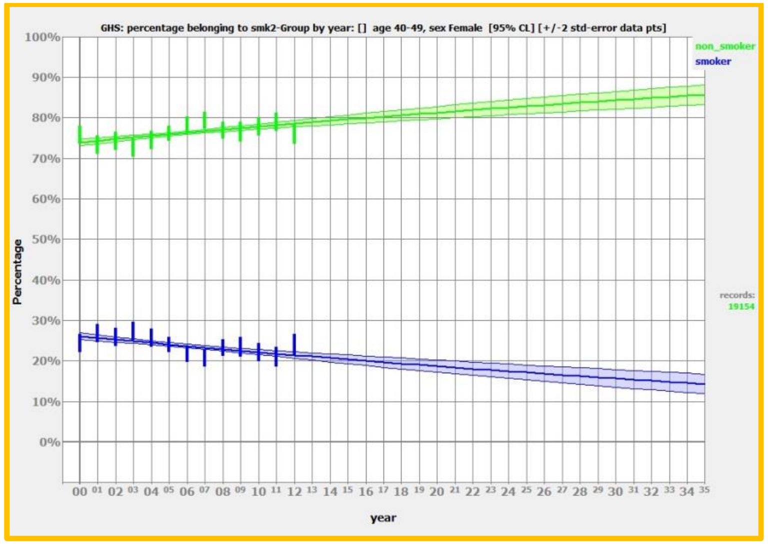


Figure 11. Projected smoking prevalence in 40-49 year old females

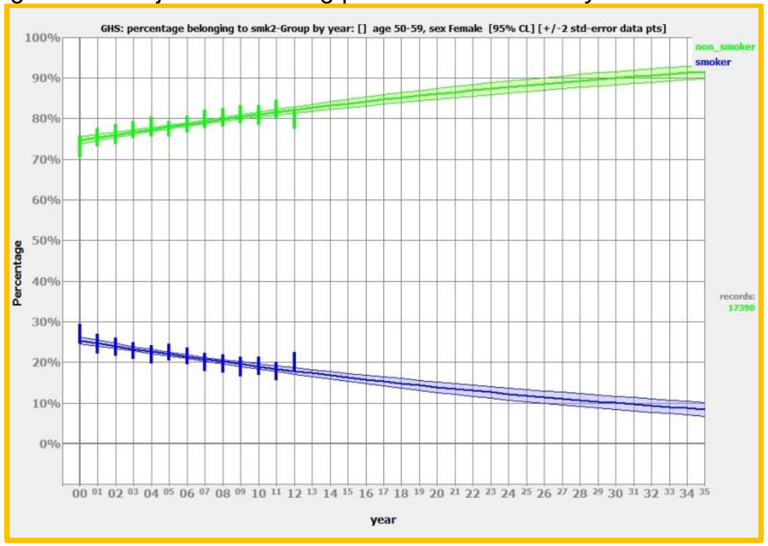


Figure 12. Projected smoking prevalence in 50-59 year old females

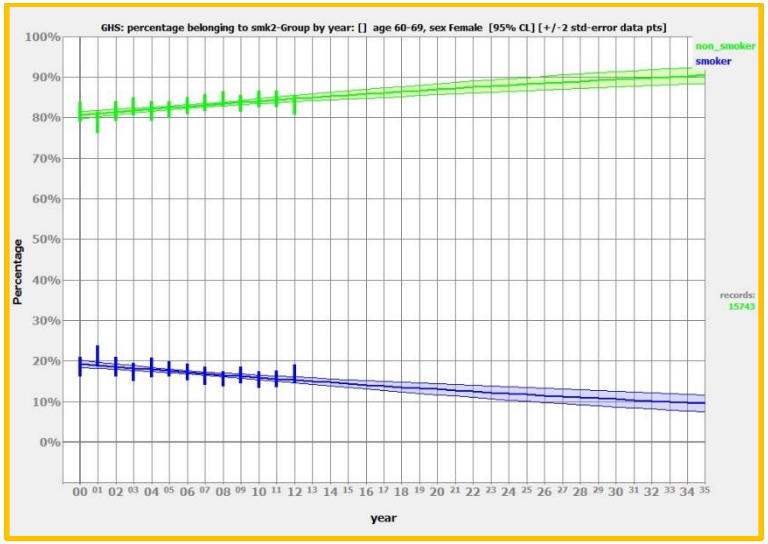


Figure 13. Projected smoking prevalence in 60-69 year old females

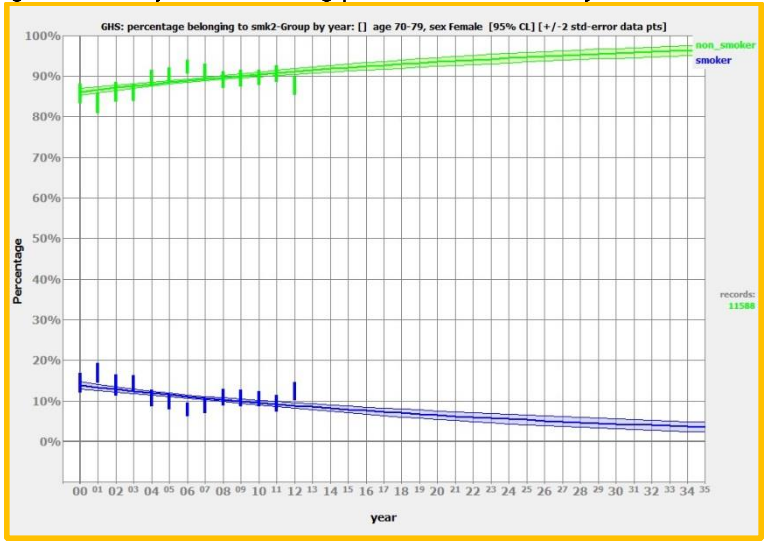


Figure 14. Projected smoking prevalence in 70-79 year old females

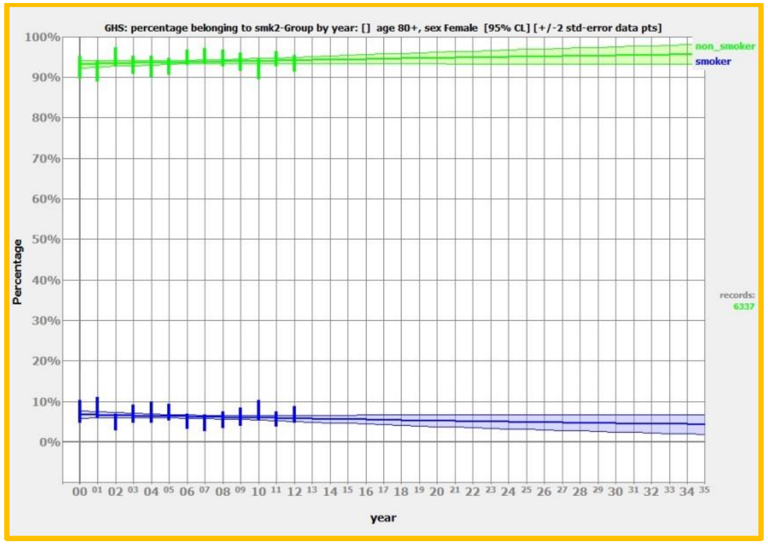


Figure 15. Projected smoking prevalence in 80+ year old females

Future trends in smoking prevalence by income quintiles: baseline scenario

Figure 16 to Figure 25 present the projected prevalence of smokers (blue) and non-smokers (green) males and females aged between 18 to 100 years old. Smoking prevalence was projected to 2035 in all figures.

Males

Figure 16 to Figure 20 present the breakdown of the male smoking projection by equivalised income quintile groups (in this case, Q1 is the lowest income and Q5 is the highest income). The prevalence of smokers is projected to decrease among all income groups. The highest income quintile group is projected to comprise the lowest proportion of smokers (2%) by 2035. Table 8 summarises these data.

