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Identifying best modelling practices for tobacco control policy simulations: a systematic review and a novel quality assessment framework

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ABSTRACT

Background Policy simulation models (PSMs) have been used extensively to shape health policies before real-world implementation and evaluate post-implementation impact. This systematic review aimed to examine best practices, identify common pitfalls in tobacco control PSMs and propose a modelling quality assessment framework.

Methods We searched five databases to identify eligible publications from July 2013 to August 2019. We additionally included papers from Feirman *et al* for studies before July 2013. Tobacco control PSMs that project tobacco use and tobacco-related outcomes from smoking policies were included. We extracted model inputs, structure and outputs data for models used in two or more included papers. Using our proposed quality assessment framework, we scored these models on population representativeness, policy effectiveness evidence, simulated smoking histories, included smoking-related diseases, exposure-outcome lag time, transparency, sensitivity analysis, validation and equity.

Findings We found 146 eligible papers and 25 distinct models. Most models used population data from public or administrative registries, and all performed sensitivity analysis. However, smoking behaviour was commonly modelled into crude categories of smoking status. Eight models only presented overall changes in mortality rather than explicitly considering smoking-related diseases. Only four models reported impacts on health inequalities, and none offered the source code. Overall, the higher scored models achieved higher citation rates.

Conclusions While fragments of good practices were widespread across the reviewed PSMs, only a few included a 'critical mass' of the good practices specified in our quality assessment framework. This framework might, therefore, potentially serve as a benchmark and support sharing of good modelling practices.

INTRODUCTION

Since 2020, it became evident that COVID-19 modelling had influenced, and on occasions dictated, disease control policies to shape the subsequent course of the pandemic.[1] For decades before this publicity, policy simulation models (PSMs) have been applied to inform evidence-based health policymaking and had contributed to many successful tobacco control policies.[2]

Various actions have been taken to end the tobacco pandemic, which killed over 100 million people worldwide during the 20th century.[3] These actions notably include policies targeting the accessibility, acceptability and affordability of tobacco products. Tobacco control models have been used extensively to shape such policies, both prior to real-world implementation and also to evaluate post-implementation impact.[4]

Two recent systematic reviews identified a plethora of tobacco control models intended for policymaking and policy evaluation.[5–7] This is a very active research area, reflecting an explosion of available data, novel methodologies and low-cost, widely available computational power.[8] However, this plethora of independently developed models may represent an unnecessary effort in replication compared with a more collaborative approach. Second, neither previous systematic review examined model quality, which perhaps reflects a lack of an appropriate quality assessment framework for simulation models.

Although several publicly available quality assessment tools exist, including Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist,[9] Grading of Recommendations, Assessment, Development and Evaluations (GRADE),[10] and the National Institute for Health and Care Excellence (NICE) Methodology Guide quality checklist,[11] none appear well suited for the diversity of tobacco control models. The NICE and CHEERS checklists are designed mainly to evaluate economics models, while the GRADE guideline focuses mainly on evidence certainty and is not topic specific.

The lack of such an applicable framework partly reflects the fast evolution of modelling approaches, the multidisciplinary nature of modelling and the multitude of questions models are asked to address. While developing a generic quality assessment framework for simulation models appears challenging, developing a domain-specific one for tobacco control simulation models might represent a more feasible first step.

We, therefore, defined two aims for this study:

1. To assess the modelling practices used in tobacco control PSMs (reviewing both best practices and common limitations).
2. To produce a quality assessment framework appropriate for tobacco control PSMs to potentially improve future policy modelling practices.

METHODS

Study design

We systematically reviewed the published tobacco control PSMs, particularly evaluating their methodological strengths and weaknesses. We then

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critically appraised and compared their modelling practices with an ideal but feasible tobacco control PSM prototype.

We report the results following the Synthesis Without Meta-Analysis statement (online supplemental table S1),[12] and present our findings in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement.[13]

Definitions

PSMs: quantitative frameworks that integrate evidence from cross-disciplinary sources to estimate the impact of existing or planned policies.

Tobacco control PSMs: PSMs that estimate existing or planned tobacco control policies impact.

Smoking-related diseases: diseases widely accepted to be causally linked to smoking, including chronic obstructive pulmonary disease (COPD), cardiovascular disease and common cancers.

External validation: comparing the model result with actual observed data not used as model inputs.[14 15]

Cross-validation: comparison of results between models which address the same problem.[14 15]

Sensitivity analysis: studying the model output changes caused by varying model inputs.[14 15]

Search strategy

We included the studies in the Feirman *et al* systematic review (to July 2013)[6] and extended the search strategy to cover the period to September 2019.

We searched five electronic databases (Embase, EconLit, PsycINFO, PubMed and CINAHL Plus). The search keywords for five databases are detailed in online supplemental text S1. We also scanned the reference lists of all included studies for potential additional papers.

Study selection and inclusion criteria

Inclusion criteria:

1. Referred to any tobacco product or tobacco use.
2. Contained peer-reviewed tobacco control PSMs that projected tobacco use and tobacco-related outcomes from tobacco control policy scenarios.
3. The model was reported in at least two peer-reviewed studies.
4. Full text in English.

We assessed the retrieved studies using the Participants, Interventions, Comparators, Outcomes and Study design approach (online supplemental table S2).

Two reviewers (VH and AH) independently screened titles and abstracts for eligibility using the inclusion and exclusion criteria, then screened the full text of all potential eligible papers. A third reviewer (CK) with modelling expertise was consulted to resolve any discrepancies. We used Zotero, reference management software, for screening.

We registered the protocol for our study with PROSPERO (CRD42020178146) and published it separately.[16]

Data extraction

We used a predefined and piloted data extraction form (online supplemental table S3) to extract study information on:

1. General information (ie, model name, code license, conflict of interest (COI)).
2. Model simulation methods.
3. Modelled population sociodemographic characteristics (ie, age, gender, ethnicity/race, socioeconomic status).
4. Risk factors.
5. Included diseases.
6. Data sources used.
7. Model outcome types (ie, health, economics).
8. Model checking, transparency, validation and calibration.
9. Model limitations reported.

We assessed data extraction quality by allowing a second reviewer to double-check 50% of the extraction forms for accuracy and completeness.

Evidence synthesis

We grouped the extracted study data by model name when reported or by the first author of the earliest publication.

We critically reviewed model data inputs, epidemiological principles, assumptions, transparency and whether they reported (a) relevant sources of parametric uncertainty, (b) potential limitations, (c) model validations and sensitivity analyses, and (d) technical documentation.

A proof-of-concept quality assessment framework

We then developed a simple quality assessment framework for model inputs, structure and outputs based on potential Good Modelling Practices (detailed in online supplemental text S2).

One point was given when each of the described criteria below was met:

- **Population:** model population data are representative of the population that the modelled policies will apply to.
- **Policy effectiveness**: the policy effectiveness data were extracted from empirical evidence.
- **Smoking status**: the model captured the cumulative effect of smoking (smoking intensity, smoking history, quitting age, etc).
- **Smoking-related diseases**: the model estimated the effect on the majority of important smoking-related diseases (quantifying both morbidity and mortality).
- **Lag time**: the model explicitly captured the time lag between exposure and disease onset.
- **Transparency:** technical or non-technical documents available to provide model transparency.
- **Uncertainty/sensitivity analysis** performed and reported.
- **Validation**: the model was validated.
- **Equity:** the model explored the equity impact of policies.

RESULTS

The search initially identified 5046 articles. After removing duplicates and screening titles and abstracts, 441 articles were eligible for full-text review. In total, 146 studies met the inclusion criteria and were included for data extraction, including 9 additional studies identified from included studies' reference lists (figure 1).[17–25]

We identified a total of 25 eligible tobacco control PSMs (table 1 and online supplemental text S3). Five models were used by only one paper in our searches. Nevertheless, we included them in our study because they were also used in papers published before July 2013, as identified in the Feirman *et al* review. The five models were Chronic Disease Model (CDM), Coronary Heart Disease Policy (CHD Policy) Model, Lung Cancer Policy Model (LCPM), Mendez model and Mejia model.

The SimSmoke model appeared to be the most used model with 18 peer-reviewed studies,[24 26–42] and the Burden of Disease Epidemiology, Equity and Economics (BODE^3) model ranked second with 11 peer-reviewed studies.[20 25 43–51]

Cohort (macro)simulation and microsimulation approaches were the most used self-reported methodologies. Agent-based

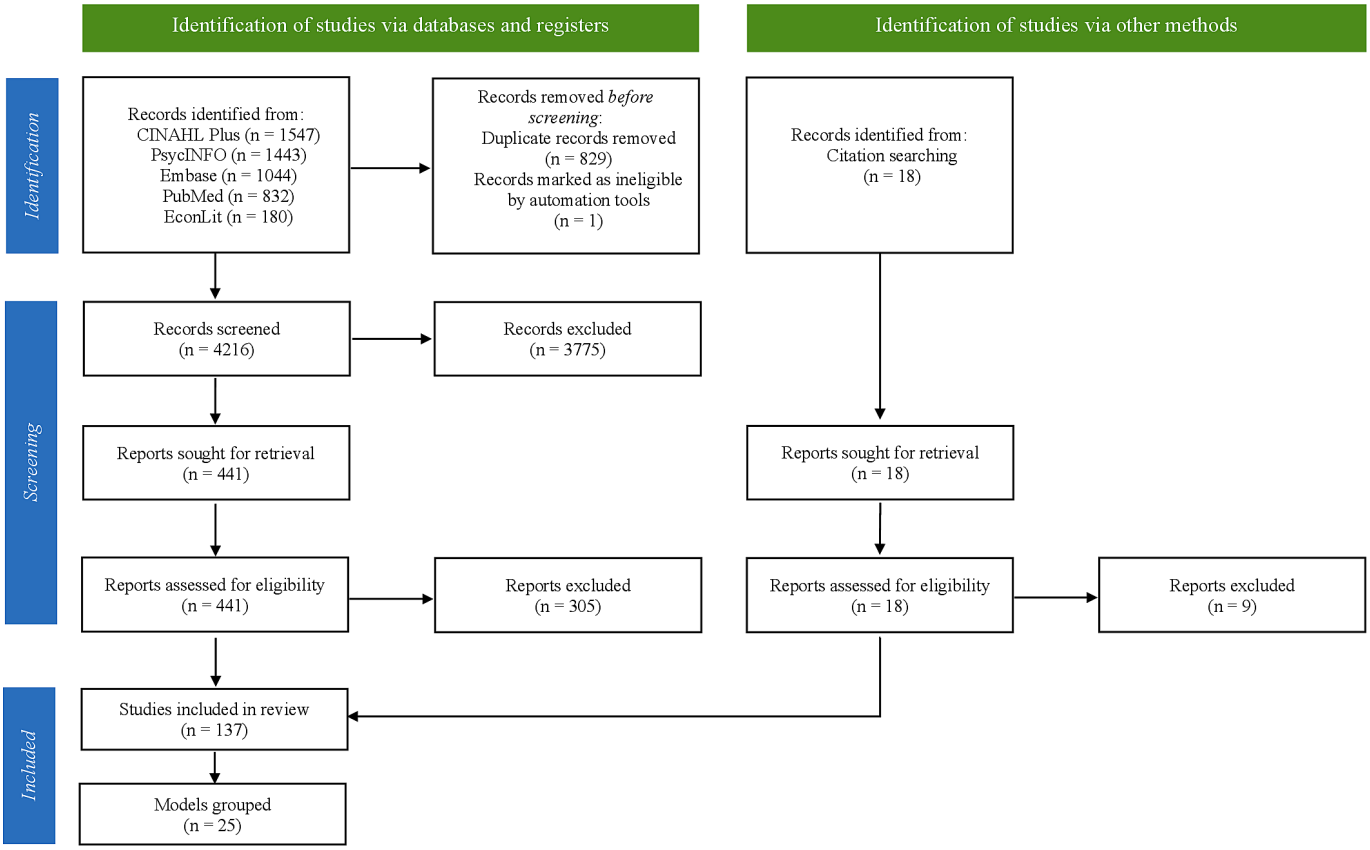

Figure 1 An adapted Preferred Reporting Items for Systematic Reviews and Meta-Analysis flow chart of identified studies.

modelling was used in just one model (Tobacco Town), likewise system dynamics in Prevention Impacts Simulation Model.

The diversity of model outcomes reflected the wide range of model purposes. Nineteen models reported health economics outcomes, 22 reported health measures including mortality or morbidity, with just one (ModelHealth: Tobacco) reporting hospital admissions (figure 2, online supplemental table S4). Only four models reported the policy impact on equity: BODE^3, CDM, extended cost-effectiveness analysis (ECEA) tobacco tax model and IMPACT.

Of the eligible 146 studies, 5 tobacco industry-funded studies reported COI or commercial funding.[52–56] However, we did not further investigate inaccurate or incomplete COI reporting.

Good Modelling Practices

Model inputs

Twenty-one of the 25 models appropriately used population data from public or administrative registries. Conversely, three used information from randomised controlled trial (RCT) participants that are rarely population representative.[17 57–62]

Eleven out of 25 models used systematic reviews or meta-analyses to inform policy effectiveness in the model. Six models used treatment-specific RCT values to estimate policy effectiveness.[17 57–69] Five models assumed the policy effectiveness by project teams or expert opinions.[18 24 26–42 52 70–78] In particular, SimSmoke, the most frequently referenced model, used the policy effect size provided by experts, likewise the ECEA tobacco tax model. Furthermore, three models calculated policy effectiveness from government reports or surveys.[79–83] Similarly, Population Health Impact Model estimated policy effectiveness by simple assumptions.

Model structure

Abiding by fundamental epidemiological principles, a tobacco simulation model structure should ideally aim to: (a) capture the cumulative effect of smoking (ie, for lung cancer and COPD[84–86]), including the intensity, duration, initiation and cessation; (b) estimate the effect on the main smoking-related diseases (ideally including both morbidity and mortality)[87]; (c) capture the time lag between exposure and disease risk[87]; (d) be transparent.[14 88]

Six models simulated smoking histories (including pack-years, pack-days) or quitting histories.[24 26–42 69–74 79 80 89–93] A further 19 models considered smoking only as a categorical exposure (ie, never/ex/current smoker).

Lag time was reported in 11 out of 25.[17 18 20 24–52 57 58 75–77 81 82 92–104] These models either estimated relative risk decline by time since cessation or cost decay by quit years. The remaining models did not report any considerations on the effect of time since cessation.

We summarised the number of diseases included in each model in figure 3 and online supplemental table S5. Models varied in how well they reflected epidemiology pathways (online supplemental table S6). Seventeen used smoking-related diseases to generate smoking-related outcomes. Two models calculated all-cause mortality directly from smoking status. The remaining six models estimated their outcomes directly, using the number of smokers or non-smokers, without explicitly modelling disease pathways.

