Population Structure Modeling to Evaluate Substitution and Dual Use of Tobacco Products in Response to Changing Policies

Eric D. Vugrin, Stephen J. Verzi, Nancy S. Brodsky, Leland B. Evans
Sandia National Laboratories

Joint Statistical Meetings 2013
Montréal, Québec, Canada
August 3 – 8, 2013

This work was funded by the U.S. Food and Drug Administration through a contract with the U.S. Department of Energy/Sandia National Laboratories (funding document 224109011).

The information in this presentation is not a formal dissemination of information by the FDA and does not represent agency position or policy. The contents are the responsibility of the authors alone.
A Changing Landscape

New products and policies have potential to affect tobacco use and public health
Tobacco Population Models

• Tobacco control objectives
  - Decrease smoking and cigarette-related health risks
  - Decrease tobacco-related health risks

• Several models for smoking policy evaluation
  - E.g., Levy [SimSmoke], Mendez & Warner, Homer et al. [PRISM]
  - Models have single product (cigarettes) focus

• Limited modeling capabilities for other tobacco products
  - Existing smoking models cannot represent switching between tobacco products, dual use, & other behaviors
  - May not be able to completely capture impacts of new products and policies

New multi-product models are needed to assess population health impacts of a changing landscape
Model Objectives

- Include multiple products (e.g., cigarettes, smokeless, e-cigs, etc.)
- Represent product use transitions (e.g., initiation, cessation, switching, etc.)
- Assess tobacco use and population health using:
  - Prevalence
  - Tobacco-attributable deaths (from multiple products) and related metrics
- Represent baseline (status quo) and alternative scenario conditions in a changing marketplace

Sandia is developing a multi-product model to estimate impacts on population health
Conceptual Model

- Markov model of state transition

- State is unique combination of:
  - Age
  - Sex
  - Tobacco product use: never/current/former user status for each product considered
  - Mortality status (alive or dead)

- Transition from one state to another is a stochastic process
  - Probability of transition depends only upon current state

- Some basic assumptions
  - State changes once per year
  - Age increases by 1 annually
  - Current and former cannot transition to never
Key Input Parameters

- Initial population
  - Distribution of states at time 0

- Transition probabilities
  - Initiation, cessation, switching, and relapse
  - Depend upon sex, age, and tobacco product use status
  - Need to think about transition in terms of multiple products

- Relative risks (RR)
  - Depend upon state

\[
RR = \frac{\text{prob}(\text{dying} | \text{tobacco product use})}{\text{prob}(\text{dying} | \text{never used tobacco products})}
\]
Product Use Transition: 1 Products

Never → Current → Former

- Initiation
- Cessation
- Relapse

3 product use statuses & 3 product use transitions
Notation: Product use status X/Y should be interpreted as X (never, current or former) denotes use status for product 1 and Y (never, current or former) denotes use status for product 2.
Mathematical Model: 2 product example

\[ \text{prob}_{s_1 \rightarrow s_2} (t_i) = \text{prob}\left( N / C \rightarrow C / F \mid \text{state} = s_1, \ t = t_i \right) \times \left[ 1 - \text{prob}\left( \text{dying} \mid \text{state} = s_2, \ t = t_i \right) \right] \]

\[ s_1 = \{ \text{sex = male, age = 24, use status = N / C, alive} \} \]

\[ s_2 = \{ \text{sex = male, age = 25, use status = C / F, alive} \} \]

State transition probability = probability of changing tobacco-use status
\times probability of not dying
Mathematical Model

Average # of people that transition into state $s_j$

$$Pop_{s_j}(t_{i+1}) = \sum_i prob_{s_i \rightarrow s_j}(t_i) Pop_{s_i}(t_i) + M_{s_j}(t_{i+1}) + B_{s_j}(t_{i+1})$$

Migration rate (from census)

Birth rate (from census)
Example Scenario

• 2 products
  - Cigarettes
  - Novel product: all cause mortality rate is 50% lower than rate for cigarettes

• Assumptions
  - Novel product has low prevalence (~2 %) prior to 2015
  - Hypothetical scenario: popularity of novel product increases dramatically, causing changes in tobacco usage behaviors
    • 50% of smokers to switch to novel product in 2015
    • 50% of youths “expected” to start smoking instead start using novel product
  - Unintended result: Initiation rate of novel product increases an additional 50%

• Analysis metrics: prevalence and deaths

*Scenario and assumptions are notional to illustrate model utility; the scenario and results are not intended to represent a real scenario or product
Results: Single Product (Cigarettes) Model

By 2050, model estimates 30k fewer deaths/year.

Increase in novel product popularity appears to decrease deaths.
Results: Multi-Product (Cigarettes & Novel Product) Model

Failure of 1-product model to represent switching and novel product initiation results in overestimation of benefits to population health.
Summary and Challenges

- Evolving tobacco product marketplace requires new models for evaluating population health impact
  - Multiple products
  - Capture unintended consequences

- Significant data challenges for multiple products

- What can be done
  - Gather more data
  - Mathematical techniques (e.g., parameter fitting and model calibration)
  - Characterize model sensitivity and uncertainty, i.e., identify “what matters” and “how much does it matter”