Table 8 Prevalence of smoking by income quintile, males (18-100 year olds)

Quintile	Year	Non-smoker	Lower CI	Upper CI	Smoker	Lower CI	Upper CI
1	2015	**0.7388**	0.7217	0.7559	**0.2612**	0.2441	0.2783
	2035	**0.8427**	0.8087	0.8768	**0.1573**	0.1232	0.1913
2	2015	**0.8050**	0.7911	0.8190	**0.195**	0.1810	0.2089
	2035	**0.8899**	0.8648	0.9151	**0.1101**	0.0849	0.1352
3	2015	**0.8363**	0.8250	0.8475	**0.1637**	0.1525	0.1750
	2035	**0.9317**	0.9166	0.9468	**0.0683**	0.0532	0.0834
4	2015	**0.8581**	0.8486	0.8676	**0.1419**	0.1324	0.1514
	2035	**0.9528**	0.9427	0.9629	**0.0472**	0.0371	0.0573
5	2015	**0.9054**	0.8979	0.9129	**0.0946**	0.0871	0.1021
	2035	**0.9757**	0.9698	0.9816	**0.0243**	0.0184	0.0302

Females

Figure 21 to Figure 25 present the breakdown of the female smoking projection by equivalised income quintile groups (in this case, Q1 is the lowest income and Q5 is the highest income). The prevalence of smokers is projected to decrease among all income groups. The highest income quintile group is projected to comprise the lowest proportion of smokers (3%) by 2035. Table 9 summarises these data.

Table 9 prevalence of smoking by income quintile, females (18-100 year olds)

Quintile	Year	Non-smoker	Lower CI	Upper CI	Smoker	Lower CI	Upper CI
1	2015	**0.7649**	0.7515	0.7784	**0.2351**	0.2216	0.2485
	2035	**0.8572**	0.8309	0.8836	**0.1428**	0.1164	0.1691
2	2015	**0.8088**	0.7969	0.8206	**0.1912**	0.1794	0.2031
	2035	**0.8833**	0.8604	0.9061	**0.1167**	0.0939	0.1396
3	2015	**0.8375**	0.8271	0.8479	**0.1625**	0.1521	0.1729
	2035	**0.9223**	0.9064	0.9382	**0.0777**	0.0618	0.0936
4	2015	**0.8804**	0.8717	0.8891	**0.1196**	0.1109	0.1283
	2035	**0.9611**	0.9522	0.97	**0.0389**	0.03	0.0478
5	2015	**0.9153**	0.9081	0.9225	**0.0847**	0.0775	0.0919
	0.9153	**0.9745**	0.9679	0.9812	**0.0255**	0.0188	0.0321

