Modelling the implications of reducing smoking prevalence: the benefits of increasing the UK tobacco duty escalator to public health and economic outcomes

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WHAT THIS PAPER ADDS

- This paper is the first to calculate the substantially improved health outcomes that could be delivered from increasing the tobacco duty escalator in the UK.
- Increasing the tobacco duty escalator on cigarettes from 2% to 5% above inflation could reduce smoking prevalence from an estimated 10% to around 6% in the UK, avoiding around 75,200 cases of disease in the next twenty years.
- Increasing the tobacco duty escalator would also have a substantial impact on reducing costs to the NHS, social care and wider society.

ABSTRACT

Introduction

Taxing tobacco is one of the most effective ways to reduce smoking prevalence, mitigate its devastating consequential health harms, and progress towards a tobacco-free society. This study modelled the health and economic impacts of increasing the existing cigarette tobacco duty escalator (TDE) in the UK from the current 2% above consumer price inflation to 5%.

Methods

A two-stage modelling process was used. Firstly, a non-linear multivariate regression model was fitted to cross-sectional smoking data, creating longitudinal projections from 2015 to 2035. Secondly, these projections were used to predict the future incidence, prevalence and cost of 17 smoking-related diseases using a Monte Carlo microsimulation approach. A sustained increase in the duty escalator was evaluated against a baseline of continuing historical smoking trends and the existing duty escalator.

Results

A sustained increase in the TDE is projected to reduce adult smoking prevalence to 6% in 2035, from 10% in a baseline scenario. After increasing the TDE, only 65% of female and 60% of male would-be smokers would actually be smoking in 2035. The intervention is projected to avoid around 75,200 new cases of smoking-related diseases between 2015-2035. In 2035 alone, £49m in NHS and social care costs and £192m in societal premature mortality and morbidity costs is projected to be avoided.

Conclusion

Increasing the UK TDE to 5% above inflation could effectively reduce smoking prevalence, prevent diseases, and avoid healthcare costs. It would deliver substantial progress towards a tobacco-free society, and should be implemented by the UK Government with urgency.

INTRODUCTION

At 219% of the EU average, the UK price level index (PLI) of tobacco is the highest among EU member states.[1] The tobacco tax in the UK is currently paid through a combination of specific duty (a price per quantity of product, £3.93 per pack of 20 cigarettes in 2016), ad valorem duty (a percentage of the retail price, 16.5% in 2016), and a standard rate of 20% value-added tax (VAT).[2] The two main products in the UK tobacco market are cigarettes and hand-rolled tobacco (HR-T), and separate duties are paid for each. Recent UK policies include a minimum excise tax to establish a base rate of tax per pack of cigarettes which impacts on the cheapest available options[3] and increased duty on HR-T. Both policies are likely to discourage 'downtrading' to cheaper tobacco products.[4]

Over the last 25 years, a notable UK policy has been a duty escalator on cigarettes that rises above consumer price inflation, continuously increasing the price of cigarettes.[5] This measure is unique among developed economies. In 1991, the Chancellor of the Exchequer found "*strong arguments for a big duty increase on tobacco"*,[6] which followed in 1992/93. A duty escalator above inflation was implemented in certain years up to 2001, including at 5% above inflation from 1997-2001, before being scrapped and subsequently re-introduced in 2010. Since then the duty escalator has been set at 2% above inflation, other than one year of increase to 5% above inflation in 2012-13.

Simulation models can inform fiscal policies, predict the impact of tobacco taxation on smoking prevalence, disease and economic burdens, and disaggregate the impact of a tax from other tobacco control interventions. To date, simulation modelling has typically quantified the impact of decreasing smoking prevalence on disease and economic outcomes.[7-15] There are fewer examples of estimating the impact of specific taxation policies on public health and economic outcomes. Particular countries have implemented significant rises in tobacco excise taxes and modelled or evaluated outcomes, including New

Zealand[12, 16-18] and Australia,[19] where 12.5% tobacco excise increases are planned until 2020. Other recent international examples include Lebanon and Greece.[20, 21]

Our study estimated the impact of increasing the TDE on cigarettes and HR-T from 2% to 5% above inflation each year from 2015 to 2035 in the UK, against a natural progression baseline scenario based on projections of current and historical smoking prevalence and evaluated the impact on disease burden and resulting costs to the UK National Health Service (NHS), social care and society.

