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Population health impact of non-tobacco flavour restrictions in electronic vapour products: a dynamic modelling study in the United Kingdom

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Article

Keywords: Electronic vapour products, Flavour ban, Harm reduction, Dynamic population model, Smoking prevalence, United Kingdom

Posted Date: August 6th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10279711/v1

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Additional Declarations: No competing interests reported.

Abstract

Smoking is a cause of serious disease, with most harm arising from the combustion of tobacco and the inhalation of smoke. In response, there is growing interest in tobacco harm reduction strategies, particularly the substitution of smoking cigarettes with Next Generation Products, such as Electronic Vapour Products. However, concerns about their appeal to youth and non-smoking adults have prompted regulatory proposals to restrict or ban certain features of EVP, particularly non tobacco flavours. Such plans may influence the behaviour of current adult users, generating population level changes in smoking, vaping, and associated health outcomes. In this study, we predict the potential population health impact of a ban on non-tobacco flavoured EVP in the United Kingdom using a previously published dynamic population model projecting smoking and vaping prevalence to 2040. Historical prevalence data (2014–2022) were used to forecast future trends, and potential behavioural responses among current users of non-tobacco flavoured EVP were modelled across a range of scenarios. Mortality outcomes were estimated using excess relative risk assumptions ranging from 5% to 50% for EVP use relative to smoking. Results showed that future EVP prevalence and mortality outcomes were highly dependent on behavioural responses. Relapse to smoking was the dominant driver of harm, whereas switching or cessation produced substantially smaller effects. Overall, the results suggest that behavioural responses to a ban on non-tobacco flavoured EVP, especially the extent of smoking relapse, are likely to be important determinants of its population-level health impact.

Introduction

Cigarette smoking is a well-established cause of serious disease, including lung cancer, emphysema and cardiovascular disease, and is responsible for more than seven million deaths worldwide each year [1]. These adverse health effects primarily arise from repeated exposure to toxic chemicals produced during tobacco combustion and inhaled in cigarette smoke [2–5].

Smoking cessation substantially reduces the risk of developing smoking-related diseases [6], and many adults who smoke report a desire to quit [7]. However, fewer than 10% of adults who smoke successfully quit each year [7]. As a result, Tobacco Harm Reduction (THR) has emerged as an important public health strategy esp. for those smokers with no intention to quit [8, 9]. THR seeks to reduce the health risks associated with tobacco smoking, including in individuals who may continue to use nicotine or tobacco. This approach involves substituting cigarettes with alternative nicotine delivery systems that significantly reduce exposure to harmful toxicants [6, 10–12].

Over the past two decades, New Generation Products (NGPs) have been developed to enable THR. For adults who smoke who are unwilling or uninterested to quit and who would otherwise continue to smoke, a growing number of public health organizations, including Public Health England and the UK Royal College of Physicians, have suggested that reduced-risk products such as Electronic Vapor Products (EVP), commonly known as e-cigarettes, may represent a potentially less harmful alternative. EVP deliver nicotine alongside substantially fewer and lower levels of toxicants compared with cigarette smoke [13] and therefore have the potential to reduce the burden of smoking-related disease [14].

Evidence from randomized controlled trials and observational studies indicates that EVP reduce the exposure to toxicants from combustion and can support smoking cessation [15–23]. In addition, modelling studies predict that widespread adoption of EVP could lead to substantial public health gains through reductions in smoking-related morbidity and mortality [24–26].

Despite this potential “off-ramp” for adults who smoke, concerns persist regarding EVP use among never-smokers, particularly youth. EVP availability could hypothetically create an “on-ramp” to nicotine initiation and potentially to combustible cigarette use, a phenomenon often described as the “gateway” hypothesis [27–30]. A major focus of these concerns is the availability and impacts of non-tobacco flavours in EVP. These products are offered in a wide range of flavours, including fruit, candy/confectionary, mint, and menthol, and there is concern that such flavours may be more appealing to unintended users, especially youth, than tobacco flavours. Consequently, several jurisdictions have proposed restrictions or bans on non-tobacco flavoured EVP [31–34].