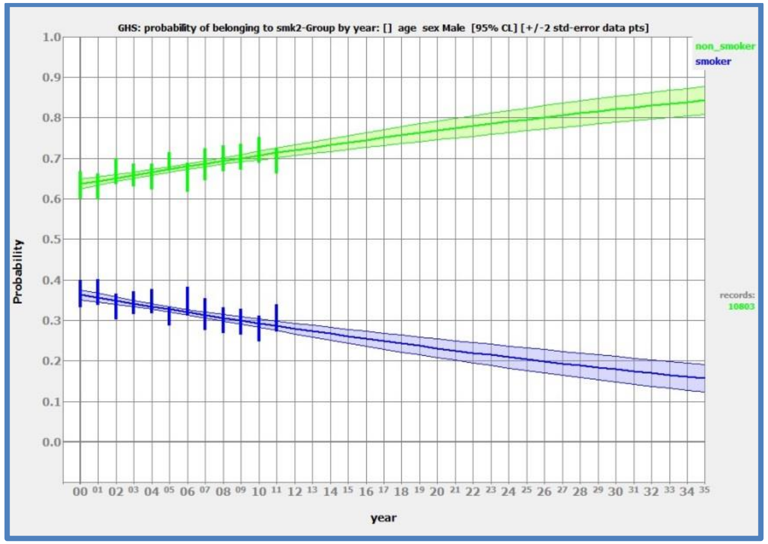


Figure 16. Smoking projections for equivalised income Q-1, males

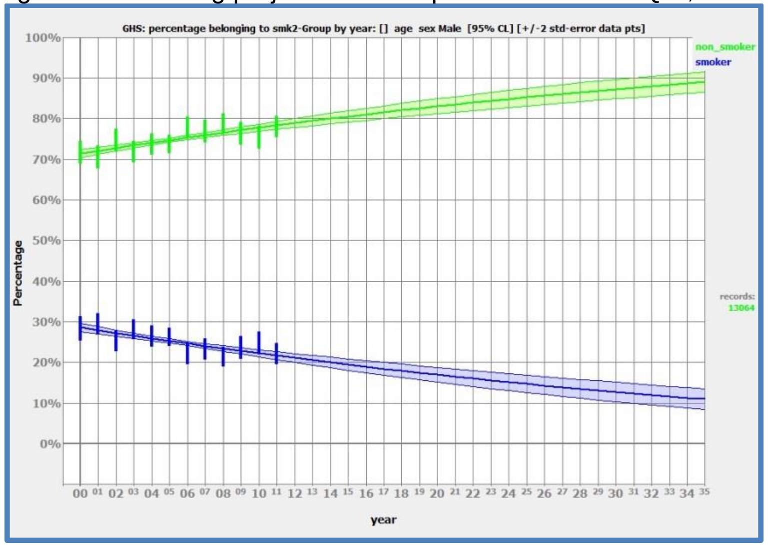


Figure 17. Smoking projections for equivalised income Q-2, males

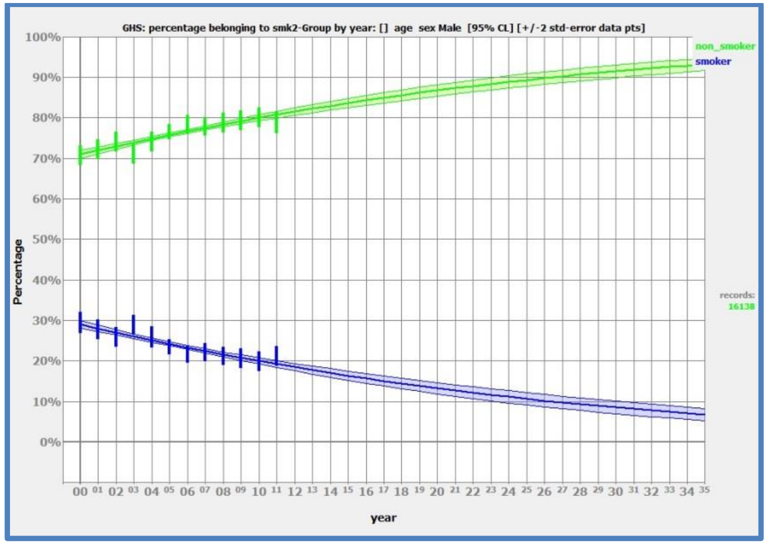


Figure 18. Smoking projections for equivalised income Q-3, males

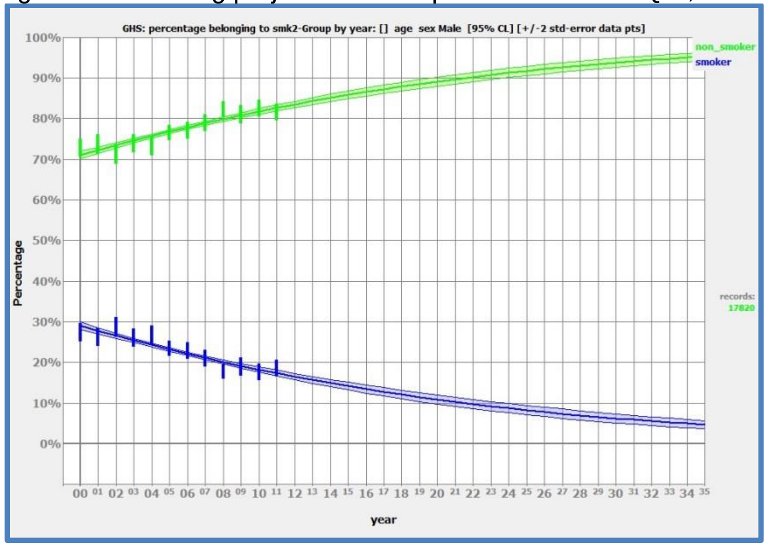


Figure 19. Smoking projections for equivalised income Q-4, males

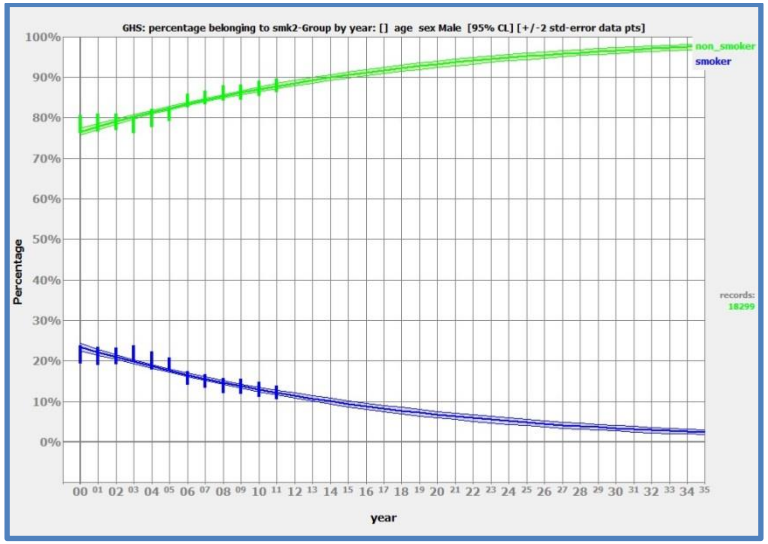


Figure 20. Smoking projections for equivalised income Q-5, males

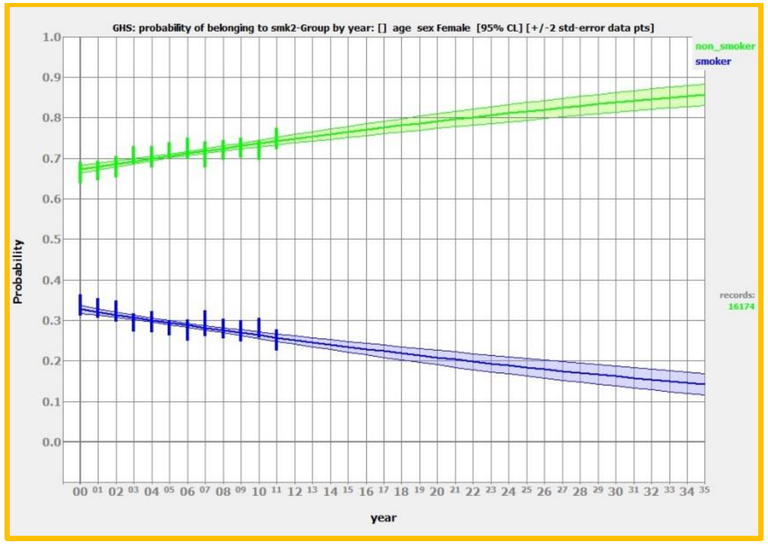


Figure 21. Smoking projections for equivalised income Q-1, females

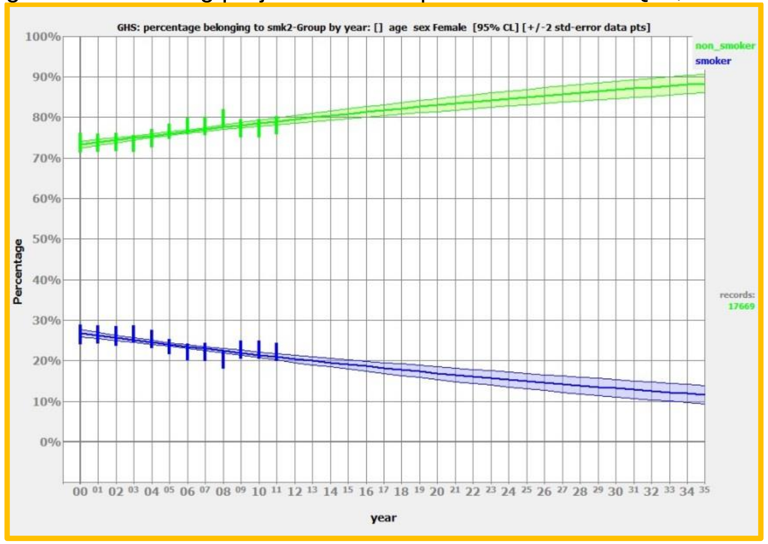


Figure 22. Smoking projections for equivalised income Q-2, females

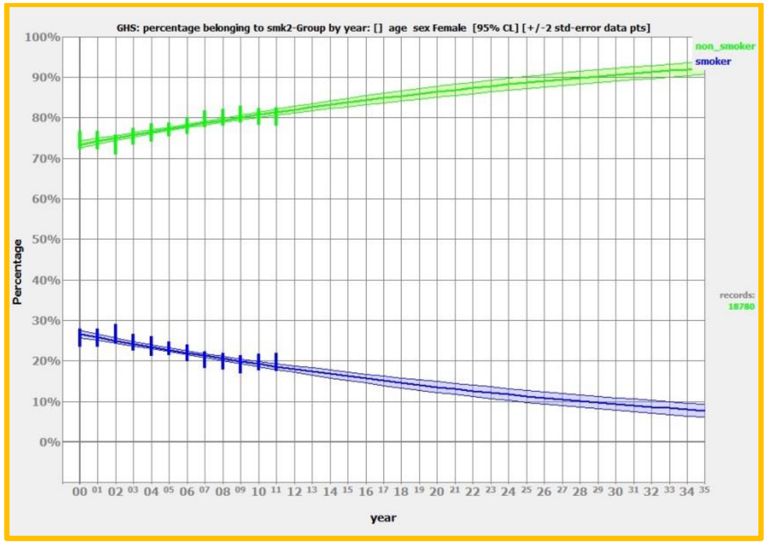


Figure 23. Smoking projections for equivalised income Q-3, females

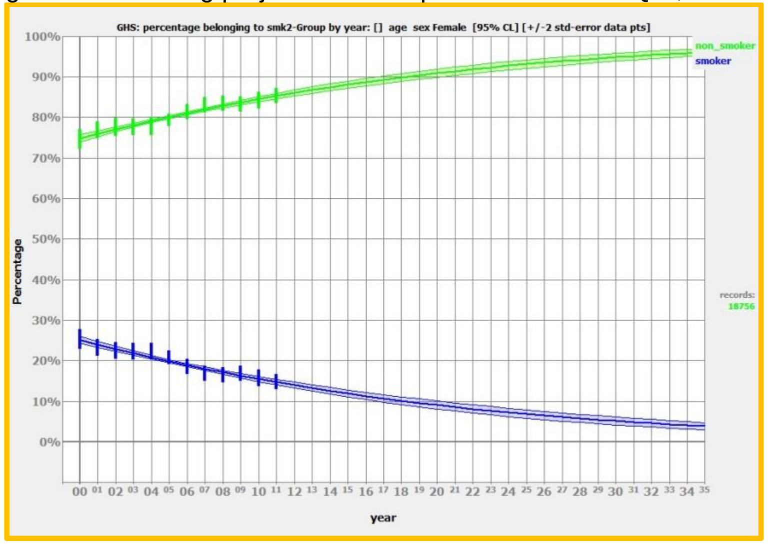


Figure 24. Smoking projections for equivalised income Q-4, females

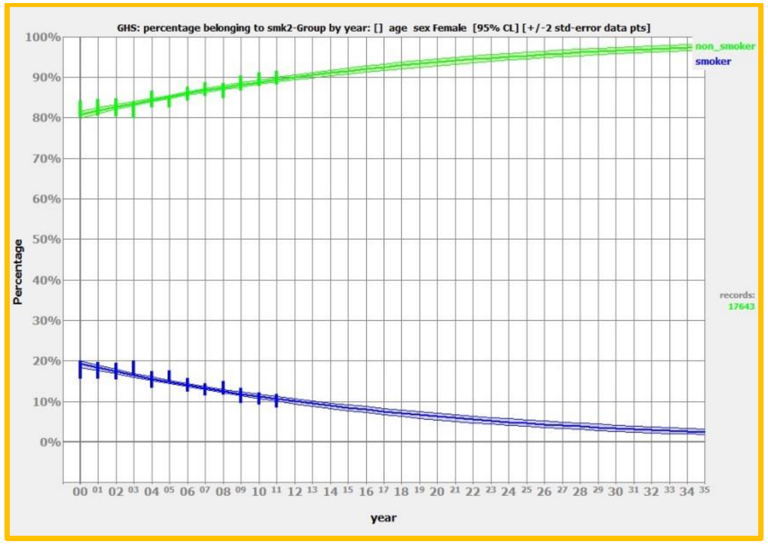


Figure 25. Smoking projections for equivalised income Q-5, females

Results of the impact of smoking on future disease burden

Hypothetical scenarios

The impact of seven hypothetical scenarios was tested on a total of 17 diseases, of which 14 were cancers (AML, bladder, bowel, cervical, CML, kidney, laryngeal, liver, lung, oesophageal, oral and pharyngeal, ovarian, pancreatic and stomach cancer), and the remaining 3 diseases were CHD, COPD and stroke.