METHODS

Statistical analysis: The UKHF Microsimulation Model

A dual-module modelling process written in C++ software, is described in depth in Supplementary File 1 and Hunt et al,[15] was used for this study. The year 2015 was chosen as the start year since the analysis was carried out in 2015. The year 2035 was selected since a policy of interest in the UK tobacco control community is the Government establishing a 'tobacco-free ambition' of 5% smoking prevalence or less by 2035.[22]

Data sources

The literature was searched for the most recent incidence, prevalence, mortality, survival, and relative risk data. Model data inputs including epidemiological parameters disease cost data drawn from NHS programme budget costs,[23] and references are presented in the supplementary online material.

Table 1. Data inputs
Risk Factor data
1. Historical and current prevalence of smoker status (never smoker, ex-smoker and smoker) by age, sex and income quintile
Disease data

2. Most recent incidence, mortality and survival of the diseases of interest, by age and sex
3. Relative risk of acquiring the diseases of interest, by age and sex
Demographic data
4. Most recent UK population, 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 without medical intervention
7. Most recent direct NHS costs associated with the diseases of interest
8. Most recent indirect societal costs associated with the diseases of interest
Tobacco duty escalator assumptions
9. Overall average retail price of cigarettes: £7.13(24)
10. Price of HR-T: £7.89(25)
11. Price elasticity: -0.5 for cigarettes, and -1.17 for HR-T(26)
12. Consumer price index: 2%
13. Level of taxation: • VAT at 20%; • ad valorem duty at 16.5%; • specific duty would increase from £176.20 per 1,000 cigarettes in 2013(25)
14. Pass on rate: 100%
15. Illicit trade: 10% of the total market

The model included 14 different smoking-related cancers classified by the International Agency for Research on Cancer.[27]

These are acute myelogenous leukaemia (AML), bladder, cervical, chronic myelogenous leukaemia (CML), colorectal, gallbladder, kidney, laryngeal, liver, lung, oesophageal, oral, ovarian, pancreatic. It also included Coronary Heart Disease (CHD), Chronic Obstructive Pulmonary Disease (COPD) and stroke.

Table 1 and the supplementary file 5 provide detail of the assumptions used in the TDE scenario. To note, as well as average retail price, the prices of the two tobacco products were further defined by the rate of consumer price inflation, level of taxation, the 'pass-on' rate, and illicit trade. Assumptions on UK tobacco taxation levels and size of the illicit tobacco market were based on existing policies and the most recently available data at the time of data collection.[28] It was estimated that the illicit tobacco market would remain stable at 10% of the total market. The illicit price of tobacco in the UK is estimated to be 50% of the legal price,[13] so the illicit price of both cigarettes and HR-T was modelled as such.

A sensitivity analysis was carried out on the price elasticity for cigarettes to explore the impact of this on later outcomes (supplementary file 6).

RESULTS

Increasing and sustaining the TDE in the UK would increase the price of cigarettes by 87.6% and HR-T products by 78.2% in 2035 relative to the baseline continuation of the 2% duty escalator, as displayed in Table 2. This results in an average price of £17.38 per pack of 20 cigarettes and £15.57 of HR-T products in 2035.

Table 2. Predicted impact of the tobacco duty escalator in the baseline and intervention scenario on the future price of cigarette products and hand-rolled tobacco (HR-T) between 2015 and 2035

	Cigarettes		**Hand-rolled tobacco (HR-T)**	
	Average price in baseline scenario	**Average price in intervention scenario**	**Average price in baseline scenario**	**Average price in intervention scenario**
2015	£7.05	£7.36	£6.61	£6.87
2020	£7.78	£9.07	£7.30	£8.37
2025	£8.59	£11.23	£8.06	£10.26
2030	£9.48	£13.95	£8.89	£12.61
2035	£10.47	£17.38	£9.82	£15.57

Over the full course of the simulation period, the prevalence of UK adult smokers in the baseline scenario is predicted to decline slowly but consistently based on previous trends, reaching 10.0% in 2035 for both men and women (**Error! Reference source not found.**). Supplementary appendix 7 illustrates baseline trends by socioeconomic gradient.

Increasing the TDE would deliver a clear additional impact on decreasing smoking prevalence relative to baseline, with this trend sustained throughout the intervention period.

Table 3 demonstrates the impact on male and female smoking prevalence in five-year time periods. In just 5 years, smoking prevalence is predicted to fall an additional 0.8% for women (from 15.0% to 14.2%) and 0.9% for men (16.0 to 15.1%). By 2025, smoking prevalence is predicted to fall an additional 1.6% for women (13.0% to 11.4%) and 2.0% for men (14.0% to 12.1%). This rate of decline increases further to 2035, where 6.0% of men and 6.5% of women smoke compared to 10.0% for both in the baseline.