However, such measures may carry important implications for THR. Flavoured EVP are widely used by adults [35]. Farsalinos et al. [36] report that non-tobacco flavours, particularly fruit and dessert/pastry/bakery varieties, were the most commonly used by established, adult US vapers and were frequently used at the time of smoking cessation. These findings align with results from a large cross-sectional US survey of more than 20,000 participants [37]. The role of non-tobacco flavours in EVP is therefore complex, involving multiple competing factors that influence overall population-level health effects. When developing policy, regulators should carefully consider all these factors, including the ways in which flavoured EVP may support smoking cessation among adults whilst protecting youth and non-smoking adults. Maintaining flavour diversity may help reduce smoking prevalence and improve public health as drivers of transitioning behaviours. Accordingly, proposals to ban non-tobacco flavours may insufficiently account for their potential impact on adults who smoke and former smokers, who remain the predominant users of EVP.

Assessing these policy complexities requires analytical methods capable of representing population-level behaviours, transitions between different product use states, and their evolution over time, as well as associated long-term health outcomes. Dynamic population models are well suited to this purpose, as they simulate changes in population exposure and risk under alternative policy scenarios. The incorporation of synthetic population approaches within such models provides a means to address key obstacles related to data availability, scale, and privacy. Synthetic population generation enables the construction of statistically representative cohorts that preserve observed real-world demographic characteristics, behavioural patterns, and transition probabilities, without reliance on identifiable individual-level data. When calibrated and validated against empirical data, synthetic populations can be integrated into dynamic modelling frameworks to support scenario analysis, policy evaluation, and

long-term projections in contexts such as tobacco harm reduction, where randomized longitudinal evidence is limited. These approaches complement real-world data by extending analytical capacity while maintaining scientific rigour, transparency, and fitness for purpose.

Building on this framework, the present study estimates, through behaviourally plausible scenarios among current adults who use EVP, the potential impact of banning non-tobacco flavours on product use patterns and associated health outcomes. Using a dynamic population model (DPM) applied to the United Kingdom (UK), we project prevalence trajectories and health outcomes, specifically changes in overall mortality, under multiple policy scenarios. The analysis explores how outcomes may depend on behavioural adjustments among EVP users, with scenarios serving as structured approximations rather than precise predictions.

Methods

The dynamic model employed in this study has been described previously by Verron et al. [38] and consists of three main steps.

First, historical trends in smoking and vaping prevalence are used to generate time-series forecasts up to 2040. Second, these projected prevalences are combined with representative smoking and vaping trajectories and mortality models to estimate mortality outcomes. Finally, a baseline scenario (no flavour ban) is compared with alternative scenarios reflecting plausible consumer responses to a non-tobacco flavours ban, including vaping cessation, relapse to smoking, and product switching.

This framework allows the assessment of potential public health impacts under a range of behavioural assumptions.

This model adopts conservative assumptions, with smoking and vaping initiation rates held constant. It focuses on behavioural changes among current EVP users, highlighting that policies aimed at protecting potential non-users may unintentionally increase tobacco-related mortality among existing users. It also does not account for risks from potentially more harmful, unregulated black market products.

Data sources and prevalence framework

Prevalence data from 2014 to 2022 were obtained from the Office for National Statistics [39]. Prevalences were calculated for the nine combined cigarette smoking statuses (never, current, former) and EVP use status (never, current, former), as defined in Table 1 and reported in Table 2.

Table 1
Product-use categories (cigarette and EVP)

Status	Cigarettes status	EVP status	Notation
Never Smoker; Never EVP user	Never	Never	**NVR;NVR**
Current smoker; Never EVP user	Current	Never	**CUR;NVR**
Former smoker; Never EVP user	Former	Never	**FMR;NVR**
Never smoker; Current EVP user	Never	Current	**NVR;CUR**
Smoker; EVP user	Current	Current	**CUR;CUR**
Former smoker; Current EVP user	Former	Current	**FMR;CUR**
Never smoker; Former EVP user	Never	Former	**NVR;FMR**
Current Smoker; Former EVP user	Current	Former	**CUR;FMR**
Former Smoker; Former EVP user	Former	Former	**FMR;FMR**