Impact on incidence and prevalence

The incidence and cumulative incidence was found to be highest for CHD, followed by stroke and COPD for the baseline smoking scenario (scenario 0) in 2035 (Table 10 and Table 11). Of the cancers, lung cancer and bowel cancer were found to have the highest *incidence* and *cumulative incidence* at baseline (scenario 0) in 2035.

By 2035, the baseline *cumulative incidence* in the UK for CHD, stroke and COPD are predicted to reach 1,961,426 cases, 1,837,844 cases and 1,494,025 cases, respectively. The baseline *cumulative incidence* in 2035 in the UK for lung and bowel cancer are predicted to reach 1,427,056 cases and 956,894 cases , respectively.

Overall, the greater the decrease in the prevalence of smokers (i.e. from scenario 1 through to scenario 5), the greater the extent to which *incidence* and *prevalence* cases can be avoided in the future. For example, a 10% reduction in the prevalence of smokers (scenario 2) is predicted to have the greatest impact on COPD (37,972 cases), lung cancer (33,139 cases), stroke (25,545 cases) and CHD (20,022 cases) by 2035 in terms of *cumulative incidence cases avoided*. A similar trend is observed for *prevalence cases avoided*.

Table 10 Incidence cases in the UK in 2015 and 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
Scenario 0	2015	Incidence	98,056	46,106	81,172	3,896	5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	8,442	12,338	87,666	12,338	238,321
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	99,552	49,413	65,399	2,907	5,087	10,900	7,993	85,745	13,080	3,633	3,633	727	8,720	8,720	11,627	58,859	10,900	196,197
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 1	2015	Incidence	97,406	46,106	80,523	3,896	5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	9,091	12,338	87,666	12,338	238,970
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	100,279	49,413	64,672	2,907	5,087	10,900	7,993	85,745	13,080	3,633	3,633	727	8,720	8,720	12,353	58,859	10,173	196,197
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 2	2015	Incidence	96,757	46,106	79,224	3,896	5,195	16,884	11,689	104,549	16,884	3,247	3,247	649	9,091	9,091	12,338	87,016	12,338	237,672
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	98,825	49,413	63,219	2,907	5,087	10,900	7,993	85,745	13,080	3,633	3,633	727	8,720	8,720	12,353	57,406	10,900	195,471
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 3	2015	Incidence	96,108	46,106	78,574	3,896	5,195	16,884	11,039	103,900	16,884	3,247	3,247	649	8,442	8,442	12,338	85,718	11,689	233,775
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	98,825	49,413	61,766	2,907	5,087	10,900	7,267	84,292	13,080	2,907	3,633	727	8,720	8,720	11,627	55,226	10,900	191,111
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 4	2015	Incidence	94,159	46,106	73,379	3,896	5,195	16,234	11,039	100,653	16,884	3,247	3,247	649	8,442	8,442	12,338	81,821	11,689	229,230
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	95,192	49,413	55,226	2,180	5,087	9,447	6,540	82,112	12,353	3,633	3,633	727	8,720	7,993	11,627	49,413	10,173	180,937
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 5	2015	Incidence	90,913	45,456	66,886	3,247	5,195	14,936	9,741	96,108	15,585	3,247	3,247	649	8,442	7,793	11,689	75,328	11,689	216,242
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	90,832	48,686	45,779	2,180	5,087	7,993	5,813	77,026	11,627	3,633	3,633	727	8,720	7,993	10,900	39,239	10,173	166,404
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	0	0	727

Table 11 Incidence cases avoidable in the UK in 2015 and 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
Scenario 1 rel to 0	2015	Inc. avoidable	649	0	649	0	0	0	0	0	0	0	0	0	0	-649	0	0	0	-649
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Inc. avoidable	-727	0	727	0	0	0	0	0	0	0	0	0	0	0	-727	0	727	0
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 2 rel to 0	2015	Inc. avoidable	1,299	0	1,948	0	0	649	0	1,299	0	0	0	0	0	-649	0	649	0	649
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Inc. avoidable	727	0	2,180	0	0	0	0	0	0	0	0	0	0	0	-727	1,453	0	727
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 3 rel to 0	2015	Inc. avoidable	1,948	0	2,598	0	0	649	649	1,948	0	0	0	0	649	0	0	1,948	649	4,546
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Inc. avoidable	727	0	3,633	0	0	0	727	1,453	0	727	0	0	0	0	0	3,633	0	5,087
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 4 rel to 0	2015	Inc. avoidable	3,896	0	7,793	0	0	1,299	649	5,195	0	0	0	0	649	0	0	5,844	649	9,091
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Inc. avoidable	4,360	0	10,173	727	0	1,453	1,453	3,633	727	0	0	0	0	727	0	9,447	727	15,260
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
Scenario 5 rel to 0	2015	Inc. avoidable	7,143	649	14,286	649	0	2,598	1,948	9,741	1,299	0	0	0	649	649	649	12,338	649	22,079
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Inc. avoidable	8,720	727	19,620	727	0	2,907	2,180	8,720	1,453	0	0	0	0	727	727	19,620	727	29,793
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028

'Inc. avoidable': incidence avoidable
'rel to': relative to

Table 12 Cumulative incidence cases in the UK from 2015 to 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
Scenario 0	2015	Cumu. Inc.	98,056	46,106	81,172	3,896	5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	8,442	12,338	87,666	12,338	238,321
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,961,426	956,894	1,494,025	69,730	106,322	272,708	194,002	1,837,844	289,968	69,730	67,659	15,879	176,052	176,742	246,473	1,427,056	220,928	4,290,145
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382
Scenario 1	2015	Cumu. Inc.	97,406	46,106	80,523	3,896	5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	9,091	12,338	87,666	12,338	238,970
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,958,664	957,585	1,489,883	69,730	106,322	270,637	193,312	1,832,321	290,658	69,040	67,659	15,879	175,362	176,742	245,782	1,424,295	220,928	4,283,931
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382
Scenario 2	2015	Cumu. Inc.	96,757	46,106	79,224	3,896	5,195	16,884	11,689	104,549	16,884	3,247	3,247	649	9,091	9,091	12,338	87,016	12,338	237,672
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,941,404	954,823	1,456,053	68,350	106,322	266,494	188,479	1,812,300	287,206	69,040	66,969	15,879	173,981	175,362	244,402	1,393,917	218,857	4,230,080
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382
Scenario 3	2015	Cumu. Inc.	96,108	46,106	78,574	3,896	5,195	16,884	11,039	103,900	16,884	3,247	3,247	649	8,442	8,442	12,338	85,718	11,689	233,775
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,926,216	953,442	1,416,010	66,969	105,631	260,971	183,646	1,792,278	284,445	68,350	66,969	15,879	173,981	173,290	242,330	1,358,016	218,166	4,172,086
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382
Scenario 4	2015	Cumu. Inc.	94,159	46,106	73,379	3,896	5,195	16,234	11,039	100,653	16,884	3,247	3,247	649	8,442	8,442	12,338	81,821	11,689	229,230
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,870,984	947,919	1,308,998	61,446	103,560	245,092	169,148	1,730,832	276,160	67,659	66,278	15,879	172,600	167,077	238,188	1,253,766	214,024	3,998,796
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382
Scenario 5	2015	Cumu. Inc.	90,913	45,456	66,886	3,247	5,195	14,936	9,741	96,108	15,585	3,247	3,247	649	8,442	7,793	11,689	75,328	11,689	216,242
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,783,993	941,015	1,121,209	52,470	100,798	217,476	144,294	1,623,130	260,971	65,588	65,588	15,879	169,148	158,792	229,213	1,081,166	207,120	3,709,518
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382