Transparency

Nineteen models provided model documentation to explain model technical details for readers (all except Benefits of Smoking Cessation on Outcomes model, Baker model, Cantor

Table 1 Model summary (in descending order of the number of peer-reviewed articles)

Model name/first author: SimSmoke **Model type (self-reported):** discrete Markov model, macrosimulation **Risk factors included (smoking status provided with details):** smoking status (never, former, current), years since quitting **Diseases:** NA **Outcomes:** mortality, smoking prevalence, maternal and child health outcomes (smoking-attributable low birth weight, preterm births and sudden infant death syndrome) cases, uncertainty **Sensitivity analysis:** performed sensitivity analysis **Validation:** External validation **Number of peer-reviewed articles in this search:** 18 **Related papers:** 24 26–42	**Model name/first author: Burden of Disease Epidemiology, Equity and Economics model** **Model type (self-reported):** a proportional multistate life-table, macrosimulation, Markov model **Risk factors included (smoking status provided with details):** smoking status (never, former, current) **Diseases:** 16 diseases—CHD, stroke, COPD, lower respiratory tract infection, and multiple cancers: lung, oesophageal, stomach, liver, head and neck, pancreas, cervical, bladder, kidney, endometrial, melanoma, and thyroid (with smoking protecting against the latter three cancers) **Outcomes:** equity, health-systems cost-savings, smoking prevalence, QALYs gained, health-adjusted life years, uncertainty **Sensitivity analysis:** PSA **Validation:** cross-validation, external validation **Number of peer-reviewed articles in this search:** 11 **Related papers:** 20 25 43–51
Model name/first author: IMPACT **Model type (self-reported):** cell-based model **Risk factors included (smoking status provided with details):** blood pressure, cholesterol, diabetes, fruit and vegetable, smoking status (never smoker, long-term ex-smoker, recent ex-smoker, current smoker), salt intake, saturated fat intake, BMI, physical activities **Diseases:** CHD, T2DM **Outcomes:** equity, CHD mortality, smoking prevalence, life-years gained, uncertainty **Sensitivity analysis:** Monte Carlo simulation **Validation:** external validation **Number of peer-reviewed articles in this search:** 6 **Related papers:** 23 107–111	**Model name/first author: extended cost-effectiveness analysis (ECEA) tobacco tax model** **Model type (self-reported):** ECEA **Risk factors included (smoking status provided with details):** smoking prevalence, number of cigarettes smoked daily; age at quitting **Diseases:** COPD, heart disease, stroke, lung cancer, bladder cancer **Outcomes:** disease treatment costs, averted premature death, life-years gained, additional revenues generated, equity, uncertainty **Sensitivity analysis:** one-way, Monte Carlo simulation **Validation:** validated model **Number of peer-reviewed articles in this search:** 5 **Related papers:** 70–74
Model name/first author: EQUIPTMOD **Model type (self-reported):** Markov state-transition cohort model, macrosimulation **Risk factors included (smoking status provided with details):** smoking status (former, current) **Diseases:** COPD, CHD, stroke, lung cancer **Outcomes:** cost, ROI, ICER, QALY **Sensitivity analysis:** univariate, others **Validation:** no model validation **Number of peer-reviewed articles in this search:** 5 **Related papers:** 112–116	**Model name/first author: DYNAMO-HIA model** **Model type (self-reported):** macrosimulation, Markov-based life-table **Risk factors included (smoking status provided with details):** alcohol intake, BMI, smoking status, secondhand smoking **Diseases:** COPD, IHD, stroke, cancers, T2DM **Outcomes:** mortality, morbidity, morbidity-free years, life expectancy, number of deaths **Sensitivity analysis:** performed sensitivity analysis **Validation:** no model validation **Number of peer-reviewed articles in this search:** 5 **Related papers:** 94–98
Model name/first author: Benefits of Smoking Cessation on Outcomes model **Model type (self-reported):** discrete-time Markov model **Risk factors included (smoking status provided with details):** smoker, recent quitter and long-term quitter **Diseases:** COPD, CHD, stroke, lung cancer, asthma exacerbation, chronic obstructive lung diseases **Outcomes:** total morbidity and mortality, economics impact **Sensitivity analysis:** one-way, PSA **Validation:**no model validation **Number of peer-reviewed articles in this search:** 4 **Related papers:** 63–66	**Model name/first author: Jiménez model** **Model type (self-reported):** closed cohort Markov model **Risk factors included (smoking status provided with details):** smoking status, willingness to quit history **Diseases:** COPD, CVD, T2DM **Outcomes:** incremental cost-savings, number of quitters **Sensitivity analysis:** univariate sensitivity analysis **Validation:** internal validation **Number of peer-reviewed articles in this search:** 3 **Related papers:** 89–91
Model name/first author: Johansson model **Model type (self-reported):** a Markov model **Risk factors included (smoking status provided with details):** smoking status (former, current) **Diseases:** COPD, CHD, stroke, cancers **Outcomes:** QALY, life years lost, cost, uncertainty **Sensitivity analysis:** univariable, multivariable, PSA **Validation:** external validation **Number of peer-reviewed articles in this search:** 3 **Related papers:** 17 57 58	**Model name/first author: Prevention Impacts Simulation Model** **Model type (self-reported):** system dynamics model **Risk factors included (smoking status provided with details):** blood pressure, cholesterol, secondhand smoking, obesity, psychological distress, fruit and vegetable, smoking status (never smoker, long-term ex-smoker, recent ex-smoker, current smoker), blood glucose categories (normal, pre-diabetic, diabetic), periodontal disease, sleep apnoea, small particulate air pollution and inadequate use of aspirin for primary prevention **Diseases:** CVD **Outcomes:** mortality and morbidity, healthcare cost, productivity loss, uncertainty **Sensitivity analysis:** PSA **Validation:** external validation **Number of peer-reviewed articles in this search:** 3 **Related papers:** 75–77

Continued

Table 1 Continued

Model name/first author: Baker model **Model type (self-reported):** closed cohort Markov model **Risk factors included (smoking status provided with details):** eligible smoker, ineligible smoker, initial quitter, successful quitter **Diseases:** NA **Outcomes:** number of quitters, morbidity, mortality, medical expenditures **Sensitivity analysis:** univariate, multivariable analyses **Validation:** no model validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 99 100	**Model name/first author: Barnett model** **Model type (self-reported):** a Markov model **Risk factors included (smoking status provided with details):** smoking status (former, current) **Diseases:** NA **Outcomes:** mortality, healthcare cost, QALY, uncertainty **Sensitivity analysis:** one-way, PSA **Validation:** no model validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 59 60
Model name/first author: Cantor model **Model type (self-reported):** decision-analytical model **Risk factors included (smoking status provided with details):** smoking status **Diseases:** NA **Outcomes:** cost, QALY **Sensitivity analysis:** one-way, two-way uncertainty analyses **Validation:** no model validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 61 62	**Model name/first author: Chevreul model** **Model type (self-reported):** Markov state transition model **Risk factors included (smoking status provided with details):** smoking status (smoker, former smoker), diagnosed with either lung cancer, COPD or CVD such as stroke or coronary artery disease and dead (smoker: ≥1 cigarette/day) **Diseases:** COPD, CVD, lung cancer **Outcomes:** ICER **Sensitivity analysis:** deterministic sensitivity analysis, Monte Carlo simulation **Validation:** internal validation, external validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 101 102
Model name/first author: Cost-Effectiveness of Preventing AIDS Complications-US model **Model type (self-reported):** microsimulation **Risk factors included (smoking status provided with details):** smoking intensity (packs/day)—heavy/moderate/light, CD4+T cell count, viral load, history of opportunistic disease and antiretroviral treatment use **Diseases:** lung cancer **Outcomes:** life expectancy, mortality **Sensitivity analysis:** two-way **Validation:** internal validation, external validation and cross-validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 92 93	**Model name/first author: ModelHealth: Tobacco** **Model type (self-reported):** microsimulation **Risk factors included (smoking status provided with details):** smoking status (never, former, current) **Diseases:** CVD, stroke, lung cancer, respiratory disease **Outcomes:** medical cost, hospitalisation, mortality and morbidity, productivity loss, QALY, smoking prevalence **Sensitivity analysis:** one-way **Validation:** internal validation, external validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 103 104
Model name/first author: Parrott model **Model type (self-reported):** decision tree **Risk factors included (smoking status provided with details):** childhood exposure to maternal smoking, smoking status (current, former) **Diseases:** COPD, CHD, stroke, lung cancer, asthma, pregnancy-related (placental abruption, ectopic pregnancy, pre-eclampsia, placenta previa and miscarriage, infant morbidities: low infant birth weight, stillbirth, premature birth) **Outcomes:** ICER, QALY, uncertainty **Sensitivity analysis:** PSA **Validation:** no model validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 67 68	**Model name/first author: Population Health Impact Model** **Risk factors included (smoking status provided with details):** never tobacco users, former tobacco users, current cigarette smokers, current cMRTP users, current dual users **Diseases:** COPD, IHD, stroke, lung cancer **Outcomes:** mortality, cMRTP uptake **Sensitivity analysis:** performed sensitivity analysis **Validation:** model validated **Number of peer-reviewed articles in this search:** 2 **Related papers:** 18 52
Model name/first author: Tobacco Town **Model type (self-reported):** agent-based model **Risk factors included (smoking status provided with details):** smoking intensity (cigarettes/day) **Diseases:** NA **Outcomes:** cost, tobacco purchase behaviour **Sensitivity analysis:** performed sensitivity analysis **Validation:** no model validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 79 80	**Model name/first author: UK Health Forum simulation** **Model type (self-reported):** microsimulation **Risk factors included (smoking status provided with details):** smoking status (never, former, current) **Diseases:** COPD, CHD, stroke, 14 cancers **Outcomes:** cost, morbidity, smoking prevalence, uncertainty **Sensitivity analysis:** performed sensitivity analysis **Validation:** no model validation **Number of peer-reviewed articles in this search:** 2 **Related papers:** 81 82
Model name/first author: Chronic Disease Model **Model type (self-reported):** closed cohort multistate Markov model **Risk factors included (smoking status provided with details):** smoking status (never, former, current) **Diseases:** acute myocardial infarction, chronic heart failure, COPD, stroke (CVA), T2DM, and cancer of the lung, stomach, oesophagus, larynx, bladder, kidney, pancreas, and oral cavity **Outcomes:** cost, QALY, number of quitters **Sensitivity analysis:** one-way **Validation:** no model validation **Number of peer-reviewed articles in this search:** 1 **Related papers:** 117	**Model name/first author: Chronic Heart Disease Policy Model** **Model type (self-reported):** state-transition (Markov) computer-simulation model **Risk factors included (smoking status provided with details):** active smoker or secondhand smoke exposure, systolic blood pressure, BMI, level of high-density lipoprotein cholesterol, level of low-density lipoprotein, diabetes **Diseases:** CHD and stroke **Outcomes:** CHD incidence, prevalence, mortality, costs, uncertainty **Sensitivity analysis:** Monte Carlo simulations **Validation:** no model validation **Number of peer-reviewed articles in this search:** 1 **Related papers:** 118

Continued

Table 1 Continued

Model name/first author: Lung Cancer Policy Model **Model type (self-reported):** state-transition microsimulation model **Risk factors included (smoking status provided with details):** smoking history (length of time a person smoked and cigarettes smoked per day) **Diseases:** three cancers from any of the following five lung cancer cell types: adenocarcinoma (including adenocarcinoma in situ), large cell, squamous cell, small cell and other **Outcomes:** mortality rate and cost-effectiveness **Sensitivity analysis:** performed sensitivity analysis **Validation:** model validated **Number of peer-reviewed articles in this search:** 1 **Related papers:** 69	**Model name/first author: Mendez model** **Model type (self-reported):** Excel-based Markov model **Risk factors included (smoking status provided with details):** smoking status (never, former, current) **Diseases:** NA **Outcomes:** cost, DALY, smoking prevalence **Sensitivity analysis:** PSA **Validation:** model validated **Number of peer-reviewed articles in this search:** 1 **Related papers:** 78*
Model name/first author: Mejia model **Model type (self-reported):** decision tree model used in Monte Carlo simulations **Risk factors included (smoking status provided with details):** smoking status (current cigarette user, current e-cigarette, dual user) **Diseases:** NA **Outcomes:** morbidity, uncertainty **Sensitivity analysis:** performed sensitivity analysis **Validation:** no model validation **Number of peer-reviewed articles in this search:** 1 **Related papers:** 83	

*Paper mentioned that this simulation model is based on the model developed by Mendez, Warner and Courant.
BMI, body mass index; CHD, coronary heart disease; cMRTP, candidate modified risk tobacco products; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; CVD, cardiovascular disease; DALY, disability-adjusted life year; ICER, incremental cost-effectiveness ratio; IHD, ischaemic heart disease; NA, not available; PSA, probabilistic sensitivity analysis; QALY, quality-adjusted life year; ROI, return on investment; T2DM, type 2 diabetes mellitus.

model, Chevreul model, CHD Policy Model and Jiménez model). Some models provided detailed model information. One of the SimSmoke models, in particular, provided a detailed data source and modelling diagram.[105] However, none of the models provided the source code or the pseudo-code of their algorithms.

Model output

Finally, existing modelling guidelines recommend model validation, propagation of uncertainty and sensitivity analysis.[88 106]

First, 11 of 25 models reported result uncertainty. Furthermore, the SimSmoke model reported uncertainty in some studies but not in others. The types of uncertainty that were reflected in the reported uncertainty intervals varied widely.

Validation is used to check result accuracy. Figure 4 and online supplemental table S7 illustrate the wide gamut of validation approaches, including external validation, cross-validation and internal validation. We treated all models published in peer-reviewed journals as face validated by experts during the peer-review process. Hence, we did not count face validation for plotting or reporting.

External validation, considered the strongest validation form, was employed by eight models.[17 20 23–51 57 58 75–77 92 93 101–104 107–111] BODE^3 model and Cost-Effectiveness of Preventing AIDS Complications-US model employed cross-validations. However, some of the models did not mention the validation methods explicitly. Twelve (48%) models did not mention any validity check (without consideration of the face validation).[59–68 79–83 94–100 112–118]

Modellers perform a sensitivity analysis to check model outputs' variation by input uncertainty.[106] All models in our review reported some sensitivity analysis using one-way, multivariable or probabilistic sensitivity analysis (PSA). Three models applied a one-way sensitivity test only.[89–91 103 104 117] Five models applied PSA only.[20 25 43–51 67 68 75–78 118] Additionally, eight models used various approaches when testing different input parameters.[17 57–66 70–74 99–102 112–116]

Equity

Given the strong socioeconomic gradient of smoking in many countries, we also considered it essential to report policy outcomes on equity. Four models reported policy equity impact.[20 23 25 43–51 70–74 107–111 117] A range of socioeconomic status (SES) measures were used. IMPACT model used area deprivation (index of relative area-level deprivation) or education level to

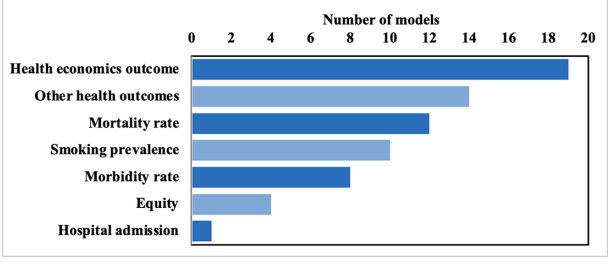

Figure 2 Occurrence of model outcome types (some models included more than one output type).