Table 2
Smoking and vaping prevalence (%) in the UK from 2014 to 2022

Year	NVR;NVR	CUR;NVR	FMR;NVR	NVR;CUR	CUR;CUR	FMR;CUR	NVR;FMR	CUR;FMR	FMR;FMR
2014	58.2	12.0	20.2	0.1	2.1	1.5	0.5	4.4	1.0
2015	58.1	9.4	19.9	0.1	2.6	1.8	0.8	5.9	1.3
2016	58.2	8.2	20.2	0.4	2.1	2.9	0.9	5.5	1.6
2017	57.9	9.0	20.1	0.2	2.4	2.8	0.8	4.9	1.7
2018	56.3	11.4	22.1	0.5	2.3	3.4	0.4	2.6	1.0
2019	58.2	12.0	22.1	0.1	2.4	2.9	0.1	1.1	1.0
2020	58.5	7.2	20.2	0.7	2.5	3.1	0.8	4.7	2.3
2021	60.2	6.1	19.6	1.0	3.1	3.8	0.7	3.4	2.2
2022	61.2	5.5	18.6	1.5	2.9	4.1	0.9	2.6	2.7

Insert Table 1 **here**

Table 2 presents the observed prevalence of smoking and vaping statuses in the UK from 2014 to 2022.

Insert Table 2 **here**

For each combined cigarette-EVP status, a Prophet time-series model [40] was trained on the prevalence data from 2014 to 2022 and use to forecast the prevalences from 2023 to 2040.

All analyses were conducted in R (version 4.3.2) [41] using Rstudio Server [42]. Data manipulation and time series forecasting were performed using the tidyverse [43] and Prophet [40] packages.

Behavioural scenarios following a non-tobacco flavour ban

Across all scenarios, we assume that initiation rate into EVP use does not change in response to a ban on non-tobacco flavours. Instead, the scenarios focus specifically on how current users of non-tobacco-flavoured EVP might alter their behaviour. According to the ASH Smokefree GB Adult Survey 2023, around 70% of current vapers use non-tobacco-flavoured e-liquids [44]. Consequently, the scenarios examine behavioural changes exclusively among this existing group of EVP users.

To simulate these transitions, we assume that β% of users of non-tobacco flavoured EVP transition to tobacco flavoured EVP, α% move to cigarette smoking, and the remaining fraction γ (defined as $\gamma = (1 - \alpha - \beta)\%$) quits all EVP use.

Parameters α and β can take any value between 0% and 100%, provided that $\alpha + \beta \leq 100\%$. These proportions may be adjusted based on available empirical evidence or expert consensus.

Based on this parameterization, specific scenarios can be defined:

Static scenario

This scenario corresponds to $\beta = 100\%$. All users of non-tobacco flavoured EVP switch to tobacco-flavoured EVP. Total vaping prevalence therefore remains constant, with an internal distribution shift from non-tobacco flavoured to tobacco-flavoured EVP. **Optimistic scenario**

This scenario corresponds to $\gamma = 100\%$. All users of non-tobacco flavoured EVP stop vaping entirely. This results in a reduction in overall vaping prevalence without any corresponding rise in smoking prevalence. It reflects the most favourable public-health outcome, assuming complete cessation rather than product substitution.

Pessimistic scenario

This scenario corresponds to $\alpha = 100\%$. All users of non-tobacco flavoured EVP switch to cigarette smoking. This leads to an increase in smoking prevalence alongside a decrease in vaping prevalence, potentially reversing harm-reduction gains.

In addition to these three extreme scenarios, the full range of possible combinations of α, β, and γ was considered, allowing for partial and simultaneous transitions across behaviours. These intermediate combinations capture mixed and transitional patterns of product use, including

varying degrees of concurrent use of EVP and cigarettes, and thus reflect more realistic behavioural responses. Together, these scenarios provide a comprehensive assessment of potential population-level impacts under differing behavioural assumptions.

Insert Table 3 **here**

Table 3
Sensitivity analysis of cumulative premature death differences (thousands) between status-quo and modelled scenarios across varying ERR for vaping, by 2040.