'Cumu. inc.': cumulative incidence

Table 13 Cumulative incidence cases avoidable in the UK from 2015 to 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
Scenario 1 rel to 0	2015	Cumu. inc. avoidable	649	0	649	0	0	0	0	0	0	0	0	0	0	-649	0	0	0	-649
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. inc. avoidable	2,762	-690	4,142	0	0	2,071	690	5,523	-690	690	0	0	690	0	690	2,762	0	6,214
		95% CI	2,762	2,071	2,762	690	690	690	690	2,762	690	690	690	0	690	690	690	2,762	690	4,142
Scenario 2 rel to 0	2015	Cumu. inc. avoidable	1,299	0	1,948	0	0	649	0	1,299	0	0	0	0	0	-649	0	649	0	649
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. inc. avoidable	20,022	2,071	37,972	1,381	0	6,214	5,523	25,545	2,762	690	690	0	2,071	1,381	2,071	33,139	2,071	60,065
		95% CI	2,762	2,071	2,762	690	690	690	690	2,762	690	690	690	0	690	690	690	2,762	690	4,142
Scenario 3 rel to 0	2015	Cumu. inc. avoidable	1,948	0	2,598	0	0	649	649	1,948	0	0	0	0	649	0	0	1,948	649	4,546
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. inc. avoidable	35,210	3,452	78,015	2,762	690	11,737	10,356	45,566	5,523	1,381	690	0	2,071	3,452	4,142	69,040	2,762	118,058
		95% CI	2,762	2,071	2,762	690	690	690	690	2,762	690	690	690	0	690	690	690	2,762	690	4,142
Scenario 4 rel to 0	2015	Cumu. inc. avoidable	3,896	0	7,793	0	0	1,299	649	5,195	0	0	0	0	649	0	0	5,844	649	9,091
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. inc. avoidable	90,442	8,975	185,027	8,285	2,762	27,616	24,854	107,012	13,808	2,071	1,381	0	3,452	9,666	8,285	173,290	6,904	291,349
		95% CI	2,762	2,071	2,762	690	690	690	690	2,762	690	690	690	0	690	690	690	2,762	690	4,142
Scenario 5 rel to 0	2015	Cumu. inc. avoidable	7,143	649	14,286	649	0	2,598	1,948	9,741	1,299	0	0	0	649	649	649	12,338	649	22,079
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. inc. avoidable	177,433	15,879	372,816	17,260	5,523	55,232	49,709	214,714	28,997	4,142	2,071	0	6,904	17,950	17,260	345,890	13,808	580,626
		95% CI	2,762	2,071	2,762	690	690	690	690	2,762	690	690	690	0	690	690	690	2,762	690	4,142

'Cumu. inc. avoidable': cumulative incidence avoidable
'rel to': relative to

Impact on direct NHS costs

Overall, the greater the decrease in the prevalence of smokers, the greater the extent to which direct NHS costs can be avoided in the future (Table 14). Among the 5 hypothetical scenarios, the largest shift in *direct NHS costs avoidable* can be observed between scenarios 4 and 5. For COPD, moving from scenario 4 to scenario 5 results in marked changes in *direct NHS cost avoidances* (shifting from £68 million/year to £139 million/year for 2035), whereas shifting from scenario 2 to scenario 3 does not result in the same level of increase in cost avoidances (shifting from £15 million/year to £29 million/year for 2035). Full results of these findings are presented in Appendix 6F.

Of the 17 smoking-related diseases under investigation, the most marked impact on direct NHS costs can be observed for COPD and CHD, closely followed by AML. A 10% reduction in the prevalence of smoking (scenario 2) is expected to result in *direct NHS cost avoidances* of £14 million/year for COPD, £14 million/year for CHD and £13 million/year for AML for 2035 (Table 14).

Of the 14 smoking-related cancers, the most marked impact on direct NHS costs can be observed for AML, followed by lung cancer and oesophageal cancer. A 10% reduction in the prevalence of smoking (scenario 2) is expected to result in avoidances of £13 million/year for AML, £8 million/year for lung cancer and £3 million/year for oesophageal cancer for 2035. AML is not a prevalent disease but the costs per case are high, hence the high impact on NHS costs relative to other, more prevalent diseases. However, the confidence intervals for AML are extremely wide, inferring a high level of uncertainty with which this level of cost avoidance is likely to occur.

The cancer with the least direct NHS costs avoidable is CML; despite a 100% reduction in the smoking prevalence (scenario 5), no cost avoidance is expected to be achievable relative to the baseline smoking scenario. It is important to note, however, that these values are in absolute terms, thus it is expected that CML are to be associated with small direct costs changes since they are also less prevalent.

Table 14 Direct NHS costs avoidable in the UK in 2015 and 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
Scenario 1 rel to 0	2015	Direct NHS costs av. (£ millions)	2	-1	1	0	0	0	0	0	0	0	0	0	0	-1	0	1	0	-1
		95% CI	3	1	1	0	1	1	0	2	0	0	5	0	1	1	0	1	1	6
	2035	Direct NHS costs av. (£ millions)	1	-1	1	1	0	2	0	2	0	0	0	0	0	0	0	0	0	1
		95% CI	3	2	1	0	1	1	0	2	0	0	7	0	1	1	0	1	2	7
Scenario 2 rel to 0	2015	Direct NHS costs av. (£ millions)	2	-1	1	0	0	0	0	2	0	0	0	1	0	-1	0	2	0	1
		95% CI	3	1	1	0	1	1	0	2	0	0	5	0	1	1	0	1	1	6
	2035	Direct NHS costs av. (£ millions)	14	0	14	1	-3	3	1	9	1	0	13	0	2	1	1	8	0	27
		95% CI	3	2	1	0	1	1	0	2	0	0	6	0	1	1	0	1	2	7
Scenario 3 rel to 0	2015	Direct NHS costs av. (£ millions)	2	0	2	0	0	1	1	1	0	0	0	0	0	0	0	3	0	5
		95% CI	3	1	1	0	1	1	0	2	0	0	5	0	1	1	0	1	1	6
	2035	Direct NHS costs av. (£ millions)	27	0	29	1	0	5	3	17	1	1	13	0	0	2	1	17	0	42
		95% CI	3	2	1	0	1	1	0	2	0	0	6	0	1	1	0	1	2	7
Scenario 4 rel to 0	2015	Direct NHS costs av. (£ millions)	6	0	3	0	0	1	1	4	0	0	0	1	2	0	0	9	0	14
		95% CI	3	1	1	0	1	1	0	2	0	0	5	0	1	1	0	1	1	6
	2035	Direct NHS costs av. (£ millions)	71	3	68	3	0	11	7	40	2	1	13	0	2	4	2	41	3	91
		95% CI	3	2	1	0	1	1	0	1	0	0	6	0	1	1	0	1	2	7
Scenario 5 rel to 0	2015	Direct NHS costs av. (£ millions)	11	1	7	1	0	4	1	7	0	0	0	1	0	0	0	15	3	26
		95% CI	3	1	1	0	1	1	0	2	0	0	5	0	1	1	0	1	1	6
	2035	Direct NHS costs av. (£ millions)	138	4	139	6	3	20	15	80	4	1	25	0	4	8	3	84	9	185
		95% CI	3	2	1	0	1	1	0	1	0	0	6	0	1	1	0	1	2	7

'Direct NHS costs av.': Direct NHS costs avoidable
'rel to': relative to

Impact on indirect societal costs

Overall, the greater the decrease in the prevalence of smokers, the greater the extent to which indirect societal costs can be avoided in the future. A 10% decrease in the prevalence of smokers is expected to result in the avoidance of £0.4 billion/year in terms of *indirect societal costs* for all smoking-related diseases in 2035.

