Using System Dynamics modeling to assess the impact of launching e-cigarettes in the US market

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Introduction
In 2012, the FDA suggested using mathematical models as tools for assessing the impact in terms of population health outcome of releasing new nicotine or tobacco products. Since then, several models have been developed using different approaches (1,2,3). These models, although based on distinct underlying methodologies, all of them try to provide simplified representations of the behaviour and mechanisms associated with nicotine use such as, initiation, switching and quitting nicotine use. Projections from models rely on relevant historic data and/or assumptions, which are generally expressed in a comparative manner with hypothesis scenarios.

As response to this guidance, BAT in collaboration with Ventana Systems UK has developed a System Dynamics compartmental model for two nicotine product categories (2). This initial model was built and calibrated using data from the United Kingdom. To better represent the US population, 4 race/ethnicity categories have been included in the model. In addition, there has been a further break down of age categories to increase model resolution and some mechanisms have been simplified. This new model configuration is used to investigate scenarios as result of launching e-cigarettes in the US. In this poster we focus on the models assessment aspects. We compared our projections to official population projections and projections from other published model in an attempt to ‘validate’ the outcomes from our model.

 Aim
The aim of this work was to further develop a compartmental population impact model based on System Dynamics methodology and assess its applicability to real life data. Approaches for ‘validating’ the outcomes of these type of models are also assessed.

Methods

System Dynamics

Different smoking statuses are represented by stocks (compartment) and arrows represent the flows (Figure 1). It allows representation of complex non-linear mechanisms, including feedback effects, by simply calculating inflows and outflows based on integration of flows in relation to time.

Model Structure

The model is initiated with data from the year 2000 and it is not a cohort model, it aims to represent the whole of the population, including births, deaths and migration rates. All possible transitions for a two-nicotine product model are considered with differentiation between current/former and dual NGP users with smoking history and without. The reason of separating stocks with different mechanisms is not only because those categories are likely to have different relative risks but it is also necessary to investigate initiation from never and former smokers.

Underlying Model Assumptions

The model is built on two different types of assumptions: 1. conceptual and structural assumptions form part of the core model and do not change with implementation. These assumptions relate to the methodological limitations in the modeling approach to represent real world complexity so simple assumptions for some mechanisms are introduced. In this category of assumptions we also include those beliefs that are widely accepted by the scientific community, for example, disease relative risks (RRs) for smokers and never smokers are not different before the age of 20 years old. Type 1. assumptions are displayed in Table 1. 2. the second type of assumptions are directly related to data availability (or lack of it) for a specific implementation (Table 3).

Table 1. Model conceptual and structural assumptions.

Main Assumptions

Relative risks under 20 years of age are assumed to be zero.
People relinquishing to smoking will have the same risk of any other smokers of that age category (there is no benefit from quitting smoking for short term health effects).
Nicotine usage initiation rates start to be applied from the age of 18 and before that age is considered risk.

US population, e-cigarettes and comparative number of deaths and life-years saved as health outcome of interest

We investigated the potential benefit of launching e-cigarettes by comparing scenarios with different switching rates from smoking to sole e-cigarette use.

Data inputs

The model was initialised at year 2000 with US demographic data including smoking prevalence by gender, age and race/ethnicity categories as well as birth and death rates by age and gender. The available data provided a calibration period of 13 years up to 2012 and with a time step of a year. Data sources are listed in Table 2.

Mortality relative risks between smokers and never smokers were extracted from a report of the surgeon general (Figure 2). These estimates were provided by age and gender but race specific estimates were not available. RRs for former smokers were calculated based on the negative exponential curve previously published. Similarly, smoking initiation rates were not readily available by race category (Figure 3). Data sources for smoking related data inputs in US population.

Table 2. Data sources for smoking related data inputs in US population.

SD model projections are systematically lower than Vugrin model (2), however when assessed comparatively vs. Status Quo i.e., lives saved, both seem to reach comparable conclusions. Reinforcing this observation, nicotine use behaviours suggest to follow similar patterns (Figure 6 Top and Middle). Our results provide evidence on the SD model sensitivity to the relative risk parameter (Figure 6 Bottom).

Table 3. Assumptions for scenario A.

Conclusions

Lack of data and differences on the definitions among data sources and data collection methodologies provided inconsistent inputs which made necessary the introduction of assumptions and calculation of some parameters through model calibration. Comparative scenarios with respect to other published data and projections from other models suggest that our SD model yields sensible outputs which could provide valuable information to assess nicotine products in terms of population health outcomes.

Figure 5. US population projection Status Quo scenario up to 2100 vs. Census projection (Left) and Population distribution by age and gender from Status Quo scenario vs. US Census projections (Right).

(Left) + (Mag) Alternative Scenarios

To facilitate cross-model comparisons we used the values published by Vugrin et al. (2) for our main alternative scenario, referred as Scenario A (Table 3) and then we changed the RR for a cigarettes to 0.55 with respect to never smokers (Scenario B).

Figure 6. Smoking and E-cigarette prevalence from SD model Scenario A (Top) and Vugrin model (Middle). Below are cumulative deaths with respect of Status Quo scenario and Scenarios A and B from SD model.