Scenario	α	β	γ	ERR = 5%	ERR = 10%	ERR = 20%	ERR = 50%
Optimistic	**0%**	**0%**	**100%**	**-26.9**	**-53.8**	**-107.7**	**-269.1**
2	20%	0%	80%	99.6	71.7	15.9	-151.6
3	40%	0%	60%	226.1	197.2	139.4	-34.0
4	**60%**	**0%**	**40%**	**352.6**	**322.7**	**262.9**	**83.6**
5	80%	0%	20%	479.0	448.2	386.4	201.1
Pessimistic	**100%**	**0%**	**0%**	**605.5**	**573.7**	**509.9**	**318.7**
7	0%	20%	80%	-21.5	-43.1	-86.1	-215.3
8	20%	20%	60%	105.0	82.4	37.4	-97.7
9	**40%**	**20%**	**40%**	**231.4**	**207.9**	**160.9**	**19.8**
10	60%	20%	20%	357.9	333.4	284.4	137.4
11	80%	20%	0%	484.4	458.9	407.9	255.0
12	0%	40%	60%	-16.1	-32.3	-64.6	-161.5
13	20%	40%	40%	110.3	93.2	58.9	-43.9
14	40%	40%	20%	236.8	218.7	182.4	73.7
15	60%	40%	0%	363.3	344.2	306.0	191.2
16	0%	60%	40%	-10.8	-21.5	-43.1	-107.7
17	20%	60%	20%	115.7	104.0	80.5	9.9
18	40%	60%	0%	242.2	229.5	204.0	127.5
19	0%	80%	20%	-5.4	-10.8	-21.5	-53.8
20	20%	80%	0%	121.1	114.7	102.0	63.7
Static	**0%**	**100%**	**0%**	**0.0**	**0.0**	**0.0**	**0.0**

Mortality Estimation and Trend Analysis

To estimate population mortality under the proposed scenarios, our model integrated projected prevalence for each tobacco-use status with the mortality model established by Rogers et al. [45] and Representative Sample Trajectories (RSTs) [38]. The impact on smoking-attributable mortality was evaluated by comparing the behavioural scenarios against the baseline across a range of ERR values, ranging from 5% to 50%. An ERR of 5% represents the assumption that EVP use is 95% less harmful than smoking. By varying this risk from 5% to 50%, the model tests the robustness of the "vraisemblance of harm" even under more conservative health assumptions regarding long-term vaping.

RESULTS

Our Dynamic Population Model (DPM) was used to extrapolate potential EVP consumer responses to a non-tobacco flavoured EVP ban starting 2023, in the UK, forecasting shifts in prevalence across current, former and never vaper/smoker categories.

Figure 1 presents observed prevalence and projected trends for current EVP from 2023 to 2040, for different scenarios.

Under the static scenario, where all users of non-tobacco flavours switch to tobacco-flavoured products, prevalence of current EVP users increases steadily, reaching 15.3% by 2040. This level would correspond to the prevalence expected in a situation where the flavour ban is not implemented.

In contrast, substantially lower prevalence of EVP use is projected under the optimistic and pessimistic scenarios, at 7.1% and 4.6%, respectively.

The full range of possible combinations between α and β, represented by the grey shaded area in Fig. 1, corresponds to intermediate prevalence outcomes. Under these conditions, as expected, the projected ranges lie between the “static”, the “optimistic” and the “pessimistic” scenarios. This reflects a plausible distribution of user responses to a flavour ban.

Insert Fig. 1 **here**

To quantify the associated health effects, we integrated the projected prevalence trajectories into our mortality model to estimate cumulative premature deaths relative to a status-quo (no flavour ban), relative to the baseline.

Figure 2 presents the surface representations of the projected impact of a flavour ban on cumulative premature mortality, shown as a function of both consumer behavioural responses and the assumed ERR of vaping.

INSERT FIGURE 2 **HERE**

The triangular mixture space captures the full range of possible behavioural scenarios following a ban on non-tobacco-flavoured EVP. The three vertices correspond to the extreme reference scenarios:

- static scenario (β = 100%), where all non-tobacco flavoured EVP users switch to tobacco flavoured EVP;
- optimistic scenario (γ = 100%), where all non-tobacco flavoured EVP users quit vaping entirely;
- pessimistic scenario (α = 100%), where all non-tobacco flavoured EVP users switch to cigarette smoking.

Intermediate points within the triangle represent mixtures of these behavioural responses, and the colour-shaded surfaces shown in Fig. 2 depict the resulting continuum of projected mortality outcomes under each ERR assumption. These surfaces illustrate how realistic population-level effects are expected to fall between the extreme scenarios and vary substantially depending on both behavioural patterns and relative-risk assumptions.

Table 3 summarises the projected change in cumulative premature deaths (in thousands) under a range of intermediate behavioural responses and ERR assumptions. These results illustrate how population-level health effects are highly sensitive to both the proportion of users who relapse to smoking (α) and the assumed excess relative risk associated with vaping.