‘Tobacco-free society’ policy scenario

Impact on incidence and prevalence

The *incidence* of a number of the modelled diseases such as COPD, stroke and lung cancer is predicted to decrease from 2015 to 2035 for both the baseline and Tobacco-free scenarios. However, no discernible difference in *incidence* cases is expected to be observed between the two scenarios in 2035, with the exception of a slight difference for COPD, stroke, CHD and the following cancers: lung, ovarian, pancreatic, and oral and pharyngeal cancer).

COPD, lung cancer and stroke were predicted to result in the greatest number of *cumulative incidence cases avoided* and *prevalence cases avoided* in 2035 as a result of the Tobacco-free policy scenario relative to the baseline smoking scenario.

Table 15 Incidence cases in the UK from 2015 to 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
Scenario 0	2015	Incidence	98,056	46,106	81,172	3,896	5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	8,442	12,338	87,666	12,338	238,321
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	99,552	49,413	65,399	2,907	5,087	10,900	7,993	85,745	13,080	3,633	3,633	727	8,720	8,720	11,627	58,859	10,900	196,197
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028
TFS	2015	Incidence	98,056	46,106	81,172	3,896	5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	8,442	12,338	88,315	12,338	238,970
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Incidence	98,825	49,413	61,766	2,907	5,087	10,900	7,267	82,839	13,080	3,633	3,633	727	8,720	7,993	11,627	55,953	10,173	191,111
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028

'TFS': Tobacco-free society

Table 16 Incidence cases avoidable in the UK in 2015 and 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
TFS rel to 0	2015	Inc. avoidable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-649	0	-649
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Inc. avoidable	727	0	3,633	0	0	0	727	2,907	0	0	0	0	0	727	0	2,907	727	5,087
		95% CI	727	727	727	0	0	0	0	727	0	0	0	0	0	0	0	727	0	1,028

'TFS': Tobacco-free society
'Inc. avoidable': incidence avoidable
'rel to': relative to

Table 17 Cumulative incidence cases in the UK from 2015 to 2035, smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
Scenario 0	2015	Cumu. Inc.	98,056	46,106	81,172	3,896	5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	8,442	12,338	87,666	12,338	238,321
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,961,426	956,894	1,494,025	69,730	106,322	272,708	194,002	1,837,844	289,968	69,730	67,659	15,879	176,052	176,742	246,473	1,427,056	220,928	4,290,145
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382
TFS	2015	Cumu. Inc.	98,056	46,106	81,172		5,195	17,533	11,689	105,848	16,884	3,247	3,247	649	9,091	8,442	12,338	88,315	12,338	238,970
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc.	1,953,832	955,513	1,465,028	69,040	105,631	268,566	189,860	1,812,990	288,587	69,040	67,659	15,879	175,362	174,671	245,782	1,407,725	220,928	4,254,244
		95% CI	2,071	1,381	2,071	690	690	690	690	2,071	690	690	690	0	690	690	690	2,071	690	3,382

'TFS': Tobacco-free society
'Cumu. Inc.': Cumulative incidence

Table 18 Cumulative incidence cases avoidable in the UK from 2015 to 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
TFS rel to 0	2015	Cumu. Inc. av.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-649	0	-649
		95% CI	649	649	649	0	0	0	0	649	0	0	0	0	0	0	0	649	0	918
	2035	Cumu. Inc. av.	7,594	1,381	28,997	690	690	4,142	4,142	24,854	1,381	690	0	0	690	2,071	690	19,331	0	35,901
		95% CI	2,762	2,071	2,762	690	690	690	690	2,762	690	690	690	0	690	690	690	2,762	690	4,142

'TFS': Tobacco-free society
'Cumu. Inc. av': Cumulative incidence avoidable
'rel to': relative to

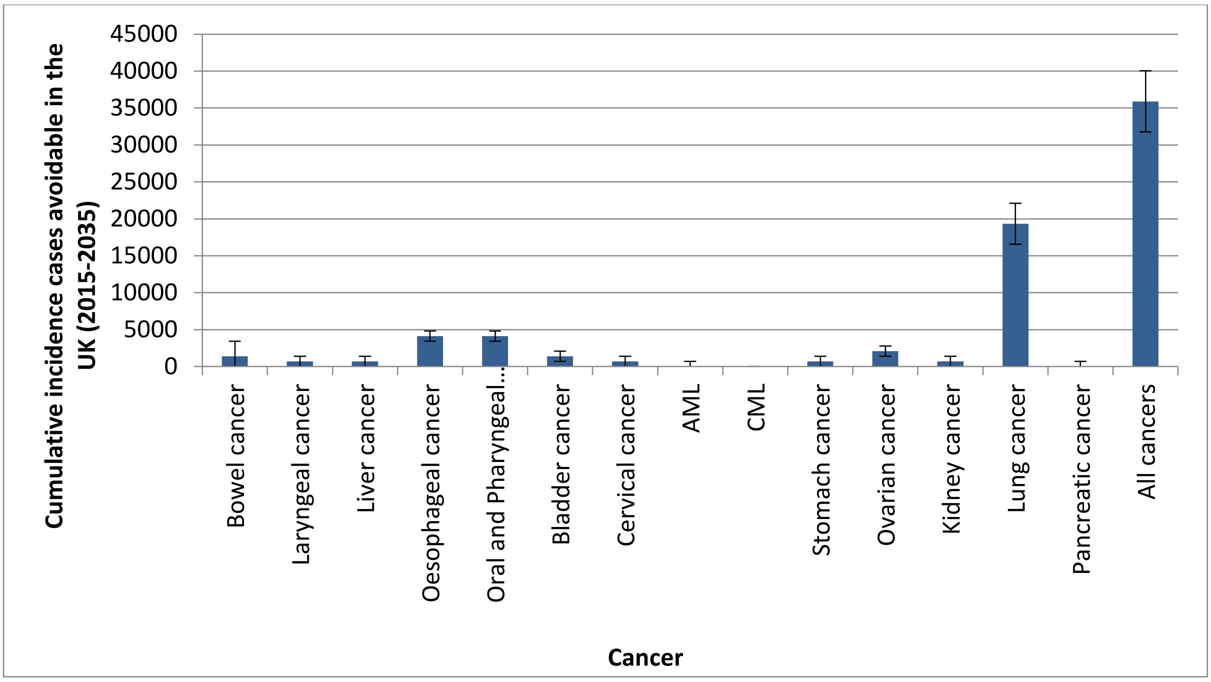


Figure 26 Cumulative incidence cases of cancers avoidable in the UK in 2035 following a TFS policy, relative to the baseline smoking scenario

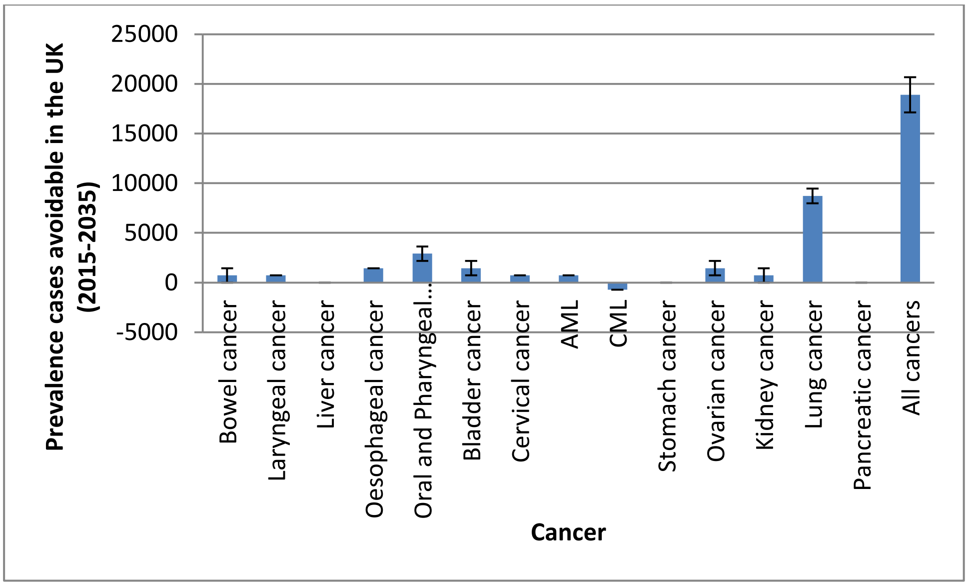


Figure 27 Prevalence cases of cancers avoidable in the UK in 2035 following a TFS policy, relative to the baseline smoking scenario

Impact on direct NHS costs

No significant difference in *direct NHS costs* between the baseline smoking and the Tobacco-free policy scenario is expected to be observed for smoking-related diseases with the exceptions of stroke, COPD and lung cancer (Table 19).