Table 3. Projected baseline and intervention future trends of smoking prevalence in the UK between 2015 and 2035

	Baseline continuation of duty escalator at 2% above inflation		**Intervention increasing the tobacco duty escalator at 5% above inflation**			
	Smoking Prevalence % (All female, 18-100)	**Smoking Prevalence % (All male, 18-100)**	**Smoking Prevalence % (All female, 18-100)**	**Smoking Prevalence % (All male, 18-100)**	**Relative reduction in smoking prevalence % (All female, 18-100)**	**Relative reduction in smoking prevalence % (All male, 18-100)**
2015	17.0	18.0	16.2	16.8	4.8	6.7
2020	15.0	16.0	14.2	15.1	5.3	5.9
2025	13.0	14.0	11.4	12.1	12.5	13.9
2030	11.0	12.0	8.6	9.0	22.2	24.8
2035	10.0	10.0	6.5	6.0	35.4	39.6

An alternative way to consider these results is the proportion of would-be smokers who would still be smoking after the intervention, by comparing the impact of the intervention on smoking prevalence against the baseline. For example, increasing the duty escalator between 2015 and 2025 would mean that only 87.6% of would-be female smokers and 86.1% of would-be male smokers are predicted to still be smoking. This impact increases over time, so that by 2035 only 64.6% of would-be female smokers and 60.4% of would-be male smokers would still be smoking.

Increasing the TDE was estimated to lead to a modest reduction in the disease burden over the time period, avoiding around 7,267 (1.6% of total) new cases of smoking-related disease in the year 2035 alone. The majority are cancers (2,907; 1.5%), predominantly lung cancers (2,180; 3.7%), followed by COPD (2,180; 3.3%) and stroke (2,180; 2.5%), with no significant change recorded for rates of CHD. These data are presented in Table 4, alongside the aggregate impact over a 20-year period. Over this time, increasing the TDE is predicted to avoid around 75,254 cumulative incident cases of disease in the UK. Supplementary file 8 presents the incidence and cumulative incidence cases every 5 years of the simulation.

Increasing the TDE is predicted to avoid £49m in direct NHS and social care costs in the year 2035 alone, mostly as a result of fewer cancer cases (£25m). The intervention could deliver savings of around £192m in non-health care costs in the year 2035 alone

Table 4. Increasing the tobacco duty escalator versus a baseline projection, health and economic outcomes by disease. All data is for the UK population in 2035, except the cumulative incidence which is 2015-2035.