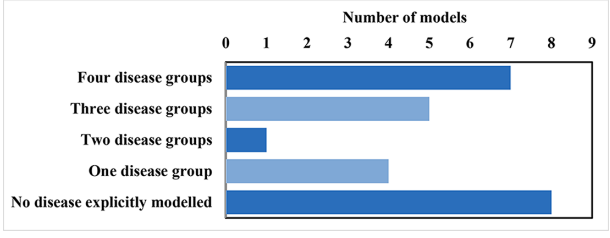

Figure 3 Occurrence of number of disease groups simulated by models. Considered disease groups: cancers, chronic obstructive pulmonary disease, cardiovascular disease and any other smoking-related diseases. The models with no diseases explicitly modelled either calculated all-cause mortality directly from smoking status or used the number of smokers or non-smokers without explicitly modelling disease pathways.

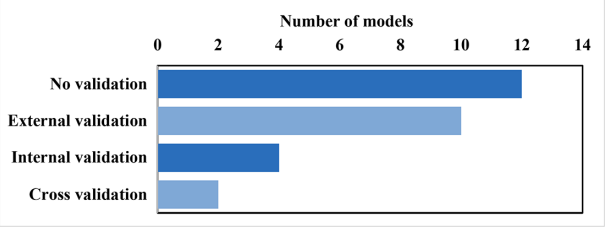

Figure 4 Occurrence of types of model validations (some models used more than one validation type).

indicate SES[23 107–111]; CDM defined SES by education levels[117]; BODE^3 used ethnicity groups[20 25 43–51] and ECEA tobacco tax model modelled income quintiles.[70–74]

Developing a proof-of-concept quality assessment framework

Online supplemental table S5 shows the models scored using the proposed quality assessment framework and presents the number of published articles using the model. BODE^3 was the highest scored model with one missing point on using the categorical smoking status. The models with higher quality scores were generally associated with more peer-reviewed publications (online supplemental figure S1 and online supplemental table S8).

DISCUSSION

This tobacco control PSM systematic review critically analysed existing models' strengths and weaknesses regarding data inputs, model structure and outputs. Going beyond previous systematic reviews, we then devised and proposed a tobacco control PSM quality assessment framework. This quality framework could potentially be used in future research to enable readers to better assess the quality of tobacco control PSMs.

Our systematic review confirmed the multitude of modelling techniques used in the field. It revealed a wide range of quality, with few achieving high scores. The diffusion of good modelling practices thus currently appears to be suboptimal.

All included models had been subjected to sensitivity analysis and most appropriately used population data from public or administrative registries to represent the population.[106 119] However, other best practices were often lacking.

Few models adequately captured the epidemiology of smoking harms. Smoking intensity and duration are essential,[120] and the risk from smoking is cumulative, especially for cancers and COPD. The risk reduction after smoking cessation is likewise gradual. In addition, considerable time lags between exposure and change in risk exist for some diseases. By ignoring these factors, many models risk overestimating the impact of the simulated tobacco control policies.[121]

Furthermore, around one in five models used no empirical evidence to inform policy effectiveness. Thus, risking substantial bias.

Most models provided documentation to explain technical details for readers. However, none offered the source code under an open-source licence to enable complete transparency and scrutiny. We consider this a missed opportunity for transparency and sharing good practice, avoiding unnecessary repetition of work between research groups, and enabling more rapid model development.[14 106 122 123] Ultimately, these coding silos hinder evidenced-based health policymaking and evaluation by needlessly slowing down model development and the dispersion of good practice.

Only four models reported on the potential equity of the simulated tobacco control policies. This is despite smoking prevalence having strong socioeconomic gradients in most countries; gradients which inequitable tobacco control policies have sometimes intensified.[121 124]

Quality assessment framework

In developing our proof-of-concept quality assessment framework, we included nine dimensions. Each appeared feasible, being achieved in at least one tobacco control PSM. Reassuringly, the models with the highest quality scores were broadly those with a higher number of publications, although two high-quality models with high publication count perhaps drove the pattern.

Public health implications

Policymakers could use this review as a registry of the currently available models. Furthermore, we propose an easy-to-use framework to assess the quality of the existing and future models, guide narratives of quality assessment during the peer-review process and foster progressively higher quality models.

Earlier guidelines powerfully informed our proposed quality assessment framework.[123] However, we would suggest that most such guidelines are primarily useful for modellers rather than model users. They are lengthy (span across seven papers), challenging for non-technical users to digest and practice, and too generic to directly cover specific tobacco epidemiology characteristics (such as the cumulative nature of the risk and long lags between exposure and some diseases). These shortcomings may perhaps help explain the lack of any quality assessment in the two previous systematic reviews on tobacco models. We believe that our proposed quality assessment framework would be simple to apply directly to tobacco control PSMs and would not require the user to have any deep technical background.

The quality assessment framework we are proposing may also incentivise modelling complexity. We argue that complexity is necessary to integrate the increasingly available information, enabling richer, more accurate and comparable modelling outputs for policymakers and planners.[124] Increased collaboration between modelling teams is thus urgently needed to mitigate many of the potential pitfalls of complexity and improve quality.

Organisations that facilitate collaboration among health policy modellers could play an important role. For instance, CISNET, a National Cancer Institute-funded modelling consortium, shares model common inputs and common intermediate/final outputs; modellers can then compare prediction results between different models.[125 126]

In the longer term, such collaboration would create a virtuous circle of modellers having a framework to support them and policymakers having consistently better models.

Strengths and limitations

Building on previous reviews, we applied broader inclusion requirements and enhanced systematic methods. Our systematic review thus offers a broader and deeper view of the current tobacco control PSM landscape.

Additionally, we went beyond the traditional methodology review to provide an easy-to-use framework for the quality assessment of existing and future models. This should facilitate the development of higher quality tobacco control PSMs and may be useful during the peer-review process.

This review has potential limitations. First, we only analysed PSMs used in more than two studies to better represent the most actively used tobacco control PSMs. Likewise, we excluded models with more than two studies if these were all published before July 2013, as these can be found in the previous review by Feirman *et al*. Unavoidably, our approach has excluded some tobacco control PSMs. However, given the aims of our study, we would not expect them to have fundamentally different modelling practices than the models we included.

Second, allocating a single point in each of the nine (binary) dimensions of the quality framework was intended to be simple but risks being simplistic. However, in future real-world uses of the framework, we expect to refine these methods into more elaborate and weighted scoring schemes, perhaps tailored to the specific research aims. That further development and validation might permit an even broader and more robust assessment of model quality.

Third, due to resource constraints, we did not search for any grey literature or reports and only included studies published in English; we may thus have excluded some potentially influential models.

Finally, we included five studies funded by industry, which is liable to COI and bias. That represents a topic for further research.

CONCLUSIONS

In conclusion, we have usefully highlighted the strengths and weaknesses of tobacco control PSMs' data selection, model structure and output. We offer a nine-dimension proof-of-concept quality assessment framework to help facilitate the development of high-quality policy models in tobacco control, and perhaps more widely.

What this paper adds

What is already known on this subject

⇒ Tobacco control policy simulation models have been used to guide tobacco control policymaking during the planning stage and the evaluation of post-implementation impact. However, despite this being a very active research area, there is no widely accepted quality assessment framework for tobacco control policy simulation models.

What this paper adds

⇒ Analysing the methodology of published tobacco control policy simulation models potentially offers a broader and deeper view of the current policy modelling landscape.

⇒ We offer a proof-of-concept quality assessment framework for tobacco control policy simulation models, which may guide quality assessment narratives in the peer-review process and foster higher modelling standards.

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REFERENCES

1 McBryde ES, Meehan MT, Adegboye OA, *et al*. Role of modelling in COVID-19 policy development. *Paediatr Respir Rev* 2020;35:57–60.
2 GOV.UK. Chief medical officer annual report 2018: better health within reach. Available: https://www.gov.uk/government/publications/chief-medical-officer-annual-report-2018-better-health-within-reach [Accessed 12 Jan 2020].
3 Tobacco. Available: https://www.who.int/news-room/fact-sheets/detail/tobacco [Accessed 6 Jan 2021].
4 Europe PMC. Should prioritising health interventions be informed by modelling studies? The case of cancer control in Aotearoa New Zealand - Abstract. Available: https://europepmc.org/article/med/33767491 [Accessed 2 Apr 2021].
5 Feirman SP, Donaldson E, Glasser AM, *et al*. Mathematical modeling in tobacco control research: initial results from a systematic review. *Nicotine Tob Res* 2016;18:229–42.
6 Feirman S, Donaldson E, Pearson J, *et al*. Mathematical modelling in tobacco control research: protocol for a systematic review. *BMJ Open* 2015;5:e007269.
7 Singh A, Wilson N, Blakely T. Simulating future public health benefits of tobacco control interventions: a systematic review of models. *Tob Control* 2020;30:460–70.
8 Lay-Yee R, Cotterell G. The Role of Microsimulation in the Development of Public Policy. In: Janssen M, Wimmer MA, Deljoo A, eds. *Policy practice and digital science*. Cham: Springer International Publishing, 2015: 305–20.
9 Husereau D, Drummond M, Petrou S, *et al*. Consolidated Health Economic Evaluation Reporting Standards (CHEERS)--explanation and elaboration: a report of the ISPOR Health Economic Evaluation Publication Guidelines Good Reporting Practices Task Force. *Value Health* 2013;16:231–50.
10 Brozek JL, Canelo-Aybar C, Akl EA, *et al*. GRADE Guidelines 30: the GRADE approach to assessing the certainty of modeled evidence-An overview in the context of health decision-making. *J Clin Epidemiol* 2021;129:138–50.
11 NICE. Appendix I quality appraisal checklist – economic evaluations | methods for the development of NICE public health guidance (third edition) | guidance |. Available: https://www.nice.org.uk/process/pmg4/chapter/appendix-i-quality-appraisal-checklist-economic-evaluations [Accessed 10 Apr 2020].
12 Campbell M, McKenzie JE, Sowden A, *et al*. Synthesis without meta-analysis (swim) in systematic reviews: reporting guideline. *BMJ* 2020;368:l6890.
13 Page MJ, McKenzie JE, Bossuyt PM, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
14 Eddy DM, Hollingworth W, Caro JJ, *et al*. Model transparency and validation: a report of the ISPOR-SMDM modeling good research practices task Force-7. *Med Decis Making* 2012;32:733–43.
15 Model parameter estimation and uncertainty analysis: a report of the ISPOR-SMDM Modeling Good Research Practices Task Force Working Group-6 - PubMed. Available: https://pubmed.ncbi.nlm.nih.gov/22990087/ [Accessed 5 Aug 2020].
16 Huang V, Head A, Hyseni L, *et al*. Tobacco control policy simulation models: protocol for a systematic methodological review. *JMIR Res Protoc* 2021;10:e26854.
17 Johansson P. *A model for economic evaluations of smoking cessation interventions – technical report*, 35.
18 Weitkunat R, Lee PN, Baker G, *et al*. A novel approach to assess the population health impact of introducing a modified risk tobacco product. *Regul Toxicol Pharmacol* 2015;72:87–93.
19 Golden SD, Farrelly MC, Luke DA, *et al*. Comparing projected impacts of cigarette floor price and excise tax policies on socioeconomic disparities in smoking. *Tob Control* 2016;25:i60–6.
20 Cobiac LJ, Ikeda T, Nghiem N, *et al*. Modelling the implications of regular increases in tobacco taxation in the tobacco endgame. *Tob Control* 2015;24:e154–60.
21 Grace RC, Kivell BM, Laugesen M. Predicting decreases in smoking with a cigarette purchase task: evidence from an excise tax rise in New Zealand. *Tob Control* 2015;24:582–7.
22 Levy DT, Huang A-T, Currie LM, *et al*. The benefits from complying with the framework convention on tobacco control: a SimSmoke analysis of 15 European nations. *Health Policy Plan* 2014;29:1031–42.