Impact on indirect societal costs

The impact of the Tobacco-free policy scenario on *indirect societal cost* is marked: in 2035, £0.5 billion/year in indirect societal costs can expected to be avoided when compared to the baseline scenario.

Table 19 Direct NHS costs avoidable in the UK in 2015 and 2035, by smoking scenario

Scenario	Year	Parameter	CHD	ColerectalC	COPD	LarynxC	LiverC	OesC	OralC	Stroke	BladderC	CervicalC	AML	CML	StomachC	OvarianC	KidneyC	LungC	PancreaticC	All cancers
TFS rel to 0	2015	Direct NHS costs av. (£ millions)	1	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0	-1
		95% CI	3	1	1	0	1	1	0	2	0	0	5	0	1	1	0	1	1	3
	2035	Direct NHS costs av. (£ millions)	7	1	13	1	0	3	2	15	1	1	13	-1	0	2	0	11	0	32
		95% CI	3	2	1	0	1	1	0	2	0	0	6	0	1	1	0	1	2	4

‘TFS’: Tobacco-free society
‘Direct NHS costs av.’: Direct NHS costs avoidable
‘rel to’: relative to

Table 20 Indirect societal costs avoidable in the UK in 2015 and 2035, by smoking scenario

Scenario	Year	Parameter	All diseases
TFS rel to 0	2015	Indirect societal cost avoidable (£)	31,055,582
		95% CI	0
	2035	Indirect societal cost avoidable (£)	548,455,704
		95% CI	0

'TFS': Tobacco-free society
'rel to': relative to

Discussion

This study projected trends in smoking prevalence forward to 2035 and tested the impact of these changing trends on the future incidence and prevalence of smoking-related chronic diseases, as well as on direct NHS and indirect societal costs. It tested the impact of whole population-level interventions on NCDs. Below is a summary table of the key findings:

KEY STATISTICS

EVEN IF CURRENT TRENDS OF DECREASING SMOKING PREVALENCE WERE TO CONTINUE:

- Tobacco could still cause 1.35 million new cases of disease over the next twenty years[3]. This includes 580,600 cases of cancer.
- A radical upgrade in prevention would be needed to achieve our tobacco-free ambition by 2035 for the UK. If current trends were to continue, smoking prevalence could decrease from 18% and 17% among men and women in 2015 to 10% in 2035 – missing our ambition.
- The poorest in society would increasingly bear the disease burden caused by smoking over the next twenty years. 2.4% of men and 2.6% of women from the least deprived income quintile are predicted to smoke in 2035, compared to 15.7% of men and 14.3% of women from the most deprived income quintile. The prevalence of smokers is projected to drop most markedly among the highest two income groups.
- Tobacco-related diseases could cost an additional £3.6 billion per year in 2035. This includes £542 million in direct NHS costs and £3.03 billion in indirect societal costs.

ACHIEVING A TOBACCO-FREE UK WOULD DRAMATICALLY IMPROVE THE NATION'S HEALTH:

- Compared to the current trend of decline, achieving a tobacco-free UK by 2035 could avoid around new 97,500 cases of disease, including around 36,000 cancers over the next 20 years.
- In the year 2035 alone, this is equivalent to avoiding around 12,355 new cases of disease across the UK, including around 5,100 cancers.

[3] Values are derived by estimating the avoidable costs and diseases resulting from a 100% reduction in the prevalence of smoking below the predicted trend. This difference provides an estimate of the total directly attributable impact of smoking over the period of 2015 and 2035.

- Achieving a tobacco-free ambition would avoid around £615 million in costs in the year 2035 alone. These include £67 million in direct NHS costs, and £548 million in indirect societal costs.

The prevalence of smoking has steadily fallen among males and females during the past decades due to the implementation of a comprehensive range of successful tobacco control measures including tobacco taxation, a ban on smoking in public places, and controls on the marketing of tobacco. Prevalence is projected to decrease over the next 20 years among all age groups and income quintiles (Table 21 and Table 22), illustrating the effect of these enduring population level interventions.

Table 21 Prevalence of smoking by Income quintile, females

Quintile	Year	Non-smoker %	Smoker %
1	2015	76.49	23.51
	2035	85.72	14.28
2	2015	80.88	19.12
	2035	88.33	11.67
3	2015	83.75	16.25
	2035	92.23	7.77
4	2015	88.04	11.96
	2035	96.11	3.89
5	2015	91.53	8.47
	2035	97.45	2.55

Table 22 Prevalence of smoking by Income quintile, males

Quintile	Year	Non-smoker %	Smoker %
1	2015	73.88	26.12
	2035	84.27	15.73
2	2015	80.50	19.50
	2035	88.99	11.01
3	2015	83.63	16.37
	2035	93.17	6.83
4	2015	85.81	14.19
	2035	95.28	4.72
5	2015	90.54	9.46
	2035	97.57	2.43

Interestingly, GHS data revealed a 1% increase in smoking prevalence in males in 2012 relative to 2011. A multinomial nonlinear regression was applied to 12 years of cross-sectional data and trends were extrapolated forward to 2035, revealing a downward trend in smoking rates to 2035. This raises the question of whether fewer data points should be included in the extrapolation of trends. Comparisons between projections using the full data set (2000 to 2012) and data from fewer data points (2007 to 2012) illustrated that the latter projection would lead to an increase in the smoking prevalence in the future (Appendix 1E) – this is also qualified by ONS in their report of the 2012 OLS data (formally named GLS) (42). The projections will be updated with new data as they come, enabling us to determine whether this apparent upward trend in smoking in 2012 is in fact a real shift in trend of smoking habits or is a one-off occurrence. One possibility of the apparent upward trend in 2012 is that the proliferation of e-cigarette use over the past five years (43) might have resulted in ex-smokers classifying themselves as a smoker again where previously they had classified themselves as ex-smokers. However, this is likely to be a small number of people so further monitoring of this trend is required, and closer attention to classification of smoker status in surveys would be required.

Consistent with previous findings, people in lower income groups smoke more (44), suggesting that interventions that reach low income groups in particular is necessary to reduce social inequalities. Reducing uptake in smoking and increasing cessation will improve health, increase income and improve quality of life of the population. It was not possible to explore ways to achieve the tobacco-free policy target since it was outside of the scope of this project.

We modelled the health impact of a range of hypothetical scenarios by 2035, relative to the baseline smoking scenario, taking account of changes in uptake and cessation over time. These interventions are summarised below:

Table 23 Scenarios and interventions

Scenarios/interventions	Details
Scenario 0 (Baseline scenario)	No change in smoker prevalence projections; maintain projections as predicted using GHS/GLS cohort data
Scenario 1	Reduction of baseline smoker prevalence projection by 1%
Scenario 2	Reduction of baseline smoker prevalence projection by 10%
Scenario 3	Reduction of baseline smoker prevalence projection by 20%
Scenario 4	Reduction of baseline smoker prevalence projection by 50%
Scenario 5	Reduction of baseline smoker prevalence projection by 100%
'Tobacco free society' (TFS)	Smoking prevalence reduces to 5% across all age groups and sex by 2035

Despite downward trends in smoking, further reductions in smoking prevalence were shown to have an important impact upon disease incidence and prevalence relative to the 'steady state' or baseline scenario. For example, a 20% reduction in smoking prevalence is expected to result in *cumulative incidence cases avoided* in the UK of about 35,200 cases, 78,000 cases and 69,000 cases for CHD, COPD and lung cancer, respectively, by 2035. These scenarios accounted for individuals who give up smoking as well as those who take up smoking. It is accepted that an ex-smoker's relative risk for many of the diseases, particularly cancers, takes almost two decades to return to that of a never smoker's, whereas never starting smoking has a more substantially positive health impact. The ex-smoker relative risks were computed using a method developed by Hoogenveen and colleagues (22), and as part of the EU-funded DYNAMO project. These are the most robust relative risk values available; however, the estimations of the beneficial effects of smoking cessation are conservative, particularly over the relatively short time period of this study. Further work should compare scenarios that test *either* the impact of reduction in uptake *or* increases in cessation, to quantify the difference in effect of giving up versus never starting smoking. Further work should also involve testing out these scenarios over a period longer than 20 years. Different policy options apply to uptake and cessation; for example, the impact of a plain packaging policy may prevent children and young people from starting smoking (45), whereas 'stop smoking' programmes help existing smokers to quit.