Tobacco-related disease	**Baseline incidence (95%CI)**	**TDE scenario incidence (95%CI)**	**Incidence cases avoidable (95%CI)**	**Baseline cumulative incidence (95%CI)**	**TDE scenario cumulative incidence (95%CI)**	**Cumulative incidence cases avoidable (95%CI)**	**Direct costs avoided (95%CI) /£million**
Coronary Heart Disease (CHD)	99552 (98825-100279)	99552 (98825-100279)	0 (-727-727)	1961426 (1959355-1963497)	1957284 (1955212-1959355)	4142 (1380-6904)	5 (2-8)
Chronic Obstructive Pulmonary Disease (COPD)	65399 (64672-66126)	63219 (62492-63946)	2180 (1453-2907)	1494025 (1491954-1496096)	1474004 (1471932-1476075)	20022 (17260-22784)	9 (8-10)
Stroke	85745 (85018-86472)	83566 (82839-84292)	2180 (1453-2907)	1837844 (1835773-1839915)	1817823 (1815752-1819894)	20022 (17260-22784)	10 (8-12)
Smoking-related cancers	196197 (195169-197225)	193291 (192564-194017)	2907 (1879-3935)	4290145 (4286763-4293527)	4259077 (4255694-4262459)	31068 (26926-35210)	25 (18-32)
Acute Myeloid Leukaemia (AML)	3633 (3633-3633)	3633 (3633-3633)	0 (0-0)	67659 (66969-68349)	67659 (66969-68349)	0 (-690-690)	13 (7-19)
Bladder Cancer	13080 (13080-13080)	13080 (13080-13080)	0 (0-0)	289968 (289278-290658)	288587 (287897-289278)	1381 (691-2071)	0 (0-0)
Bowel Cancer	49413 (48686-50140)	49413 (48686-50139)	0 (-727-727)	956894 (955513-958275)	956204 (954823-957585)	690 (-1381-2761)	0 (-2-2)
Cervical Cancer	3633 (3633-3633)	3633 (3633-3633)	0 (0-0)	69730 (69040-70420)	69730 (69040-70420)	0 (-690-690)	0 (0-0)
Chronic Myeloid Leukaemia (CML)	727 (727-727)	727 (727-727)	0 (0-0)	15879 (15879-15879)	15879 (15879-15879)	0 (0-0)	0 (0-0)
Gastric Cancer	8720 (8720-8720)	8720 (8720-8720)	0 (0-0)	176052 (175362-176742)	175362 (174671-176052)	690 (0-1380)	0 (-1-1)
Hepatic Cancer	5087 (5087-5087)	5087 (5087-5087)	0 (0-0)	106322 (105632-107012)	105631 (104941-106322)	690 (0-1380)	0 (-1-1)
Laryngeal Cancer	2907 (2907-2907)	2907 (2907-2907)	0 (0-0)	69730 (69040-70420)	69040 (68350-69730)	690 (0-1380)	1 (1-1)
Lung Cancer	58859 (58132-59586)	56679 (55953-57406)	2180 (1453-2907)	1427056 (1424985-1429127)	1410487 (1408416-1412558)	16570 (13808-19332)	8 (7-9)
Oesophageal Cancer	10900 (10900-10900)	10900 (10900-10900)	0 (0-0)	272708 (272018-273398)	269256 (268566-269946)	3452 (2762-4142)	2 (1-3)
Oral Cancer	7993 (7993-7993)	7993 (7993-7993)	0 (0-0)	194002 (193312-194692)	190550 (189860-191241)	3452 (2762-4142)	1 (1-1)
Ovarian Cancer	8720 (8720-8720)	8720 (8720-8720)	0 (0-0)	176742 (176052-177432)	175362 (174671-176052)	1381 (691-2071)	1 (0-2)
Pancreatic Cancer	10900 (10900-10900)	10173 (10173 -10173)	727 (727-727)	220928 (220238-221618)	219547 (218857-220238)	1381 (691-2071)	0 (-2-2)
Renal Cancer	11627 (11627-11627)	11627 (11627-11627)	0 (0-0)	246473 (245783-247163)	245782 (245092-246473)	690 (0-1380)	0 (0-0)
Total	446,894 (445,268-448,519)	439,627 (438,002-441,253)	7,267 (5,642-8,891)	9,583,440 (9,578,510-9,588,371)	9,508,187 (9,503,256-9,513,117)	75,254 (68,926-81,581)	49 (40-57)

DISCUSSION

This study finds substantial benefits of increasing the TDE. While benefits begin to appear within a five-year period, equivalent to one UK Parliamentary term, it could also deliver substantial progress towards achieving a tobacco-free ambition. As a consequence, findings show that increasing the TDE could avoid new cases of disease, as well as avoid substantial costs to the NHS and wider society.

This impact could be further maximised by allocating the costs avoided or revenue raised to support tobacco control. Using a recent estimate by Claxton *et al*,[29] investing the £49m of direct health costs avoided in this study elsewhere in the NHS would generate the equivalent of 1,923 Quality Adjusted Life Years (QALYs), additional to health gains directly attributable to the intervention.

One recurrent tobacco industry claim against increased taxation is its impact on illicit trade. While ongoing support to enforce protections against tobacco smuggling is required to underpin successful taxation policy, research has found industry claims inconsistent with independent data.(30) Substantial progress has been made in the UK with illicit trade rates having halved since 2000-01.[28, 31] In addition, a European assessment found the supply of illicit tobacco, rather than its price, is a key factor contributing to tax evasion.[32]

The findings of this study demonstrate the importance of effective tobacco tax policy in improving health as well as yielding economic benefits. They strengthen the case that, adequately supported with measures to tackle illicit tobacco, increasing the TDE can effectively reduce the disease and economic burden caused by smoking in the UK.

Limitations and future work

This study has a number of limitations. First, it was not able to account for recent policy developments. In particular, the UK Government's 2016 commitment to a one-off 3% increase in duty on HR-T has not been captured in this research.[33] However, this study also

modelled the increase in duty of cigarettes and HR-T both by 5% above inflation annually. In reality, this calculation would not resolve existing disparity in duty between the tobacco products, given a lower baseline duty on HR-T. In another discrepancy between products, the rate of illicit trade for cigarettes was also applied to HR-T products in the model, despite data suggesting higher rates of illicit trade for these products in the UK. Further, research shows that use of HR-T has increased over recent years.[34] Future work will be able to explore the impact of this recent, additional increase in duty on the prevalence of HR-T use, and other policy mechanisms to address HR-T use such as a tax based on the minimum consumption of tobacco products.