For the lower risk assumption (ERR = 5%), mortality outcomes span from a reduction of 26,900 deaths in the optimistic scenario (α = 0%, β = 0%, γ = 100%) to an increase of 605,500 deaths in the pessimistic scenario (α = 100%, β = 0%, γ = 0%). Intermediate behaviours fall proportionally between these extremes. For instance, a scenario in which 40% of displaced non-tobacco-flavour users relapse to smoking and 60% quit (α = 40%, β = 0%, γ = 60%) yields an estimated 226,100 additional premature deaths. Conversely, if 80% of users switch to tobacco-flavoured EVP and only 20% relapse (α = 20%, β = 80%, γ = 0%), the model projects a far smaller increase of 121,100 premature deaths. These two illustrative scenarios are highlighted in red in Fig. 2, indicating their positions within the behavioural mixture space and showing how each maps onto the corresponding mortality surface.

As the assumed ERR for vaping increases, the gradient between scenarios narrows, reflecting the diminishing relative benefit of continuing EVP use compared with quitting or relapsing to smoking. However, even under a high ERR assumption of 50%, outcomes remain strongly dependent on behavioural patterns. At ERR = 50%, the optimistic scenario still produces substantial mortality reductions (269,100 fewer premature deaths), whereas the pessimistic scenario continues to generate considerable harm (318,700 additional premature deaths).

Intermediate behavioural mixes again produce proportionate effects. For example, in a scenario where 40% of displaced non-tobacco flavour users relapse to smoking, 40% quit, and 20% switch to tobacco-flavoured EVP (α = 40%, β = 20%, γ = 40%), projected excess premature deaths reach 19,800. In contrast, a scenario with a higher relapse rate and no switching to tobacco flavours (α = 60%, β = 0%, γ = 40%) results in an estimated 83,600 additional premature deaths compared with a situation where non-tobacco flavours remained available. These two illustrative scenarios are highlighted in orange in Fig. 2.

INSERT Table 3 **HERE**

Using an ERR of 5%, a value reported in the literature for EVP (46, 47), our analysis indicates that, by 2040, a non-tobacco flavours ban would result in a net negative impact on population mortality in approximately 76% of 21 tested scenarios. Naturally, as the risk difference between cigarettes and EVP narrows, that is, as the ERR increases, the negative impact diminishes accordingly. However, across all simulations (21 scenarios * 4 ERR:, from 5%, 10%, 20% and 50%), 71% of cases show ddetrimental health effect for people who were EVP users at the time a flavour ban was introduced..

DISCUSSION

The present modelling analysis suggests that a regulatory ban on non-tobacco flavoured EVP may lead to population-level outcomes that depend critically on how displaced users adjust their behaviour. While the applied scenarios serve as structured approximations rather than predictions, they underscore the importance of behavioural heterogeneity in shaping the net public health impact of flavour policies. A key finding from this analysis is the strong imbalance between the health implications of smoking relapse and those of vaping cessation: Even small increases in transitions from vaping to smoking produce far greater population-level harm than the corresponding health gains that occur when similar proportions of users cease

using nicotine. This imbalance reflects the well-established difference in risk between combustible cigarette use and vaping, with smoking carrying substantially higher excess mortality. As a result, modelled scenarios involving relapse to smoking have a disproportionately large impact on overall mortality outcomes.

Realistic scenarios, which combine elements of cessation and relapse, illustrate this point most clearly. When cessation dominates, the projected health benefits are modest but consistent. However, when relapse becomes more prevalent, even at similar magnitudes, the model estimates substantially higher premature mortality by 2040. These findings highlight the sensitivity of policy outcomes to behaviours and they reinforce concerns that restrictive flavour policies may have unintended consequences for adult users who currently rely on non-tobacco flavoured EVP as an alternative to cigarettes.

Flavour availability may play an important role in product satisfaction, switching behaviour, and sustained abstinence from smoking, especially among adults who formerly smoked. Within this context, policies that remove flavours may unintentionally diminish the interest in vaping for some groups, potentially increasing risk of relapse to smoking.

The modelled results also suggest that population-level effects cannot be inferred from changes in vaping prevalence alone. In the optimistic scenario, declining EVP use leads to substantial health gains only because it is assumed to reflect true cessation. In contrast, the pessimistic scenario also shows declining vaping prevalence but large increases in premature deaths because the decline occurs through transitions to smoking. This finding underscores the importance of distinguishing between reductions in vaping driven by cessation and those driven by substitution with more harmful products. Policies affecting EVP use may therefore produce divergent public health outcomes depending on the behavioural pathways they influence.