23 Allen K, Kypridemos C, Hyseni L, *et al*. The effects of maximising the UK's tobacco control score on inequalities in smoking prevalence and premature coronary heart disease mortality: a modelling study. *BMC Public Health* 2016;16:292.
24 Levy D, Rodríguez-Buño RL, Hu T-W, *et al*. The potential effects of tobacco control in China: projections from the China SimSmoke simulation model. *BMJ* 2014;348:g1134.
25 Pearson AL, van der Deen FS, Wilson N, *et al*. Theoretical impacts of a range of major tobacco retail outlet reduction interventions: modelling results in a country with a smoke-free nation goal. *Tob Control* 2015;24:e32–8.
26 Szklo AS, Yuan Z, Levy D. Update and extension of the Brazil SimSmoke model to estimate the health impact of cigarette smoking by pregnant women in Brazil. *Cad Saude Publica* 2017;33:e00207416.
27 Levy DT, Fouad H, Levy J, *et al*. Application of the abridged SimSmoke model to four eastern Mediterranean countries. *Tob Control* 2016;25:413–21.
28 Levy D, Abrams DB, Levy J, *et al*. Complying with the framework convention for tobacco control: an application of the abridged SimSmoke model to Israel. *Isr J Health Policy Res* 2016;5.
29 Reynales-Shigematsu LM, Fleischer NL, Thrasher JF, *et al*. Effects of tobacco control policies on smoking prevalence and tobacco-attributable deaths in Mexico: the SimSmoke model. *Rev Panam Salud Publica* 2015;38:316–25.
30 Levy D, Mohlman MK, Zhang Y. Estimating the potential impact of tobacco control policies on adverse maternal and child health outcomes in the United States using the SimSmoke tobacco control policy simulation model. *Nicotine Tob Res* 2016;18:1240–9.
31 Levy DT, Meza R, Zhang Y, *et al*. Gauging the effect of U.S. tobacco control policies from 1965 through 2014 using SimSmoke. *Am J Prev Med* 2016;50:535–42.
32 Fleischer NL, Thrasher JF, Reynales-Shigematsu LM, *et al*. Mexico SimSmoke: how changes in tobacco control policies would impact smoking prevalence and smoking attributable deaths in Mexico. *Glob Public Health* 2017;12:830–45.
33 Levy DT, Wijnhoven TMA, Levy J, *et al*. Potential health impact of strong tobacco control policies in 11 South eastern who European region countries. *Eur J Public Health* 2018;28:693–701.
34 Levy DT, Mays D, Yuan Z, *et al*. Public health benefits from pictorial health warnings on us cigarette packs: a SimSmoke simulation. *Tob Control* 2017;26:649–55.
35 Maslennikova GY, Oganov RG, Boytsov SA, *et al*. Russia SimSmoke: the long-term effects of tobacco control policies on smoking prevalence and smoking-attributable deaths in Russia. *Tob Control* 2014;23:484–90.
36 Near AM, Blackman K, Currie LM, *et al*. Sweden SimSmoke: the effect of tobacco control policies on smoking and snus prevalence and attributable deaths. *Eur J Public Health* 2014;24:451–8.
37 Levy DT, Huang A-T, Currie LM, *et al*. The benefits from complying with the framework convention on tobacco control: a SimSmoke analysis of 15 European nations. *Health Policy Plan* 2014;29:1031–42.
38 Levy D, Rodriguez-Buno RL, Hu T. The Potential Effects of Tobacco Control in China: Projections from the China SimSmoke Simulation Model. In: Hu T, ed. *Economics of Tobacco Control in China: From Policy Research to Practice. World Scientific Series in Global Health Economics and Public Policy*. London and Singapore: World Scientific, 2016: vol. 4. 189–213. https://liverpool.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=ecn&AN=1745241&site=ehost-live&scope=site
39 Levy DT, Yuan Z, Li Y. The US SimSmoke tobacco control policy model of smokeless tobacco and cigarette use. *BMC Public Health* 2018;18:696.
40 Sanna M, Gao W, Chiu Y-W, *et al*. Tobacco control within and beyond WHO MPOWER: outcomes from Taiwan SimSmoke. *Tob Control* 2020;29:36–42.
41 Levy D, Fergus C, Rudov L, *et al*. Tobacco policies in Louisiana: recommendations for future tobacco control investment from SimSmoke, a policy simulation model. *Prevention Science* 2016;17:199–207.
42 Levy DT, Lindblom EN, Fleischer NL, *et al*. Public health effects of restricting retail tobacco product displays and ads. *Tob Regul Sci* 2015;1:61–75.
43 Nghiem N, Cleghorn CL, Leung W, *et al*. A national Quitline service and its promotion in the mass media: modelling the health gain, health equity and cost-utility. *Tob Control* 2018;27:434–41.
44 Blakely T, Cobiac LJ, Cleghorn CL, *et al*. Health, health inequality, and cost impacts of annual increases in tobacco tax: multistate life table modeling in New Zealand. *PLoS Med* 2015;12:e1001856.
45 van der Deen FS, Wilson N, Cleghorn CL, *et al*. Impact of five tobacco endgame strategies on future smoking prevalence, population health and health system costs: two modelling studies to inform the tobacco endgame. *Tob Control* 2018;27:278–86.
46 Cleghorn CL, Blakely T, Kvizhinadze G, *et al*. Impact of increasing tobacco taxes on working-age adults: short-term health gain, health equity and cost savings. *Tob Control* 2018;27:e167–70.
47 Singh A, Petrović-van der Deen FS, Carvalho N, *et al*. Impact of tax and tobacco-free generation on health-adjusted life years in the Solomon Islands: a Multistate life table simulation. *Tob Control* 2020;29:388–97.
48 Nghiem N, Leung W, Cleghorn C, *et al*. Mass media promotion of a smartphone smoking cessation APP: modelled health and cost-saving impacts. *BMC Public Health* 2019;19:283.
49 Petrović-van der Deen FS, Wilson N, Crothers A, *et al*. Potential country-level health and cost impacts of legalizing domestic sale of Vaporized nicotine products. *Epidemiology* 2019;30:396–404.
50 Petrović-van der Deen FS, Blakely T, Kvizhinadze G, *et al*. Restricting tobacco sales to only pharmacies combined with cessation advice: a modelling study of the future smoking prevalence, health and cost impacts. *Tob Control* 2019;28:643–50.
51 Pearson AL, Cleghorn CL, van der Deen FS, *et al*. Tobacco retail outlet restrictions: health and cost impacts from multistate life-table modelling in a national population. *Tob Control* 2017;26:579–85.
52 Djurdjevic S, Lee P, Weitkunat R, *et al*. Modeling the population health impact of introducing a modified risk tobacco product into the U.S. market. *Health Care* 2018;6:47.
53 Hill A, Camacho OM. A system dynamics modelling approach to assess the impact of launching a new nicotine product on population health outcomes. *Regul Toxicol Pharmacol* 2017;86:265–78.
54 Poland B. Population modeling of modified risk tobacco products accounting for smoking reduction and gradual transitions of relative risk. Available: https://kopernio.com/viewer?doi=10.1093%2Fntr%2Fntx070&token=WzIxMDU2NzcsIjEwLjEwOTMvbnRyL250eDA3MCJd.IFnWIJvql5E8bC5l8Re68t4Pwxw [Accessed 18 Apr 2020].
55 Bachand AM, Sulsky SI. A dynamic population model for estimating all-cause mortality due to lifetime exposure history. *Regul Toxicol Pharmacol* 2013;67:246–51.
56 Muhammad-Kah RS, Pithawalla YB, Boone EL, *et al*. A computational model for assessing the population health impact of introducing a modified risk claim on an existing smokeless tobacco product. *Int J Environ Res Public Health* 2019;16:E1264.
57 Feldman I, Helgason AR, Johansson P, *et al*. Cost-Effectiveness of a high-intensity versus a low-intensity smoking cessation intervention in a dental setting: long-term follow-up. *BMJ Open* 2019;9:e030934.
58 Virtanen SE, Galanti MR, Johansson PM, *et al*. Economic evaluation of a brief counselling for smoking cessation in dentistry: a case study comparing two health economic models. *BMJ Open* 2017;7:e016375.
59 Barnett PG, Wong W, Jeffers A, *et al*. Cost-Effectiveness of extended cessation treatment for older smokers. *Addiction* 2014;109:314–22.
60 Barnett PG, Jeffers A, Smith MW, *et al*. Cost-Effectiveness of integrating tobacco cessation into post-traumatic stress disorder treatment. *Nicotine Tob Res* 2016;18:267–74.
61 Daly AT, Deshmukh AA, Vidrine DJ, *et al*. Cost-Effectiveness analysis of smoking cessation interventions using cell phones in a low-income population. *Tob Control* 2019;28:88–94.
62 Cantor SB, Deshmukh AA, Luca NS, *et al*. Cost-Effectiveness analysis of smoking-cessation counseling training for physicians and pharmacists. *Addict Behav* 2015;45:79–86.
63 Baker CL, Pietri G. A cost-effectiveness analysis of varenicline for smoking cessation using data from the eagles trial. *Clinicoecon Outcomes Res* 2018;10:67–74.
64 Annemans L, Marbaix S, Nackaerts K, *et al*. Cost-effectiveness of retreatment with varenicline after failure with or relapse after initial treatment for smoking cessation. *Prev Med Rep* 2015;2:189–95.
65 Kautiainen K, Ekroos H, Puhakka M, *et al*. Re-treatment with varenicline is a cost-effective aid for smoking cessation. *J Med Econ* 2017;20:246–52.
66 von Wartburg M, Raymond V, Paradis PE. The long-term cost-effectiveness of varenicline (12-week standard course and 12 + 12-week extended course) vs. other smoking cessation strategies in Canada. *Int J Clin Pract* 2014;68:639–46.
67 Jones M, Smith M, Lewis S, *et al*. A dynamic, modifiable model for estimating cost-effectiveness of smoking cessation interventions in pregnancy: application to an RCT of self-help delivered by text message. *Addiction* 2019;114:353–65.
68 Wu Q, Parrott S, Godfrey C, *et al*. Cost-Effectiveness of computer-tailored smoking cessation advice in primary care: a randomized trial (escape). *Nicotine Tob Res* 2014;16:270–8.
69 Tramontano AC, Sheehan DF, McMahon PM, *et al*. Evaluating the impacts of screening and smoking cessation programmes on lung cancer in a high-burden region of the USA: a simulation modelling study. *BMJ Open* 2016;6:e010227.
70 Verguet S, Gauvreau CL, Mishra S, *et al*. The consequences of tobacco tax on household health and finances in rich and poor smokers in China: an extended cost-effectiveness analysis. *Lancet Glob Health* 2015;3:e206–16.
71 Salti N, Brouwer E, Verguet S. The health, financial and distributional consequences of increases in the tobacco excise tax among smokers in Lebanon. *Soc Sci Med* 2016;170:161–9.
72 Global Tobacco Economics Consortium. The health, poverty, and financial consequences of a cigarette price increase among 500 million male smokers in 13 middle income countries: compartmental model study. *BMJ* 2018;361:k1162.
73 Verguet S, Laxminarayan R, Jamison DT. Universal public finance of tuberculosis treatment in India: an extended cost-effectiveness analysis. *Health Econ* 2015;24:318–32.
74 Verguet S, Tarr G, Gauvreau CL, *et al*. Distributional benefits of tobacco Tax and smoke-free workplaces in China: a modeling study. *J Glob Health* 2017;7:020701.
75 Soler R, Orenstein D, Honeycutt A, *et al*. Community-Based interventions to decrease obesity and tobacco exposure and reduce health care costs: outcome estimates

from communities putting prevention to work for 2010-2020. *Prev Chronic Dis* 2016;13:E47.
76 Honeycutt A, Bradley C, Khavjou O, *et al*. Simulated impacts and potential cost effectiveness of communities putting prevention to work: tobacco control interventions in 21 U.S. communities, 2010-2020. *Prev Med* 2019;120:100–6.
77 Homer J, Wile K, Yarnoff B, *et al*. Using simulation to compare established and emerging interventions to reduce cardiovascular disease risk in the United States. *Prev Chronic Dis* 2014;11:E195.
78 Jin L, Kenkel D, Liu F, *et al*. Retrospective and prospective Benefit-Cost analyses of U.S. anti-smoking policies. *J Benefit Cost Anal* 2015;6:154–86.
79 Combs TB, McKay VR, Ornstein J, *et al*. Modelling the impact of menthol sales restrictions and retailer density reduction policies: insights from tobacco town Minnesota. *Tob Control* 2020;29:502–9.
80 Luke DA, Hammond RA, Combs T, *et al*. Tobacco town: computational modeling of policy options to reduce tobacco Retailer density. *Am J Public Health* 2017;107:740–6.
81 Knuchel-Takano A, Hunt D, Jaccard A, *et al*. Modelling the implications of reducing smoking prevalence: the benefits of increasing the UK tobacco duty escalator to public health and economic outcomes. *Tob Control* 2018;27:e124–9.
82 Hunt D, Knuchel-Takano A, Jaccard A, *et al*. Modelling the implications of reducing smoking prevalence: the public health and economic benefits of achieving a 'tobacco-free' UK. *Tob Control* 2018;27:129–35.
83 Kalkhoran S, Glantz SA. Modeling the health effects of expanding e-cigarette sales in the United States and United Kingdom: a Monte Carlo analysis. *JAMA Intern Med* 2015;175:1671–80.
84 Lubin JH, Couper D, Lutsey PL, *et al*. Risk of cardiovascular disease from cumulative cigarette use and the impact of smoking intensity. *Epidemiology* 2016;27:395–404.
85 Forey BA, Thornton AJ, Lee PN. Systematic review with meta-analysis of the epidemiological evidence relating smoking to COPD, chronic bronchitis and emphysema. *BMC Pulm Med* 2011;11:36.
86 Tammemägi MC, Church TR, Hocking WG, *et al*. Evaluation of the lung cancer risks at which to screen ever- and never-smokers: screening rules applied to the PLCO and NLST cohorts. *PLoS Med* 2014;11:e1001764.
87 Bonnie RJ, Stratton K, Kwan LY. *The effects of tobacco use on health*. National Academies Press (US), 2015. https://www.ncbi.nlm.nih.gov/books/NBK310413/
88 Webber L, Mytton OT, Briggs ADM, *et al*. The Brighton declaration: the value of non-communicable disease modelling in population health sciences. *Eur J Epidemiol* 2014;29:867–70.
89 Cedillo S, Sicras-Mainar A, Jiménez-Ruiz CA, *et al*. Budgetary impact analysis of reimbursement varenicline for the smoking-cessation treatment in patients with cardiovascular diseases, chronic obstructive pulmonary disease or type-2 diabetes mellitus: a national health system perspective. *Eur Addict Res* 2017;23:7–18.
90 Jiménez-Ruiz CA, Solano-Reina S, Signes-Costa J, *et al*. Budgetary impact analysis on funding smoking-cessation drugs in patients with COPD in Spain. *Int J Chron Obstruct Pulmon Dis* 2015;10:2027–36.
91 Rejas-Gutiérrez J, López-Ibáñez de Aldecoa A, Casasola M, *et al*. Economic evaluation of combining Pharmaco- and behavioral therapies for smoking cessation in an occupational medicine setting. *J Occup Environ Med* 2019;61:318–27.
92 Reddy KP, Parker RA, Losina E, *et al*. Impact of cigarette smoking and smoking cessation on life expectancy among people with HIV: a US-Based modeling study. *J Infect Dis* 2016;214:1672–81.
93 Reddy KP, Kong CY, Hyle EP, *et al*. Lung cancer mortality associated with smoking and smoking cessation among people living with HIV in the United States. *JAMA Intern Med* 2017;177:1613–21.
94 Holm AL, Brønnum-Hansen H, Robinson KM, *et al*. Assessment of health impacts of decreased smoking prevalence in Copenhagen: application of the DYNAMO-HIA model. *Scand J Public Health* 2014;42:409–16.
95 Leão T, Perelman J, Clancy L, *et al*. Economic evaluation of five tobacco control policies across seven European countries. *Nicotine Tob Res* 2020;22:1202–9.
96 Fischer F, Kraemer A. Health Impact Assessment for Second-Hand Smoke Exposure in Germany--Quantifying Estimates for Ischaemic Heart Diseases, COPD, and Stroke. *Int J Environ Res Public Health* 2016;13:198.
97 Füssenich K, Nusselder WJ, Lhachimi SK, *et al*. Potential gains in health expectancy by improving lifestyle: an application for European regions. *Popul Health Metr* 2019;17:N.PAG-N.PAG.
98 Lhachimi SK, Nusselder WJ, Smit HA, *et al*. Potential health gains and health losses in eleven EU countries attainable through feasible prevalences of the life-style related risk factors alcohol, BMI, and smoking: a quantitative health impact assessment. *BMC Public Health* 2016;16:734.
99 Baker CL, Ding Y, Ferrufino CP, *et al*. A cost-benefit analysis of smoking cessation prescription coverage from a US payer perspective. *Clinicoecon Outcomes Res* 2018;10:359–70.
100 Baker CL, Ferrufino CP, Bruno M, *et al*. Estimated budget impact of adopting the Affordable care act's required smoking cessation coverage on United States healthcare payers. *Adv Ther* 2017;34:156–70.
101 Cadier B, Durand-Zaleski I, Thomas D, *et al*. Cost effectiveness of free access to smoking cessation treatment in France considering the economic burden of smoking-related diseases. *PLoS One* 2016;11:e0148750.
102 Chevreul K, Cadier B, Durand-Zaleski I, *et al*. Cost effectiveness of full coverage of the medical management of smoking cessation in France. *Tob Control* 2014;23:223–30.
103 Maciosek MV, LaFrance AB, Dehmer SP, *et al*. Health benefits and cost-effectiveness of brief clinician tobacco counseling for youth and adults. *Ann Fam Med* 2017;15:37–47.
104 Maciosek MV, LaFrance AB, St Claire A, *et al*. Twenty-Year health and economic impact of reducing cigarette use: Minnesota 1998-2017. *Tob Control* 2020;29:564–9.
105 Levy D, Fergus C, Rudov L, *et al*. Tobacco policies in Louisiana: recommendations for future tobacco control investment from SimSmoke, a policy simulation model. *Prev Sci* 2016;17:199–207.
106 Weinstein MC, O'Brien B, Hornberger J, *et al*. Principles of good practice for decision analytic modeling in health-care evaluation: report of the ISPOR Task Force on Good Research Practices--Modeling Studies. *Value Health* 2003;6:9–17.
107 Björck L, Rosengren A, Winkvist A, *et al*. Changes in dietary fat intake and projections for coronary heart disease mortality in Sweden: a simulation study. *PLoS One* 2016;11:e0160474.
108 Sözmen K, Unal B, Capewell S, *et al*. Estimating diabetes prevalence in turkey in 2025 with and without possible interventions to reduce obesity and smoking prevalence, using a modelling approach. *Int J Public Health* 2015;60 Suppl 1:13–21.
109 O'Flaherty M, Bandosz P, Critchley J, *et al*. Exploring potential mortality reductions in 9 European countries by improving diet and lifestyle: a modelling approach. *Int J Cardiol* 2016;207:286–91.
110 Sahan C, Sozmen K, Unal B, *et al*. Potential benefits of healthy food and lifestyle policies for reducing coronary heart disease mortality in Turkish adults by 2025: a modelling study. *BMJ Open* 2016;6:e011217.
111 Scholes S, Bajekal M, Norman P, *et al*. Quantifying policy options for reducing future coronary heart disease mortality in England: a modelling study. *PLoS One* 2013;8:e69935.
112 Trapero-Bertran M, Muñoz C, Coyle K, *et al*. Cost-Effectiveness of alternative smoking cessation scenarios in Spain: results from the EQUIPTMOD. *Addiction* 2018;113 Suppl 1:65–75.
113 Huber MB, Präger M, Coyle K, *et al*. Cost-Effectiveness of increasing the reach of smoking cessation interventions in Germany: results from the EQUIPTMOD. *Addiction* 2018;113 Suppl 1:52–64.
114 Németh B, Józwiak-Hagymásy J, Kovács G, *et al*. Cost-Effectiveness of possible future smoking cessation strategies in Hungary: results from the EQUIPTMOD. *Addiction* 2018;113 Suppl 1:76–86.
115 Coyle K, Coyle D, Lester-George A, *et al*. Development and application of an economic model (EQUIPTMOD) to assess the impact of smoking cessation. *Addiction* 2018;113 Suppl 1:7–18.
116 Cheung K-L, Wijnen BFM, Hiligsmann M, *et al*. Is it cost-effective to provide Internet-based interventions to complement the current provision of smoking cessation services in the Netherlands? An analysis based on the EQUIPTMOD. *Addiction* 2018;113 Suppl 1:87–95.
117 Over EAB, Feenstra TL, Hoogenveen RT, *et al*. Tobacco control policies specified according to socioeconomic status: health disparities and cost-effectiveness. *Nicotine Tob Res* 2014;16:725–32.
118 Konfino J, Ferrante D, Mejia R, *et al*. Impact on cardiovascular disease events of the implementation of Argentina's national tobacco control law. *Tob Control* 2014;23:e6.
119 Nuijten MJ. The selection of data sources for use in modelling studies. *Pharmacoeconomics* 1998;13:305–16.
120 Leffondré K, Abrahamowicz M, Siemiatycki J, *et al*. Modeling smoking history: a comparison of different approaches. *Am J Epidemiol* 2002;156:813–23.
121 Hoogenveen RT, van Baal PH, Boshuizen HC, *et al*. Dynamic effects of smoking cessation on disease incidence, mortality and quality of life: the role of time since cessation. *Cost Eff Resour Alloc* 2008;6:1.
122 Roberts M, Russell LB, Paltiel AD, *et al*. Conceptualizing a model: a report of the ISPOR-SMDM Modeling Good Research Practices Task Force--2. *Value Health* 2012;15:804–11.
123 Caro JJ, Briggs AH, Siebert U, *et al*. Modeling good research practices--overview: a report of the ISPOR-SMDM Modeling Good Research Practices Task Force-1. *Med Decis Making* 2012;32:667–77.
124 White M, Adams J, Heywood P. *How and why do interventions that increase health overall widen inequalities within populations? health, inequality and society*. Bristol: Policy Press, 2009: 12.
125 CISNET: about. Available: https://cisnet.cancer.gov/about/index.html [Accessed 27 Apr 2021].
126 Executive summary | JNCI Monographs | Oxford academic. Available: https://academic-oup-com.liverpool.idm.oclc.org/jncimono/article/2006/36/1/917189 [Accessed 15 May 2021].