We assumed that the ad valorem rate of duty stayed fixed, which may in the future be hindered by European rules which fix a maximum proportion of overall tobacco tax that can be from specific duty, , which will have implications for our study on other countries. Future work might explain the impact that this will have on later outcomes.

Since this study only calculated data to 2035, and given the time lag between reducing smoking prevalence and decreased risk of developing cancer, these projections will not have captured all cases of disease avoided, nor economic burdens prevented, as a result of the intervention. In addition, not all diseases caused or exacerbated by smoking were included in the model, such as type 2 diabetes mellitus. As such, findings are likely to underestimate the total impact of the TDE across the life course.

While this research assumed a pass-through rate of 100%, emerging research has found the tobacco industry may over-shift prices in brand segments other than ultra-low price cigarettes. There is evidence from the United Kingdom,[35] United States[36] and New Zealand[37] indicating that tobacco prices increase differently across product categories after taxation. Ongoing research is required to simulate the complexities of tobacco industry

pricing strategies, and encourage more sophisticated responses from governments that mitigate against ‘down-trading’ to cheaper tobacco products.

This study also did not calculate the impact of increasing the TDE on smoking prevalence amongst more deprived groups, as disease outputs were not available. However, with higher smoking prevalence in the UK (as in many other countries) among those in routine and manual professions, compared to professional and managerial roles,[38] it is reasonable to assume the benefit of reducing prevalence from a TDE would be disproportionately seen in groups of higher smoking prevalence.

At the time of analysis only smoking prevalence data to 2012 were available. Subsequent to that we have observed further declines in smoking prevalence (in line with our predictions). Therefore, the results are not a full reflection of the number of disease cases that could be avoided if the intervention was introduced in 2017, nor the full time-scale of all disease that could occur across a person’s lifetime.

While data intensive, a review by the OECD deemed the microsimulation method the most suitable for risk factor and chronic disease modelling, and is a strength of this study.[39] However, as with any model a number of assumptions have to be made, which may lead to different sets of results. We used the most robust data inputs available, and validated assumptions using both expert opinion and the literature. We carried out a sensitivity analysis on the price elasticity (supplementary file 6) where small changes were observed in the disease outcomes over time. Unfortunately, it was not possible to carry out a full stochastic sensitivity analysis given the many thousands of calculations and parameters within the microsimulation, and the necessity of super computers. However, our future work will use a variance based method (Sobol’s indices method) on a deterministic model (Jaccard et al, *forthcoming*).

The model includes a number of risk factors and a functionality to run multiple risks, and has been utilised in over 70 countries.[40-44] However, certain inputs were not included that should be considered in future work, either because data are lacking or it was not within the scope of the study. Examples include: cross-price elasticity figures of illicit tobacco products; elasticity figures for tobacco products stratified by socio-economic class; cross-elasticities between smoking, drinking and other behavioural risk factors; pass-on rates for tobacco products; and recent price elasticity of demand figures. The proportion of smokers using cigarettes and HR-T was kept constant throughout the intervention, because of an absence of evidence calculating the cross-price elasticities between tobacco products. Similarly, this study did not explore the impact of other lower priced alternatives, such as e-cigarettes, in the market on the effectiveness of increased taxation on smoking.

In relation to costs, price discounting was not included in calculations in the model. It also did not assess the impact of increasing the TDE on revenue collection through tax receipts. Indirect cost calculations only explored those resulting from indirect morbidity and mortality and not the full range of harms of smoking to society, such as passive smoking, domestic fires or litter.

To inform taxation policy, future research could: include a scenario analysis to compensate for different levels of taxation mechanisms or a different time horizon; could calculate the revenue generated; predict the negative implications of decreasing tobacco taxation on health outcomes;[45] and incorporate years of life saved through policy interventions. If conducted in countries where a subsidised or nationalised health system (such as the NHS) is not accessible by all, future research should consider the informal costs of treating a tobacco-related disease to the individual and family.

Figure legends:

Figure 1: Smoking prevalence by sex from 2015 to 2035 for baseline and TDE scenarios.

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AUTHOR CONTRIBUTIONS

All authors were involved in the design of the study. AKT, AJ, LR and MB developed the model methodology, including development of algorithms and model assumptions. AKT, AB, AJ, LR and LW provided information on the study methodology, data inputs and carried out the analysis of outputs, and DH wrote the introduction and discussion. AKT, DH, SH, LB and LW have contributed to manuscript revisions.

COMPETING INTERESTS

AKT and AB worked at the UK Health Forum when this research was undertaken. No other interests are declared.

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