Interpretation of these results should consider limitations inherent to model-based approaches. First, behavioural responses to flavour bans remain uncertain, and empirical estimates of cessation and relapse probabilities vary across populations, type of EVP and regulatory settings. Second, although ERRs for vaping were varied extensively in sensitivity analyses, the long-term risk profile of EVP use remains an active area of research. Third, the modelling does not account for potential compensatory market dynamics, such as increased use of illicit products or product innovation, that could alter real world outcomes. Finally, across all scenarios, we assume that smoking and vaping initiation rates remain unchanged following a non-tobacco flavours ban. Specifically, initiation into EVP use is held constant and does not decline after the ban. This represents a conservative, or even pessimistic, assumption, given that flavour bans are typically introduced with the objective of reducing experimentation and initiation, particularly among youth. As a result, the scenarios focus exclusively on behavioural changes among current adult EVP users, without incorporating potential reductions in future uptake. While this limits the scope of the model, it does not materially affect the primary conclusions. The central driver of the projected mortality outcomes is the balance between cessation and relapse among existing flavoured-EVP users. Therefore, even though our model does not capture possible declines in initiation, the overall findings remain robust: small increases in relapse to smoking among current adult users exert a far greater influence on cumulative premature mortality by 2040 than plausible reductions in future vaping initiation would.

Despite these limitations, this analysis contributes to the ongoing debate on flavour regulations by illustrating how different behavioural trajectories can shape population health outcomes over time. The findings suggest that, under plausible behavioural patterns, regulatory bans on non-tobacco EVP may carry a substantial risk of unintended negative consequences, particularly through increases in smoking among adults currently using flavoured vaping products. In simple terms, banning non-tobacco flavours might increase relapse to smoking thereby in itself designing a gateway into smoking for EVP users. Policymakers considering flavour restrictions may therefore benefit from considering a broader range of behavioural responses, including relapse, product switching and cessation, for regulatory impact assessments. Future research should prioritise empirical evaluation of user behaviour following actual flavour policy implementations to refine model assumptions and enhance the accuracy of population-level projections.

CONCLUSION

Next Generation Products (NGP), including Electronic Vapour Products (EVP), deliver nicotine without the combustion of tobacco and therefore have the potential to support tobacco harm reduction (THR). However, concerns regarding their appeal to youth have led to regulatory proposals aimed at restricting or banning certain EVP features, particularly non-tobacco flavours. Such policies may affect the behaviour of current adult users, resulting in population-level changes in smoking, vaping, and associated health outcomes.

Our dynamic population modelling analysis illustrates that the public health impact of a ban on non-tobacco flavoured EVP is highly dependent on how current adult users would adjust their behaviour as a result of a potential ban.

Across a wide range of plausible behavioural responses and assumptions regarding the relative harm of vaping, the model consistently identifies transitions from vaping to cigarette smoking as the primary driver of adverse population-level outcomes. Even relatively small increases in smoking relapse among adults using non-tobacco flavoured EVP were projected to result in substantial increases in cumulative premature mortality by 2040, outweighing the potential health gains associated with vaping cessation.

Under a wide range of possible behavioural responses, restrictions on non-tobacco flavoured EVP therefore carry a substantial risk of unintended negative consequences for adult users, primarily through increased smoking relapse. Policymakers considering flavour restrictions should therefore

carefully balance potential youth protection benefits against the risk of increased tobacco-related mortality among adults who currently use flavoured EVP as a harm reduction alternative as these restrictions may otherwise design a gateway effect into smoking in treir own regards.

From a methodological perspective, this study underscores the value of synthetic science approaches within dynamic population modelling for the evaluation of complex tobacco control policies. The use of synthetic populations enables the simulation of long-term outcomes across a broad range of behaviourally plausible scenarios while preserving real-world structure and variability, without reliance on identifiable individual level data. When appropriately calibrated and validated against empirical evidence, synthetic population modelling provides a transparent and privacy-preserving framework for policy scenario analysis, particularly in contexts such as tobacco harm reduction where randomized longitudinal evidence is limited or infeasible. Importantly, this approach complements existing real-world data, extending the analytical capacity while maintaining scientific rigour to assess regulatory measures and decisions.

Declarations

Data availability

The code and models used in the study are available from the corresponding author upon reasonable request.