Identifying best modelling practices for tobacco control policy simulations: a systematic review and a novel quality assessment framework- Supplementary Materials

Vincy Huang, Anna Head, Lirije Hyseni, Martin O'Flaherty, Iain Buchan, Simon Capewell, Chris Kypridemos

Text S1. Search strategy (adapted from Feirman et al., 2016).

PubMed

(("models, theoretical"[majr:noexp] OR "models, statistical"[majr:noexp] OR "models, economic"[majr] OR "computer simulation"[majr:noexp] OR "monte carlo method"[mesh] OR "decision support techniques"[majr:noexp] OR "decision trees"[mesh] OR "systems theory"[mesh] OR "markov chains"[mesh] OR "system dynamics"[tiab] OR "agent-based model"[tiab] OR "agent-based models"[tiab] OR "agent-based modeling"[tiab] OR "agent-based modelling"[tiab] OR "simulation model"[tiab] OR "decision analysis"[tiab] OR "decision framework"[tiab] OR "markov"[tiab] OR "cost-utility analysis"[tiab] OR "cost-utility analyses"[tiab] OR "cost-effectiveness analysis"[tiab] OR "cost-effectiveness analyses"[tiab] OR "cost-benefit analysis"[tiab] OR "cost-benefit analyses"[tiab] OR "forecasting"[mesh] OR "microsimulation"[tiab] OR "micro simulation"[tiab] OR "monte carlo"[tiab] OR "life year"[tiab] OR "life years"[tiab] OR "smoking-attributable deaths"[tiab] OR "smoking attributable deaths"[tiab] OR "deterministic"[tiab] OR "probabilistic"[tiab] OR "stochastic"[tiab] OR "dynamic transmission model"[tiab] OR "state-transition"[tiab] OR "state transition"[tiab] OR "discrete event"[tiab] OR "continuous event"[tiab] OR "analytic horizon"[tiab] OR "cohort simulation"[tiab] OR "second-order simulation"[tiab] OR "threshold analysis"[tiab] OR "years of healthy life"[tiab] OR "decision problem"[tiab] OR "transition probabilities"[tiab] OR "discount rate"[tiab]) AND ("Smoking"[Mesh] OR "Smoking Cessation"[Mesh] OR "Tobacco"[Mesh] OR "Tobacco Products"[Mesh] OR "Tobacco, Smokeless"[Mesh] OR "Smoking"[TI] OR "Tobacco"[TI] OR "Smoker"[TI] OR "Smokers"[TI] OR (cigar[TI] OR cigar'[TI] OR cigareftes[TI] OR cigaret[TI] OR cigarete[TI] OR cigarets[TI] OR cigarett[TI] OR cigarette[TI] OR cigarette'[TI] OR cigarette's[TI] OR cigarettedagger[TI] OR cigaretteinduced[TI] OR cigarettes[TI] OR cigarettes'[TI] OR cigarettesmoke[TI] OR cigaretts[TI] OR cigarillo[TI] OR cigarillos[TI] OR cigarlike[TI] OR cigarra[TI] OR cigarret[TI] OR cigarrette[TI] OR cigarrilla[TI] OR cigarro[TI] OR cigarros[TI] OR cigars[TI]) OR "Smokeless"[TIAB] OR (e cigarette[TIAB] OR e cigarette's[TIAB] OR e cigarettedagger[TIAB] OR e cigarettee[TIAB] OR e cigarettes[TIAB]) OR (electronic cigarette[TIAB] OR electronic cigarettes[TIAB]) OR "Snus"[TIAB] OR "Nicotine"[TIAB]))

CINAHL Plus

(MJ Computer Simulation OR Models, Statistical OR Forecasting OR Cost Benefit Analysis OR Quality-Adjusted Life Years OR TX “system dynamics” OR “agent-based model” OR “agent-based models” OR “agent-based modeling” OR “agent-based modelling” OR “simulation model” OR “decision analysis” OR “decision framework” or

"markov" OR "cost-utility analysis" OR "cost-utility analyses" OR "cost-effectiveness analysis" OR "cost-effectiveness analyses" OR "cost-benefit analysis" or "cost-benefit analyses" OR "microsimulation" OR "micro simulation" OR "monte carlo" OR "life year" OR "life years" OR "deterministic" OR "probabilistic" OR "stochastic" OR "dynamic transmission model" OR "state-transition" OR "state transition" OR "discrete event" OR "continuous event" OR "analytic horizon" OR "cohort simulation" OR "second-order simulation" OR "first-order simulation" OR "threshold analysis" OR "years of healthy life" OR "decision problem" OR "transition probabilities" OR "discount rate") AND (MJ Tobacco OR Smoking OR Smoking Cessation OR Smoking—Trends OR Smoking Cessation OR TX smokeless OR "Smoking" OR "Tobacco" OR "Smoker" or "Smokers" OR Cigar* OR "Smokeless" OR E-cigarette* OR Electronic cigarette* OR "Snus" OR "Nicotine" OR "smoking-attributable deaths" OR "smoking attributable deaths")

Limit: English Language

PsycINFO

((KW cost effectiveness OR economic analysis OR smoking-attributable deaths OR quality adjusted life expectancy OR economic impact OR SU "Costs and Cost Analysis" OR Health Care Policy OR Simulation OR Decision Making OR Life Expectancy OR TX "system dynamics" OR "agent-based model" OR "agent-based models" OR "agent-based modeling" OR "agent-based modelling" OR "simulation model" OR "decision analysis" OR "decision framework" or "markov" OR "cost-utility analysis" OR "cost-utility analyses" OR "cost-effectiveness analysis" OR "cost-effectiveness analyses" OR "cost-benefit analysis" or "cost-benefit analyses" OR "microsimulation" OR "micro simulation" OR "monte carlo" OR "life year" OR "life years" OR "deterministic" OR "probabilistic" OR "stochastic" OR "dynamic transmission model" OR "state-transition" OR "state transition" OR "discrete event" OR "continuous event" OR "analytic horizon" OR "cohort simulation" OR "second-order simulation" OR "first-order simulation" OR "threshold analysis" OR "years of healthy life" OR "decision problem" OR "transition probabilities" OR "discount rate") AND (KW tobacco control policies OR tobacco control policy OR smoking cessation OR smokeless tobacco OR cession treatment policies OR population smoking prevalence OR tobacco elimination OR cessation programs OR cigarette consumption OR smoking OR snus OR electronic cigarettes OR SU Smoking Cessation OR Tobacco Smoking OR Smokeless Tobacco OR TX smokeless OR "Smoking" OR "Tobacco" OR "Smoker" or "Smokers" OR Cigar* OR "Smokeless" OR E-cigarette* OR Electronic cigarette* OR "Snus" OR "Nicotine" OR "smoking-attributable deaths" OR "smoking attributable deaths"))

Population Group: Human

Language: English

Population: unselect animal

EMBASE

"theoretical model"/mj OR "statistical model"/mj OR "computer simulation"/mj OR "disease simulation"/mj OR "monte carlo method"/mj OR "decision support system"/mj OR "decision tree"/mj OR "systems theory"/mj OR "economic evaluation"/exp OR "forecasting"/exp OR "economic model":ab,ti OR "simulation model":ab,ti OR "markov":ab,ti OR "systems dynamics":ab,ti OR "agent-based model":ab,ti OR "agent-based models":ab,ti OR "agent-based modeling":ab,ti OR "agent-based modelling":ab,ti OR "decision analysis":ab,ti OR "decision framework":ab,ti OR "microsimulation":ab,ti OR "micro simulation":ab,ti OR "life year":ab,ti OR "life years":ab,ti OR "smoking-attributable deaths":ab,ti OR "smoking attributable deaths":ab,ti OR "deterministic":ab,ti OR "probabilistic":ab,ti OR "stochastic":ab,ti OR "dynamic transmission model":ab,ti OR "state-transition":ab,ti OR "state transition":ab,ti OR "discrete event":ab,ti OR "continuous event":ab,ti OR "analytic horizon":ab, ti OR "cohort simulation":ab,ti OR "second-order simulation":ab,ti OR "first-order simulation":ab,ti OR "threshold analysis":ab,ti OR "years of healthy life":ab,ti OR "decision problem":ab,ti OR "transition probabilities":ab,ti OR "discount rate":ab,ti

AND

'smoking'/mj OR 'cigarette smoke'/mj OR 'bidi smoking'/mj OR 'smoking regulation' OR 'smoking cessation'/exp OR 'tobacco'/exp OR 'smokeless tobacco'/exp OR 'electronic cigarette':ab,ti OR 'e-cigarette':ab,ti OR 'snus': ab,ti OR 'nicotine':ab,ti

NOT 'cannabis smoking'/exp NOT 'cigarette smoke condensate'/mj

EconLit

CC I180 OR CC C530 OR CC J110 OR KW "Simulation" OR CC I120 OR TX "system dynamics" OR "agent-based model" OR "agent-based models" OR "agent-based modeling" OR "agent-based modelling" OR "simulation model" OR "decision analysis" OR "decision framework" or "markov" OR "cost-utility analysis" OR "cost-utility analyses" OR "cost-effectiveness analysis" OR "cost-effectiveness analyses" OR "cost-benefit analysis" or "cost-benefit analyses" OR "microsimulation" OR "micro simulation" OR "monte carlo" OR "life year" OR "life years" OR "deterministic" OR "probabilistic" OR "stochastic" OR "dynamic transmission model" OR "state-transition" OR

"state transition" OR "discrete event" OR "continuous event" OR "analytic horizon" OR "cohort simulation" OR "second-order simulation" OR "first-order simulation" OR "threshold analysis" OR "years of healthy life" OR "decision problem" OR "transition probabilities" OR "discount rate"

AND

KW "Smoking" OR "tobacco" OR TX smokeless OR "Smoking" OR "Tobacco" OR "Smoker" or "Smokers" OR Cigar* OR "Smokeless" OR E-cigarette* OR "Electronic cigarette*" OR "Snus" OR "Nicotine" OR "smoking-attributable deaths" OR "smoking attributable deaths"

Filter: only English

Text S2. Potential Good Modelling Practices.

We examined the modelling approaches by a) model inputs (hierarchy of evidence, population representativeness), b) model structure (exposure granularity, disease epidemiology, documentation), and c) model outputs (reporting standards, uncertainty and sensitivity analysis, model validation) to identify method strengths and weaknesses.

Text S3. Summary of included models (in descending order of the number of peer-reviewed articles).