Strengths of this study

A major strength of this study is the use of the microsimulation method itself. Although data intensive, it has been cited as the most robust method for risk factor and chronic disease modelling (46). Microsimulation can recreate the characteristics of individuals – such as age, sex and disease state – within a population (as opposed to modelling cohorts of people) that evolve over time.

The microsimulation is the right approach for chronic disease modelling because it is the only modelling approach that is applicable if an individual's history matters. For example, an individual's history of risk-taking behaviour, such as smoking, alcohol use and nutrition matters for the development of certain diseases, especially chronic diseases. Microsimulation models are designed to remember an individual's history and take it into account to influence their future life course. The UKHF model includes this time series component, enabling the dynamic changes in risk factors over time to be accounted for. Other models, although less data intensive and requiring less computing power, often take a 'static' approach whereby interventions are applied at a single time point.

The computing power required to run a microsimulation is often cited as a limitation of the method; however, the UKHF model has been built in a modular way such that computation of many millions of individuals on a desktop computer takes only hours. This project ran 100 million individuals which took approximately 8 hours per scenario. The computing power required to run a microsimulation is often cited as a limitation of the method; however, the UKHF model has been built in a modular way such that computation of many millions of individuals on a desktop computer takes only hours. This project ran 100 million individuals which took approximately 8 hours per scenario. Please note that '100 million individuals' in the microsimulation was deemed, during the testing phase, as the appropriate number of runs needed to produce outputs associated with higher levels of certainty and repeatability. The general rule is that the greater the number of individuals simulated in the microsimulation software, the higher the accuracy of the epidemiological and cost outputs. The drawback of simulating large numbers of individuals is the time it takes to complete the simulation. The outputs from the microsimulation are in terms of 'per 100,000 individuals', so the outputs are scaled to the UK outside of the model in order to derive outputs in terms of the whole UK population.

Challenges and considerations

A challenge of any predictive model is that it does not take account of major future changes in circumstances such as the introduction of new drugs or technologies. In theory, their effects can be estimated by altering parameters in the model, but these will significantly increase the degrees of uncertainty. It was beyond the scope of this study, given the time constraints, to carry out an in depth uncertainty and sensitivity analysis. We are aware that this is good practice; however, there is a lack of validated datasets with which we can compare the outputs. Furthermore, given the complexity of the microsimulation involving many thousands of calculations, relative to simpler spreadsheet models, uncertainty analysis would require many thousands of consecutive runs, and would require a super computer to undertake this exercise within a realistic time scale. As part of the EU project EConDA (econdaproject.eu), we validated our models against other models existing in the Netherlands (RIVM NCD model) and US ('Pohem').

One challenge of the microsimulation method is that it is data intensive. Data are often gathered from a variety of sources, and sophisticated statistical techniques are required to standardise the various databases, so that they can be used to populate all of the desired attributes of individuals included in the sample. Incidence data for diseases other than cancers were difficult to acquire. More up-to-date and detailed disease data would be required to make more accurate estimates of future disease incidence. Also, utility weights were derived from US-based community scores for the UK population, since UK scores were not available. Furthermore, utility weights for certain cancers were not available in this data source nor from a literature search that was conducted. These included AML, CML, endometrial cancer, stomach cancer and post-menopausal breast cancer. To address these gaps in the data, utility weights were identified from the same data source for conditions that were considered to be suitable proxy measures.

The General Lifestyle Survey was used for projecting smoking forward – this survey is from England only, since data for the other UK countries were not available to us and since data from the other UK nations are less plentiful. We have used risk factor data for England, adjusted for the UK population, to estimate disease outcomes. We currently do not have access to the risk factor data that are available for other UK countries. The total prevalence figures show that smoking rates are slightly different in Wales (19.2%), Scotland (20.3%) and Northern Ireland (18.2%) (47); thus slightly different numbers of disease incidence would be expected than those observed in the present study if the smoking prevalence rates from the other UK countries were to be included in the modelling study. More in-depth comparison is necessary to ensure data from different health surveys can be similarly compared.

When developing the tobacco duty escalator model, data were found to be lacking in the following domains: recent UK-specific cross-price elasticity figures of various legal tobacco products; recent UK-specific cross-price elasticity figures of illicit tobacco products; recent UK-specific elasticity figures for tobacco products stratified by socio-economic class; and recent UK-specific pass-on rates for tobacco products.

The availability of disease cost data was limited. NHS England programme budgeting cost data were used in the model and several assumptions had to be made, which have been highlighted in the methods section of this report. It is acknowledged that the cost outputs produced by this project are crude estimates. Future iterations of the microsimulation model could incorporate a more sophisticated direct cost model that takes account of variation in cost based on disease progression and severity. Please note that discounting the costs (both direct NHS and indirect costs) were outside the scope of this project, so any cost figures may represent slight overestimates of the true cost.

There were few data on the time lag (‘latent period’) used to define the relevant time period between initiation of health risk behaviours and clinical manifestation of diseases. From a systematic literature search there were a high number of studies (48-52) that looked into the differences in life expectancy between subjects who adopted health risk behaviours such as smoking. These sets of data could not be used for the microsimulation programme since they did not specify when these subjects adopted the health risk behaviours and therefore, an estimate of the time lag period could not be calculated. A recommendation for further research would be to develop longitudinal studies that investigate time lag periods for various types of cancers, according to behavioural risk factors such as smoking.

Future Work

This project explored the independent effects of changing trends in smoking trends over time. Future work will account for combined risk factors on the progression of disease as well as the multi-stages within diseases. Demonstrations of these models can be found in the EConDA project (econdaproject.eu) which was launched in September 2015. By accounting for the multi-stages within a disease it is possible to test the impact of interventions to prevent, screen and treat diseases. Given the good quality of cancer data relative to other chronic disease data and the clear stage-like progression of the disease, further development of the model to include cancer stages would be valuable.

Further work should also include developing the model to include passive smoking and to take account of upward trends in roll your own tobacco (HRT) and e-cigarette use. However, relative risk data for these specific types of 'smoking' are necessary. ASH have reported that e-cigarettes help to cut down cigarettes by 55%, and help 51% of individuals quite entirely (53). However, we are yet to understand the health (if any) and wider social impacts of e-cigarettes. Continued monitoring of these trends in uptake and use of e-cigarettes alongside cigarettes will be necessary. It would also be interesting to quantify the different effects of changes in uptake versus changes in consumption as well as the effect of a duty escalator on different social groups.

Following completion of this project the model has since been developed to take account of multi-morbidity - the model is currently being developed to take account of the joint effect of several risk factors on disease incidence and mortality. Future work should include further expanding the scope of the model to take account of technological and economic changes and their potential effects, and also to model the clustering of risk factors and diseases in the same individuals.

The microsimulation software is built in a modular manner such that it could easily accommodate new policy interventions. For example, as part of another project (econdaproject.eu), we modelled the cost effectiveness of smoking cessation services (specifically looking at the impact of a combination of behavioural change therapy and a 12 week course of varenicline). Results showed that SCS were highly cost-effective. Future work should model the long term impact of an aggregated set of policy interventions for tobacco control.

Conclusion

This report sets out the future health and economic impact of smoking prevalence by 2035. The microsimulation method has been cited as the best method for NCD modelling because of its capacity to simulate entire populations at an individual level. However, further work is necessary to combine the UKHF risk factors models in order to draw meaningful conclusions about the total burden of diseases caused by a range of behavioural risk factors.

Significant health and indirect costs will be avoided if aspirational policies to reduce smoking-related diseases are implemented. We highlighted the importance of action and benefit to be gained from attaining the '5% ambition'. This will not only have subsequent impact upon future NCDs, but will also create economic benefits to employers and society at large.

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