Acknowledgements

The authors would like to thank the Imperial Brands Internal Reading Committee for their thoughtful review of the manuscript and valuable feedback throughout its development. In particular, we gratefully acknowledge Sarah Cordery for her detailed comments, constructive suggestions, and critical assessment of the work, which helped improve the clarity, quality, and scientific rigor of the manuscript.

Funding

This study was funded by Imperial Brands PLC, manufacturers of the EVP.

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Contributions

TV, MG and XC were primarily responsible for the study design, model development, data analyses, and drafting of the manuscript. LC and TN contributed to the study development and critically reviewed and revised the manuscript. All authors read and approved the final manuscript.

Competing interests

All authors are current employees of Imperial Brands PLC or its subsidiaries.

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Figures

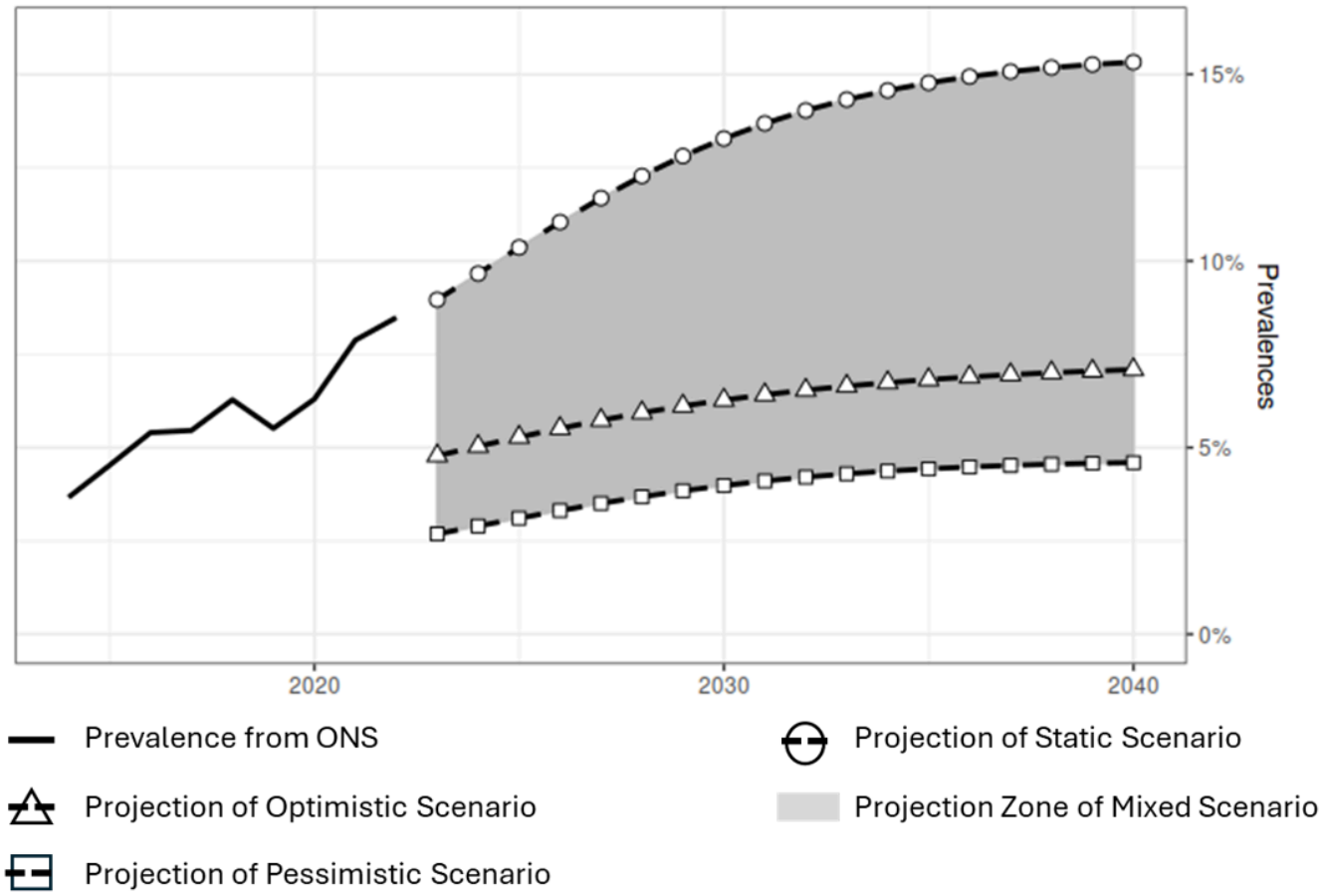

Figure 1

Observed prevalence and projected trends for current EVP users from 2023 to 2040, for different scenarios.