SimSmoke

SimSmoke is a first-order Markov model to estimate the smoking prevalence changes and smoking-attributable deaths of various tobacco control policies. SimSmoke relies on four sub-modules – population size, smoking prevalence, smoking-attributable deaths, and policy modules. Risk factors included categorical smoking status and the year since quitting. Model outcomes focus on mortality and smoking prevalence. SimSmoke was calibrated, and sensitivity analysis was performed. Readers are provided with the model documentation. The model was reported with external validation. However, there were no simulated diseases mentioned in the model. SimSmoke was also used to model smoking behaviour by dual users (SLT and cigarettes or snus and cigarettes).

Abridged SimSmoke

Abridged SimSmoke is a model that uses a single year to project policy short-term (5 years), mid-term (15 years), and long-term (40 years) effects on smoking prevalence and smoking-attributable deaths. Slightly different from the four modules in SimSmoke, Abridged SimSmoke utilises three components population size, smoking prevalence and policy modules in the approach. In this model, populations are stratified with an unemployed status.

BODE^3

BODE^3 is a multistate life-table model of 16 smoking-related diseases. It was developed to evaluate intervention effectiveness in reducing smoking prevalence, related diseases, cost, cost-effectiveness and equity on ethnicity groups. Model result certainty was reported. However, the model only modelled policy impact on New Zealand populations. There were 16 diseases included in the model - chronic obstructive pulmonary disease (COPD), cardiovascular disease (CVD), stroke, lung cancer. Probabilistic sensitivity analysis (PSA). Moreover, cross-validation and external validation were performed for this model. This model includes two modules: a population forecasting model and a multiple-state life-table.

Extended cost-effectiveness analysis (ECEA) tobacco tax model

The extended cost-effectiveness analysis (ECEA) tobacco tax model is a cost-effectiveness model in estimating the impact of tobacco taxation. It was adapted from the Asian Development Bank's framework. The population groups were stratified by income quintile. It included diseases such as COPD, CVD, stroke, lung cancer, bladder cancer and

neoplasms. The model generates cost, mortality, the number of smokers who quit, life-years gained, additional revenues generated and equity outcomes.

Moreover, it was tested with one-way sensitivity analysis and validated. The model technical document is available for readers. Nevertheless, the majority of the studies using this model focused on male-only.

IMPACT

IMPACT is a cell-based model to estimate CHD mortality changes under different policy scenarios. Risk factors included blood pressure, cholesterol, diabetes, fruit and vegetable, smoking (never smoker, long-term ex-smoker, recent ex-smoker, current smoker), salt intake, saturated fat intake, BMI and physical activities. Model simulated diseases include CHD and type 2 Diabetes. In the IMPACT model, population characteristics include age, gender and socioeconomics classes (indicated by QIMD). The model projects outcomes on equity, CHD mortality, smoking prevalence and life-years gained. Moreover, the resulting uncertainty was reported. Probabilistic sensitivity analysis (PSA) using the Monte Carlo approach was applied as the sensitivity analysis, and the model was externally validated. Moreover, the model documentation is available to readers.

European study on Quantifying Utility of Investment in Protection from Tobacco model (EQUIPTMOD)

The European study on Quantifying Utility of Investment in Protection from Tobacco model (EQUIPTMOD) is constructed as a Markov state transition model. It models smoking cessation on four diseases: stroke, lung cancer, coronary heart disease and COPD. It provides economic estimates on intervention cost, return on investment (ROI), incremental cost-effectiveness ratio (ICER) and quality-adjusted life-year (QALY). Both univariable sensitivity analysis and PSA were performed. Technical document for all countries is available on the study website. However, there was no model validity mentioned in the papers.

Benefits of Smoking Cessation on Outcomes (BENESCO) model

Benefits of Smoking Cessation on Outcomes (BENESCO) model is a discrete-time Markov model that estimates the cost-effectiveness of a single smoking cessation attempt. Smokers were modelled by quit smoking duration, including smoker, recent quitter and long-term quitter. COPD, CHD, stroke and lung cancer were included in the model. Results on mortality, morbidity, cost and QALY were generated. In addition, univariable sensitivity analysis and PSA was performed on this model. It was calibrated. However, there is no documentation provided. In addition, funding was provided by Pfizer.

Two-quit BENESCO is a model developed based on the adaption of BENESCO to model smokers that attempts two times quit smoking over a lifetime. Diseases include COPD, CHD, stroke and asthma exacerbations were modelled. One-way and PSA were performed for this model. Scenario testing and face validation were applied for this model.

DYNAMO-HIA model

The DYNAMO-HIA is a software applying a discrete-time, Markov-type multistate model. The model combines a microsimulation to simulate the risk factor exposure development and projecting the health impact over time with a macrosimulation. Moreover, three modules - population, disease, risk factors were included; eight health risk factors were included - BMI, alcohol, smoking, second-hand smoking, salt intake, physical activities, obesity. The model simulates nine smoking-related diseases: ischemic heart diseases (IHD), diabetes, COPD, stroke, lung, breast, colorectal, oral, and oesophageal cancer. The model estimates the chances of morbidity and healthy life years (HLY). The model validity checked was mention for this model.

Johansson model

Johansson model is a Markov-cycle tree model. It simulates smoking cessation on COPD, cardiovascular disease (stroke and CHD) and cancers to estimate QALY and cost impact. Sensitivity analysis was performed using multivariable analysis and PSA. Model external validation was mentioned. Moreover, the model non-technical document is available.

Prevention Impacts Simulation Model (PRISM)

Prevention Impacts Simulation Model (PRISM) is an interactive system dynamics model for cardiovascular disease prediction. Users could interact with the model parameters using the user interface. It was designed to estimate policy impact on mortality, morbidity, healthcare cost, productivity and result uncertainty. A series of risk factors were included: blood pressure, cholesterol, second-hand smoking, obesity, psychological distress, fruit and vegetable, smoking (never smoker, long-term ex-smoker, recent ex-smoker, current smoker), blood glucose categories, periodontal disease, sleep apnoea, small particulate air pollution, and inadequate use of aspirin for primary prevention. The model was externally validated, and the sensitivity analysis was checked with PSA. However, it was only applied to the US setting.

Jiménez model

Jiménez et al. developed the budgetary impact analysis (BIA) model for the Spanish population. This model incorporates a hybrid model - closed cohort and Markov chains. The model population are represented by patients diagnosed with COPD, t2-DM and CVD, who would be willing to stop smoking. Risk factors included smoking status and willingness and quit history. The model estimates costs and the number of quitters. This model was internally validated and tested with univariable sensitivity analysis. Furthermore, this model received funding from Pfizer Inc.

Baker model

Baker et al. developed a closed cohort budget impact Markov model. The model estimates the cost of smoking cessation prescriptions from the angle of US payers. Categorical smoking status is the risk factor input. It predicts the number of quitters and medical expenditures under different policy scenarios. A series of univariate and multivariate sensitivity analyses were performed on the model. However, there was no mentioning of modelled diseases and no reporting of model validation. Moreover, the model documentation was not provided by modellers. From the declaration, the authors mentioned that IQVIA employees developed the model with funding from Pfizer.

Barnett model

Barnett model is a Markov model that used for smoking cessation trial cost-effectiveness. Treatment effectiveness is extracted from the trial. It predicts the trial lifetime effect on cost, mortality and QALYs. The result range is provided. This model was tested with a one-way sensitivity method. Its technical appendix is provided, but the code is not open-source. The model was calibrated; however, there was no mentioning of the model validation and no specific modelling of diseases mentioned for this model.

Cantor model

The model designed by Cantor et al. is a two-structured decision-analytic model to assess the cost-effectiveness of smoking cessation interventions over a lifetime. The first model evaluates cost per successful quit while the second one estimates life expectancy and quality-adjusted life expectancy. This model includes a lifetime horizon to capture the smoking intervention for long-term benefit—however, the model only simulated interventions in the United States. One-way and two-way sensitivity analysis were used. The model validation is not mentioned, and there is no additional model documentation provided.

Chevreul model

Chevreul model is a Markov state-transition model that is used to predict cost-effectiveness analysis of smoking policies on the French population. The model simulates the natural history of smokers until death. It only modelled smokers diagnosed with either lung cancer, COPD or CVD, such as stroke or coronary artery disease and death. Diseases include COPD, CVD and lung cancer. Moreover, health outcomes and ICER are provided by the model. The model used sensitivity tests and was cross-validated. The model documentation is available.

Cost-Effectiveness of Preventing AIDS Complications (CEPAC)-US model

Cost-Effectiveness of Preventing AIDS Complications (CEPAC)-US model is a microsimulation model of HIV natural history and treatment. It is applicable for the HIV-infected US population. The model includes risk factors - smoking intensity(packs/day), CD4+ T-cell count, viral load, history of the opportunistic disease, and antiretroviral therapy use. Lung cancer is simulated as a disease outcome. The model predicts the number of years of life lost from smoking. Two-way sensitivity analysis was applied in this model. Moreover, this model was validated with internal and external validation. There is a link to model documentation provided; however, it is not open access.

ModelHeath: Tobacco

ModelHeath: Tobacco is a microsimulation model developed by Maciosek et al. ModelHealth: Tobacco MN is the same model for modelling the population data from Minnesota. Detailed demographic information including education level, ethnicity, disability, employment and poverty were modelled. Disease including CVD, stroke, lung cancer and respiratory disease was simulated. The model reports the health burden and cost-effectiveness of smoking behaviour, including medical cost, hospitalisation, mortality and morbidity, productivity loss, QALY and smoking prevalence. One-way sensitivity analysis was performed. Moreover, the model was validated with internal and external validation. Model documentation is provided for the readers.

Parrott model

Parrott model is used in evaluating the cost-effectiveness of clinical trials over a lifetime. The policy effectiveness was extracted from a randomised controlled trial, and other data inputs were either from the trial or national representative surveys. Diseases including COPD, CHD, stroke, lung cancer, asthma, pregnancy-related (placental abruption, ectopic pregnancy, pre-eclampsia, placenta previa and miscarriage infant morbidities: low infant birth weight, stillbirth, premature birth) were modelled. The model estimates trial outcomes on cost and QALY with a result uncertainty

range. The result was tested with PSA. Users are provided with model documentation. However, there was no mentioning of model validation.

Population Health Impact Model (PHIM)

Population Health Impact Model (PHIM) is a tobacco industry funded model by Philip Morris International. This model evaluates the health impact of a candidate modified risk tobacco product (cMRTP). It projects cMRTP uptake and mortality rate changes under alternative scenarios. cMRTP users and dual users were counted as the smoking status. In addition, smoking-related attributable deaths from lung cancer, ischemic heart disease, stroke and chronic obstructive pulmonary disease were considered. This model was tested with sensitivity analysis and validated. PHIM model comprises two modules - a population module that generates distributions of smoking histories for each scenario at the end of the period being studied and an epidemiologic risk module to estimate smoking-related attributable deaths.

Tobacco Town

This is an agent-based model. Smoking intensity (cigarettes/day) is simulated in the model. Population characteristics include priority population representation(lesbian, LGBTQ+), income, urban rich, urban poor, suburban rich, suburban poor, mode of transport, home and work locations, and route between the two locations and ethnicities. The model predicts cost and tobacco purchase behaviour. The model reported calibration and sensitivity analysis. Moreover, there is additional model documentation provided. However, there was no mentioning of model validation.

UK Health Forum (UKHF) simulation

UK Health Forum (UKHF) simulation is a two structure microsimulation model to predict the health and economic impact of smoking policies within the UK setting. Module one applies a regression model to project smoking prevalence over time. Module two uses the smoking prevalence projection in a microsimulation model to estimate the cost and health benefits of policy scenarios. Seventeen smoking-related diseases (COPD, CHD, stroke, 14 tobacco-related cancers) were included in the model. The model generates outcomes on cost, morbidity and smoking prevalence. The model was tested with sensitivity analysis. There is detailed model documentation with equations. However, there was no mentioning of validation.

Chronic Disease Model (CDM)

Chronic Disease Model (CDM) is a dynamic multistate Markov model. This model simulated 20 chronic diseases. It models population groups stratified by age, gender and socioeconomics status using education levels. This model generates the lifetime outputs on QALYs, number of quitters and cost introduced by different smoking policies.

Coronary Heart Disease (CHD) Policy Model

Coronary Heart Disease (CHD) Policy Model is a state-transition Markov model that predicts policy impact on CHD incidence, prevalence, mortality and costs. This model includes three sub-models: demographic–epidemiological, bridge and disease-history. Six risk factors linking with CHD and stroke were simulated in this model. Moreover, this model was calibrated, and sensitivity analysis was performed.

Lung Cancer Policy Model (LCPM)

The Lung Cancer Policy Model is a state-transition microsimulation that models lung cancer development, screening and treatment at the individual patient level. Detailed patient smoking histories were counted in this model. This model was calibrated and validated.

Mendez model

Mendez model is an excel-based state-transition model. It composes two submodules, namely, prevalence and epidemiological models. The model generates outputs on smoking prevalence, health and cost-effectiveness under different tobacco interventions. This model only simulates the US population.

Mejia model

Mejia model used a decision tree model in Monte Carlo simulations. It estimates the health effects of expanding e-cigarette sales in the United States and the United Kingdom. Outcomes include smoking prevalence and costs with the uncertainty range provided. Sensitivity analysis was performed. There was no mentioning of any model validation.

Text S4. Models retrieved from the search cretiria that appeared only in one publication.