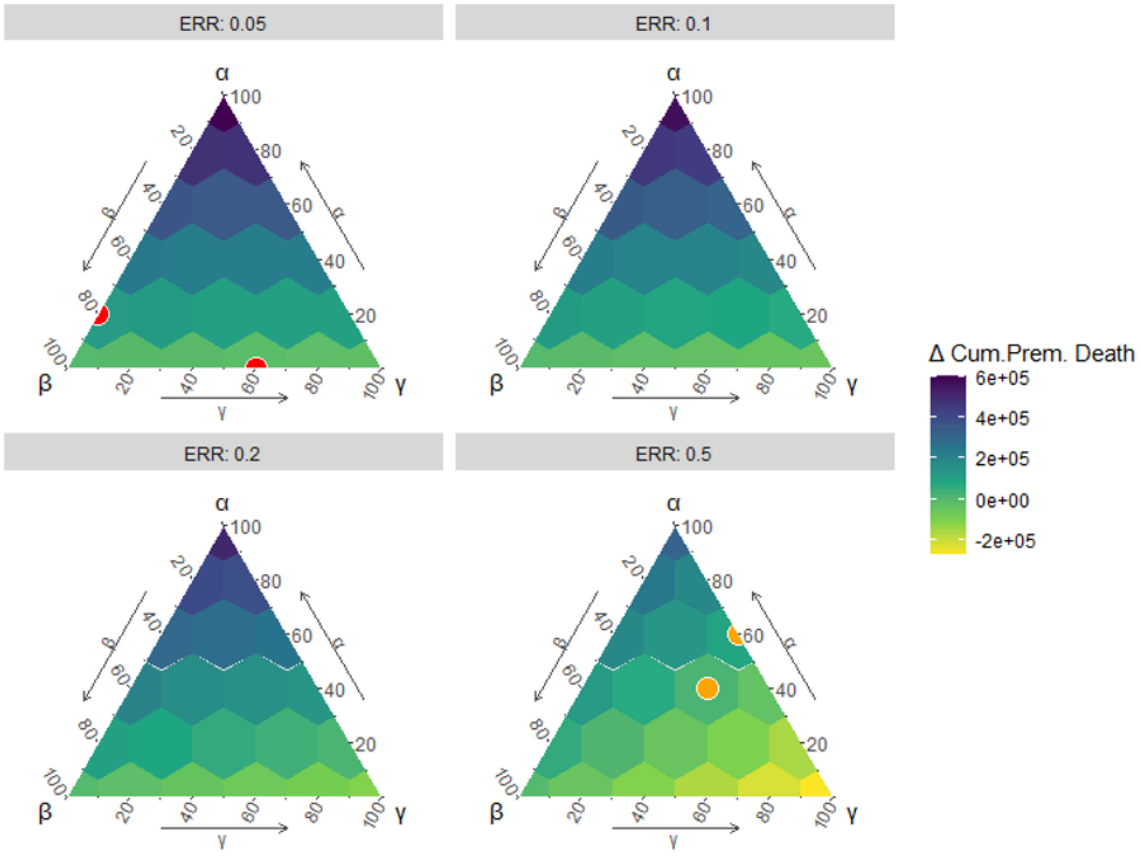

Figure 2

Estimated cumulative premature death differences by 2040 for all combinations of user behavioural responses (α: smoking relapse; β: switching to tobacco-flavoured EVP; γ: quitting) under varying vaping Excess Relative Risk (ERR) assumptions.

Red points mark two scenarios at ERR=5% (referenced in the main text):

1. α = 40%, β = 0%, γ = 60%, leading to +226,100 deaths

2. α = 20%, β = 80%, γ = 0%, leading to +121,100 deaths

Orange points mark two scenarios at ERR=50% (referenced in the main text):

1. α = 40%, β = 20%, γ = 40%, leading to +19,800 deaths

2. α = 60%, β = 0%, γ = 40%, leading to + 83,600 deaths

The colour surface indicates the projected mortality impact across the mixture space, with darker shades corresponding to higher increases in cumulative premature deaths.