1. Altman D., Clement F.M., Barnieh L., *et al.* Cost-effectiveness of universally funding smoking cessation pharmacotherapy. *Can J Respir Crit Care Sleep Med* 2019;**3**:67–75. doi:10/ggm8qb
2. Ansah JP, Inn RLH, Ahmad S. An evaluation of the impact of aggressive hypertension, diabetes and smoking cessation management on CVD outcomes at the population level: a dynamic simulation analysis. *BMC Public Health* 2019;**19**:1105. doi:10/ggm9w5
3. Apelberg BJ, Feirman SP, Salazar E, *et al.* Potential Public Health Effects of Reducing Nicotine Levels in Cigarettes in the United States. *New England Journal of Medicine* 2018;**378**:1725–33. doi:10/cmmv
4. Aungkulanon S, Pitayarangsarit S, Bundhamcharoen K, *et al.* Smoking prevalence and attributable deaths in Thailand: predicting outcomes of different tobacco control interventions. *BMC Public Health* 2019;**19**:984. doi:10/ggm9ww
5. Bachand AM, Sulsky SI. A dynamic population model for estimating all-cause mortality due to lifetime exposure history. *Regulatory Toxicology and Pharmacology* 2013;**67**:246–51. doi:10/f5gz5x
6. Basu S, Sussman JB, Rigdon J, *et al.* Benefit and harm of intensive blood pressure treatment: Derivation and validation of risk models using data from the SPRINT and ACCORD trials. *PLoS Medicine* 2017;**14**:1–26. doi:10/gb4j99
7. Benmarhnia T, Dionne P-A, Tchouaket É, *et al.* Investing in a healthy lifestyle strategy: is it worth it? *Int J Public Health* 2017;**62**:3–13. doi:10/f9tf85
8. Bertram MY, Sweeny K, Lauer JA, *et al.* Investing in non-communicable diseases: an estimation of the return on investment for prevention and treatment services. *The Lancet* 2018;**391**:2071–8. doi:10.1016/S0140-6736(18)30665-2
9. Cedillo S, Sicras-Mainar A, Jimenez-Ruiz CA, *et al.* Budgetary Impact Analysis of Reimbursement Varenicline for the Smoking-Cessation Treatment in Patients with Cardiovascular Diseases, Chronic Obstructive Pulmonary Disease or Type-2 Diabetes Mellitus: A National Health System Perspective. *Eur Addict Res* 2017;**23**:7–18. doi:10/f9q5hw

10. Chao D, Hashimoto H, Kondo N. Social influence of e-cigarette smoking prevalence on smoking behaviours among high-school teenagers: Microsimulation experiments. *PLoS One* 2019;**14**:e0221557. doi:10/ggm9xc
11. Cherng ST, Tam J, Christine PJ, *et al.* Modeling the Effects of E-cigarettes on Smoking Behavior: Implications for Future Adult Smoking Prevalence. *Epidemiology* 2016;**27**:819–26. doi:10/f9g8vn
12. Connolly MP, Kotsopoulos N, Postma MJ, *et al.* The Fiscal Consequences Attributed to Changes in Morbidity and Mortality Linked to Investments in Health Care: A Government Perspective Analytic Framework. *Value Health* 2017;**20**:273–7. doi:10/gf3mh2
13. Djalalov S, Masucci L, Isaranuwatchai W, *et al.* Economic evaluation of smoking cessation in Ontario's regional cancer programs. *Cancer Med* 2018;**7**:4765–72. doi:10/gdvtdr
14. Getsios D. et al. Smoking Cessation Treatment and Outcomes Patterns Simulation: A New Framework for Evaluating the Potential Health and Economic Impact of Smoking Cessation Interventions | Kopernio. https://kopernio.com/viewer?doi=10.1007%2Fs40273-013-0070-5&token=WzIxMDU2NzcsIjEwLjEwMDcvczQwMjczLTAxMy0wMDcwLTUiXQ.AyKvwsUkIYn0SyFzGypATSyxico (accessed 22 Jun 2020).
15. Golden SD, Farrelly MC, Luke DA, *et al.* Comparing projected impacts of cigarette floor price and excise tax policies on socioeconomic disparities in smoking. *Tobacco Control* 2016;**25**:i60–6. doi:10/f89qcb
16. Goodchild M, Perucic A-M, Nargis N. Modelling the impact of raising tobacco taxes on public health and finance. *Bull World Health Organ* 2016;**94**:250–7. doi:10/f8nx8m
17. Grace RC, Kivell BM, Laugesen M. Predicting decreases in smoking with a cigarette purchase task: evidence from an excise tax rise in New Zealand. *Tob Control* 2015;**24**:582–7. doi:10/gg5mv9
18. Healey A, Roberts S, Sevdalis N, *et al.* A Cost-Effectiveness Analysis of Stop Smoking Interventions in Substance-Use Disorder Populations. *Nicotine Tob Res* 2019;**21**:623–30. doi:10/ggm74h
19. Hill A, Camacho OM. A system dynamics modelling approach to assess the impact of launching a new nicotine product on population health outcomes. *Regulatory Toxicology and Pharmacology* 2017;**86**:265–78. doi:10/ggm62g

20. Holford TR, Meza R, Warner KE, *et al.* Tobacco Control and the Reduction in Smoking-Related Premature Deaths in the United States, 1964-2012. *JAMA* 2014;**311**:164–71. doi:10/f5np3w
21. Igarashi A, Goto R, Suwa K, *et al.* Cost-Effectiveness Analysis of Smoking Cessation Interventions in Japan Using a Discrete-Event Simulation. *Appl Health Econ Health Policy* 2016;**14**:77–87. doi:10/f8rfb4
22. Islek D, Sozmen K, Unal B, *et al.* Estimating the potential contribution of stroke treatments and preventative policies to reduce the stroke and ischemic heart disease mortality in Turkey up to 2032: a modelling study. *BMC Public Health* 2016;**16**:46. doi:10/f77z9z
23. Jones M, Smith M, Lewis S, *et al.* A dynamic, modifiable model for estimating cost-effectiveness of smoking cessation interventions in pregnancy: application to an RCT of self-help delivered by text message. *Addiction* 2019;**114**:353–65. doi:10.1111/add.14476
24. Kontis V, Mathers CD, Rehm J, *et al.* Contribution of six risk factors to achieving the 25×25 non-communicable disease mortality reduction target: a modelling study. *The Lancet* 2014;**384**:427–37. doi:10.1016/S0140-6736(14)60616-4
25. Kowada A. Cost-effectiveness of tobacco cessation support combined with tuberculosis screening among contacts who smoke. ;:8. doi:10/f7f98r
26. Kuklinski MR, Fagan AA, Hawkins JD, *et al.* Benefit–cost analysis of a randomized evaluation of Communities That Care: Monetizing intervention effects on the initiation of delinquency and substance use through grade 12. *Journal of Experimental Criminology* 2015;**11**:165–92. doi:10/f7dptp
27. Kulaylat AS, Hollenbeak CS, Soybel DI. Cost-utility analysis of smoking cessation to prevent operative complications following elective abdominal colon surgery. *Am J Surg* 2018;**216**:1082–9. doi:10/ggm64g
28. Lal A, Mihalopoulos C, Wallace A, *et al.* The cost-effectiveness of call-back counselling for smoking cessation. *Tob Control* 2014;**23**:437–42. doi:10/f6rdwn
29. Levy DT, Borland R, Lindblom EN, *et al.* Potential deaths averted in USA by replacing cigarettes with e-cigarettes. *Tobacco Control* 2018;**27**:18–25. doi:10/gbzrmj

30. Levy DT, Yuan Z, Li Y, *et al.* A modeling approach to gauging the effects of nicotine vaping product use on cessation from cigarettes: what do we know, what do we need to know? *Addiction* 2019;**114 Suppl 1**:86–96. doi:10.1111/add.14530

31. Li Y, Kong N, Lawley M, *et al.* Advancing the use of evidence-based decision-making in local health departments with systems science methodologies. *Am J Public Health* 2015;**105 Suppl 2**:S217-222. doi:10.2105/AJPH.2014.302077

32. Luo L., Pang B., Chen J., *et al.* Assessing the impact of lifestyle interventions on diabetes prevention in China: A modeling approach. *Int J Environ Res Public Health* 2019;**16**. doi:10/ggm8qg

33. Marynak KL, Xu X, Wang X, *et al.* Estimating the Impact of Raising Prices and Eliminating Discounts on Cigarette Smoking Prevalence in the United States. *Public Health Rep* 2016;**131**:536–43. doi:10.1177/0033354916662211

34. McAuley A, Denny C, Taulbut M, *et al.* Informing Investment to Reduce Inequalities: A Modelling Approach. *PLOS ONE* 2016;**11**:e0159256. doi:10.1371/journal.pone.0159256

35. McCallum DM, Fosson GH, Pisu M. Making the Case for Medicaid Funding of Smoking Cessation Treatment Programs: An Application to State-Level Health Care Savings. *Journal of Health Care for the Poor & Underserved* 2014;**25**:1922–40. doi:10/f6sc45

36. Muhammad-Kah RS, Pithawalla YB, Boone EL, *et al.* A Computational Model for Assessing the Population Health Impact of Introducing a Modified Risk Claim on an Existing Smokeless Tobacco Product. *Int J Environ Res Public Health* 2019;**16**:E1264. doi:10.3390/ijerph16071264

37. Nemeth B, Kulchaitanaroaj P, Lester-George A, *et al.* A utility of model input uncertainty analysis in transferring tobacco control-related economic evidence to countries with scarce resources: results from the EQUIPT study. *Addiction* 2018;**113 Suppl 1**:42–51. doi:10/ggm63p

38. Ngalesoni F, Ruhago G, Mayige M, *et al.* Cost-effectiveness analysis of population-based tobacco control strategies in the prevention of cardiovascular diseases in Tanzania. *PLoS One* 2017;**12**:e0182113. doi:10/ggm622

39. Pennington B, Filby A, Owen L, *et al.* Smoking Cessation: A Comparison of Two Model Structures. *Pharmacoeconomics* 2018;**36**:1101–12. doi:10/ggm632

40. Pinto M, Bardach A, Palacios A, *et al.* Burden of smoking in Brazil and potential benefit of increasing taxes on cigarettes for the economy and for reducing morbidity and mortality. *Cadernos de Saúde Pública* 2019;**35**. doi:10/gg5mwb
41. Platt JM, Keyes KM, Galea S. Efficiency or equity? Simulating the impact of high-risk and population intervention strategies for the prevention of disease. *SSM Popul Health* 2017;**3**:1–8. doi:10.1016/j.ssmph.2016.11.002
42. Poland B. Population Modeling of Modified Risk Tobacco Products Accounting for Smoking Reduction and Gradual Transitions of Relative Risk. https://kopernio.com/viewer?doi=10.1093%2Fntr%2Fntx070&token=WzIxMDU2NzcsIjEwLjEwOTMvbnRyL250eDA3MCJd.IFnWlJvql5E8bC5l8Re68t4Pwxw (accessed 18 Apr 2020).
43. Popp J, Nyman JA, Luo X, *et al.* Cost-effectiveness of enhancing a Quit-and-Win smoking cessation program for college students. *Eur J Health Econ* 2018;**19**:1319–33. doi:10/ggm63z
44. Rana P, Perez-Rios M, Santiago-Perez MI, *et al.* Impact of a comprehensive law on the prevalence of tobacco consumption in Spain: evaluation of different scenarios. *Public Health* 2016;**138**:41–9. doi:10/ggm9xv
45. Sadatsafavi M, Ghanbarian S, Adibi A, *et al.* Development and Validation of the Evaluation Platform in COPD (EPIC): A Population-Based Outcomes Model of COPD for Canada. *Medical Decision Making* 2019;**39**:152–67. doi:10/gfvh6v
46. Saidi O., O'Flaherty M., Zoghlami N., *et al.* Comparing strategies to prevent stroke and ischemic heart disease in the tunisian population: Markov modeling approach using a comprehensive sensitivity analysis algorithm. *Comp Math Methods Med* 2019;**2019**. doi:10/gf654t
47. Saxena K. Development and validation of a discrete event simulation model to evaluate the long-term use of electronic cigarettes on the U.S. population. *J Manag Care Spec Pharm* 2016;**22**:S97.
48. Selya AS, Ivanov O, Bachman A, *et al.* Youth smoking and anti-smoking policies in North Dakota: a system dynamics simulation study. *Subst Abuse Treat Prev Policy* 2019;**14**:34. doi:10/ggm748
49. Shang C, Yadav A, Stoklosa M, *et al.* Country-specific costs of implementing the WHO FCTC tobacco control policies and potential financing sources. *PLOS ONE* 2018;**13**:e0204903. doi:10/gfcsbt

50. Sonntag D, Gilbody S, Winkler V, *et al.* German EstSmoke: estimating adult smoking-related costs and consequences of smoking cessation for Germany. *Addiction* 2018;**113**:125–36. doi:10/ggm75r

51. Sung H-Y, Penko J, Cummins SE, *et al.* Economic Impact of Financial Incentives and Mailing Nicotine Patches to Help Medicaid Smokers Quit Smoking: A Cost-Benefit Analysis. *Am J Prev Med* 2018;**55**:S148–58. doi:10.1016/j.amepre.2018.08.007

52. Tosanguan J, Chaiyakunapruk N. Cost-effectiveness analysis of clinical smoking cessation interventions in Thailand. *Addiction* 2016;**111**:340–50. doi:10/ggm9xf

53. Villanti AC, Jiang Y, Abrams DB, *et al.* A Cost-Utility Analysis of Lung Cancer Screening and the Additional Benefits of Incorporating Smoking Cessation Interventions. *PLoS One* 2013;**8**:e71379. doi:10/f5c83w

54. Warner KE, Mendez D. E-cigarettes: Comparing the Possible Risks of Increasing Smoking Initiation with the Potential Benefits of Increasing Smoking Cessation. *Nicotine & Tobacco Research* 2019;**21**:41–7. doi:10.1093/ntr/nty062

55. West R, Coyle K, Owen L, *et al.* Estimates of effectiveness and reach for 'return on investment' modelling of smoking cessation interventions using data from England. *Addiction* 2018;**113**:19–31. doi:10/gg2zwn

56. Xu X, Alexander RLJ, Simpson SA, *et al.* A cost-effectiveness analysis of the first federally funded antismoking campaign. *Am J Prev Med* 2015;**48**:318–25. doi:10/ggm94k

57. Yang W, Zou Q, Tan E, *et al.* Future Health and Economic Impact of Comprehensive Tobacco Control in DoD: A Microsimulation Approach. *Mil Med* 2018;**183**:e104–12. doi:10/gc4tm7

58. La Foucade A, Gabriel S, Scott E, et al. Increased taxation on cigarettes in Grenada: potential effects on consumption and revenue. Rev Panam Salud Publica 2018;42:1–7. doi:10.26633/RPSP.2018.195

Table S1. Synthesis Without Meta-analysis (SWiM) reporting items.

The citation for the Synthesis Without Meta-analysis explanation and elaboration article is: Campbell M, McKenzie JE, Sowden A, Katikireddi SV, Brennan SE, Ellis S, Hartmann-Boyce J, Ryan R, Shepperd S, Thomas J, Welch V, Thomson H. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline BMJ 2020;368:l6890

SWiM is intended to complement and be used as an extension to PRISMA			
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
Methods			
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (e.g., groupings of populations, interventions, outcomes, study design)	Page 8 - 9	
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	NA	
2 Describe the standardised metric and transformation methods used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen, and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance consulted	NA	
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates	Page 8 - 9	

4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select the particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (e.g., based on study design, risk of bias assessments, directness in relation to the review question)	Page 9	
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it was not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity	Page 9	
6 Certainty of evidence	Describe the methods used to assess the certainty of the synthesis findings	NA	
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (e.g., tables, forest plots, harvest plots). Specify key study characteristics (e.g., study design, risk of bias) used to order the studies in the text and any tables or graphs, clearly referencing the studies included	Page 9 - 10	
Results			

8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis	Page 10 - 41	
Discussion			
9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis and how these affect the conclusions that can be drawn in relation to the original review question	Page 45 - 46	

PRISMA=Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

*If the information is not provided in the systematic review, give details of where this information is available (e.g., protocol, other published papers (provide citation details), or website (provide the URL)).

Table S2. PICOS: inclusion / exclusion criteria.

Include	Exclude
Participants	
Studies on any human populations	Studies on animals and cells
Interventions	
Tobacco control policies	Non-tobacco control policies (e.g. cancer screening program)
Comparator	
Studies where tobacco control PSMs are evaluated or compared	No tobacco control PSMs presented
Outcomes	
Studies reporting any tobacco-related outcomes	Studies reporting no tobacco-related outcomes
Study design	
PSMs	Studies without PSMs

Table S3. Data extraction form.

Paper Name	Tick if yes
1. GENERAL INFORMATION	
Paper author (First author)	
Paper published year (published online)	
Ref ID (DOI):	
Data extractor:	
Extraction date (DD/MM/YYYY)	
Funding & Conflict of interest	
General information - Others	
2.MODEL DETAILS	
Model name	
Code license/ Open source	
code URL	
Model setting - Country/Area	
Model - Initial year	
Prediction period:	
model detail - others	
3.TYPE OF MODEL	
Agent-based model	
Decision tree	
Discrete event	
Life table	
Markov model	
Macrosimulation	
Microsimulation	
System dynamic	
Open cohort	
Close cohort:	
Continuous time	

Discrete-time	
Type of model - others	
4.DEMOGRAPHIC CHARACTERISTICS	
Gender (Y, both, F, M)	
Age	
Socioeconomic status	
Education	
Income	
Race/ Ethnicity	
Urban/ Rural	
Demographic - Others	
5.RISK FACTORS	
Alcohol intake	
Alcohol intake (Unit)	
Blood pressure	
Blood pressure (Unit)	
Cholesterol	
Cholesterol (Unit)	
Competing causes	
Competing causes (Unit)	
Diabetes	
Diabetes (Unit)	
Environmental tobacco smoking	
Environmental tobacco smoking (Unit)	
Fruit and vegetable consumption	
Fruit and vegetable consumption (Unit)	
General Health status	
General Health status (Unit)	
Hypertension	
Hypertension (Unit)	

Mental health	
Mental health (Unit)	
Obesity or BMI	
Obesity or BMI (Unit)	
Physical activity	
Physical activity (Unit)	
Other risk factors (list down in box)	
Other risk factors (list down in box) (Unit)	
Smoking Status (never, former, smoker) (Unit)	
Smoking status (Unit)	
Smoking history (age star/ duration, intensity/age quit)	
Unit (pack-year, smoking duration, smoking intensity, smoking duration and intensity	
Lag time	
Lag time (Unit)	
Risk factor-others	
Risk factor-others (Unit)	
6.OUTCOME TYPE	
Equality	
Economics outcome	
Hospital admission	
Health outcomes - mortality	
Health outcomes - morbidity	
Health outcomes - other	
Smoking attitude/ Smoking prevalence	
Uncertainty	
Outcome types - Others (please describe)	
7.DISEASE CATEGORIES	
AMI (Acute myocardial infarction)	
Atrial fibrillation (AF)	
Asthma	

COPD	
CVD	
Diabetes	
Diabetic neuropathy	
Diabetic retinopathy	
Dyslipidaemia	
Lung cancer	
Obesity	
Other cancers	
Stroke	
Tuberculosis (TB)	
Hypertension	
Diseases - Others	
Disease categories - others	
8.DATA SOURCES USED	
Population	
Mortality	
Morbidity	
Policy effective/ treatment effectiveness	
Data source - Others	
9.MODEL CHECKING	
Any sensitivity analyses carried out?	
Which sensitivity analyses were carried out?	
Was the model aligned?	
Was the model calibrated?	
How was the model calibrated?	
Was the validity of the model tested?	
Face validation	
Internal validation	
Cross-validation	

External validation	
How was the validity quantified? *(e.g. % explained)*	
Validation - others	
Nontechnical & Technical documentation	
Assumptions	
Model availability for the reader (not including source code)	
Transparency - others	
Model-checking - others	
10.POTENTIAL LIMITATIONS	
Please list down Limitation	
Limitation reported/ Limitation discussed	
Limitation - others	
11.OTHER DETAILS	
Is this model an extension of another model (If yes, please mention what model it is)	
User interface	
Is this model a simulation software? (if yes, please mention the name of the software)	
Other comments	

Table S4. Occurrence of model outcome types (Some models included more than one output type).

Outcome type	Model name / First Author	Number of models
Health economics outcome	Baker model, Barnett model, BENESCO model, BODE^3, Cantor model, CDM, Chevreul model, CHD Policy model, ECEA tobacco tax model, EQUIPTMOD, Jiménez model, Johansson model, LCPM, Mendez model, ModelHeath: Tobacco, PRISM, Parrott model, Tobacco Town ABM, UKHF simulation	19
Other health outcomes	Barnett model, BENESCO model, BODE^3, Cantor model, CDM, CEPAC-US model, DYNAMO-HIA, ECEA tobacco tax model, EQUIPTMOD, IMPACT model, Johansson model, Mendez model, ModelHeath: Tobacco, Parrott model	14
Mortality rate	Barnett model, BENESCO model, CEPAC-US model, CHD Policy Model, DYNAMO-HIA, ECEA tobacco tax model, IMPACT model, LCPM, ModelHeath: Tobacco, PHIM, PRISM, SimSmoke	12
Smoking prevalence	Baker model, BODE^3, CDM, IMPACT, Jiménez model, LCPM, Mejia model, Mendez model, ModelHeath: Tobacco, UKHF simulation	10
Morbidity rate	Baker model, BENESCO model, DYNAMO-HIA, Mejia model, ModelHeath: Tobacco, PRISM, SimSmoke, UKHF simulation	8
Equity	BODE^3, CDM, ECEA tobacco tax model, IMPACT model	4
Hospital admission	ModelHeath: Tobacco	1

BENESCO model: Benefits of Smoking Cessation on Outcomes model
BODE^3: Burden of Disease Epidemiology, Equity and Economics model
CDM: Chronic Disease Model
CEPAC-US model: Cost-Effectiveness of Preventing AIDS Complications-US model
CHD Policy model: Coronary Heart Disease Policy model
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UKHF simulation: UK Health Forum simulation

Table S5.Occurrence of number of disease groups simulated by models.

Disease group	Model name / First Author	Number of models
No disease explicitly modelled	Baker model, Barnett model, Cantor model, Jiménez model, Mejia model, Mendez model, SimSmoke, Tobacco Town ABM	8
One disease group	CEPAC-US model, IMPACT, LCPM, PRISM	4
Two disease groups	CHD Policy model	1
Three disease groups	BODE^3, Chevreul model, DYNAMO-HIA, ModelHeath: Tobacco, PHIM	5
Four disease groups	BENESCO model, ECEA tobacco tax model, EQUIPTMOD, Johansson model, Parrott model, UKHF simulation, CDM	7

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Table S6. Diseases groups included in models.

Model name / First Author	Cancers	Chronic obstructive pulmonary disease	Cardiovascular disease	Other smoking-related diseases	No reported disease modelled
SimSmoke					Y - calculated smoking-attributable deaths
BODE[3]	Y		Y	Y	
IMPACT			Coronary heart disease (CHD)		
ECEA tobacco tax model	Y	Y	Y	Y	
EQUIPTMOD	Y	Y	CHD	Y	
DYNAMO-HIA model	Y	Y		Y	
BENESCO model	Y	Y	CHD	Y	
Jiménez model					Y
Johansson model	Y	Y	CHD and stroke	Y	
PRISM			Y		
Baker model					Y
Barnett model					Y - smoking related mortality risk
Cantor model					Y
Chevreul model	Y	Y	Y		
CEPAC-US model	Y				
ModelHeath: Tobacco	Y		Y	Y	
Parrott model	Y	Y	CHD	Y	
PHIM	Y	Y		Y	
Tobacco Town ABM					Y
UKHF simulation	Y	Y	CHD	Y	
CDM	Y	Y	CHD	Y	
CHD Policy model			CHD and stroke		
LCPM	Y				
Mendez model					Y
Mejia model					Y
Total number	**14**	**10**	**13**	**11**	**8**

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Supplementary Table S7. Occurrence of model validation types (Some models used more than one validation type).

Validation type	Model name / First Author	Number of models
No validation	Baker model, Barnett model, BENESCO model, Cantor model, CDM, CHD Policy model, DYNAMO-HIA model, EQUIPTMOD, Mejia model, Parrott model, Tobacco Town ABM, UKHF simulation	12
External validation	BODE^3, CEPAC-US model, Chevreul model, IMPACT, LCPM, Mendez model, ModelHeath: Tobacco, PRISM, SimSmoke, Johansson model	10
Internal validation	CEPAC-US model, Chevreul model, Jiménez model, ModelHeath: Tobacco	4
Cross validation	BODE^3, CEPAC-US model	2

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Table S8. Model score (in descending order of the number of peer-reviewed articles).

Model name / First Author	Population	Policy effectiveness	Smoking status	Smoking-related diseases	Lag time	Transparency	Sensitivity	Validation	Equity	Score	Number of publications*	Overall number of publications**
SimSmoke	1	0	1	0	1	1	1	1	0	**6**	18	**44**
BODE^3	1	1	0	1	1	1	1	1	1	**8**	11	**11**
IMPACT	1	1	0	1	0	1	1	1	1	**7**	6	**6**
ECEA tobacco tax model	1	0	1	1	0	1	1	1	1	**7**	5	**5**
EQUIPTMOD	1	1	0	1	0	1	1	0	0	**5**	5	**5**
DYNAMO-HIA model	1	1	0	1	1	1	1	0	0	**6**	5	**5**
BENESCO	1	1	0	1	0	0	1	0	0	**4**	4	**20**
Jiménez model	1	1	1	0	0	0	1	1	0	**5**	3	**3**
Johansson model	0	1	0	1	1	1	1	1	0	**6**	3	**3**
PRISM	1	0	0	1	1	1	1	1	0	**6**	3	**3**
Baker model	1	1	0	0	1	0	1	0	0	**4**	2	**2**
Barnett model	0	1	0	0	0	1	1	0	0	**3**	2	**2**
Cantor model	0	1	0	0	0	0	1	0	0	**2**	2	**2**
Chevreul model	1	1	0	1	1	0	1	1	0	**6**	2	**2**
CEPAC-US model	1	1	1	1	1	1	1	1	0	**8**	2	**2**
ModelHeath: Tobacco	1	1	0	1	1	1	1	1	0	**7**	2	**2**
Parrott model	0	1	0	1	0	1	1	0	0	**4**	2	**2**
PHIM	1	0	0	1	1	1	1	1	0	**6**	2	**2**
Tobacco Town ABM	1	1	1	0	0	1	1	0	0	**5**	2	**2**
UKHF simulation	1	1	0	1	1	1	1	0	0	**6**	2	**2**
CDM	1	1	0	1	0	1	1	0	1	**6**	1	**7**
CHD Policy model	1	1	0	1	0	0	1	0	0	**4**	1	**2**
LCPM	1	1	1	1	0	1	1	1	0	**7**	1	**2**
Mendez model	1	0	0	0	0	1	1	1	0	**4**	1	**5**
Mejia model	1	1	0	0	0	1	1	0	0	**4**	1	**2**
Number of models (%)	**21 (84%)**	**20 (80%)**	**6 (24%)**	**17 (68%)**	**11(44%)**	**19 (76%)**	**25 (100%)**	**13 (52%)**	**4 (16%)**			

* Search period between July 2013 to August 2019

** Search period before August 2019
BENESCO model: Benefits of Smoking Cessation on Outcomes model
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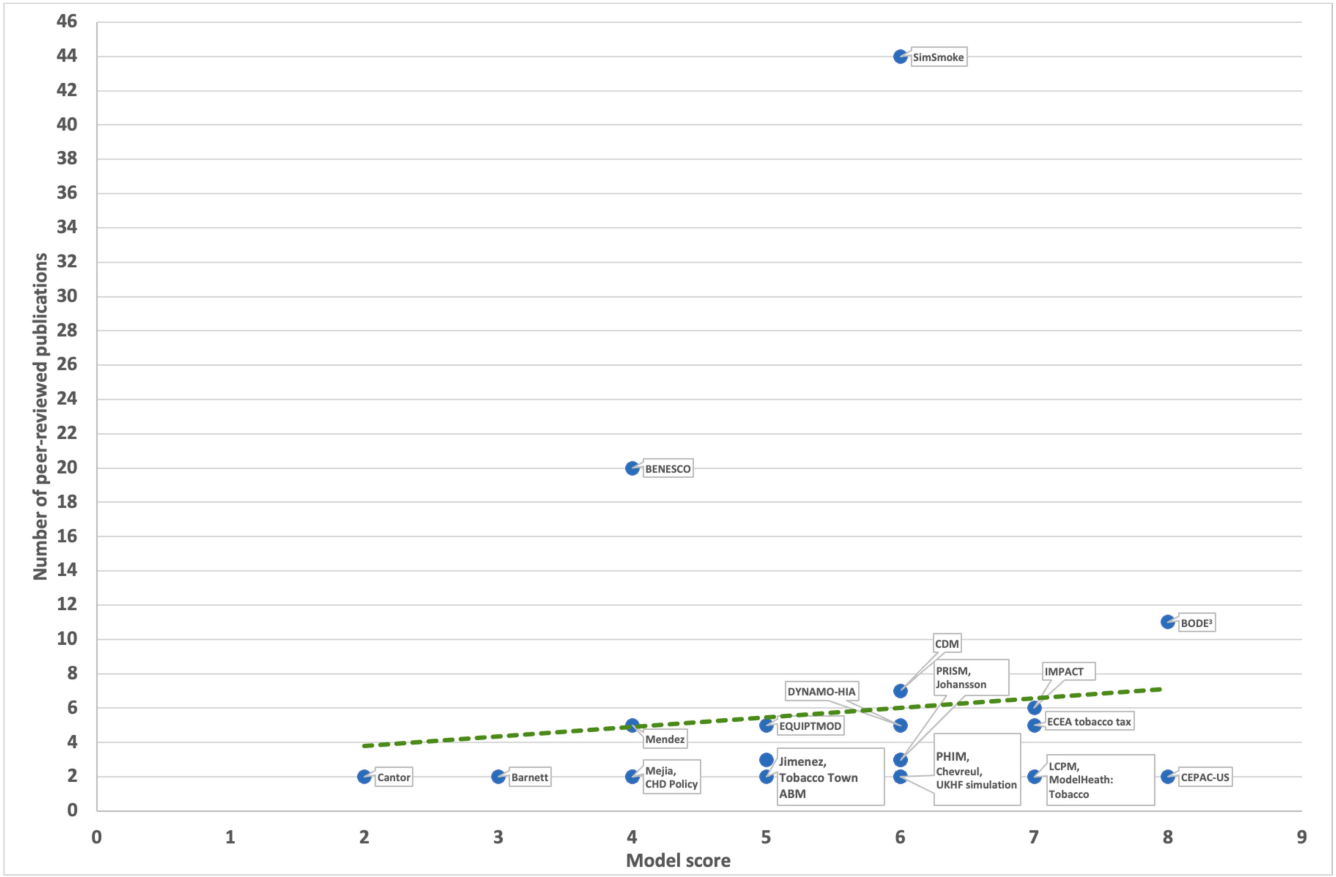
Figure S1. Model score and number of peer-reviewed publications* linked to the model.

The slope remained positive even after removing SimSmoke and BENESCO models



* Search period before August 2019

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