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

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# A Changing Landscape


electronic cigarettes

traditional cigarettes


dissolvable tobacco


ban of flavored cigarettes


graphic warning labels

**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

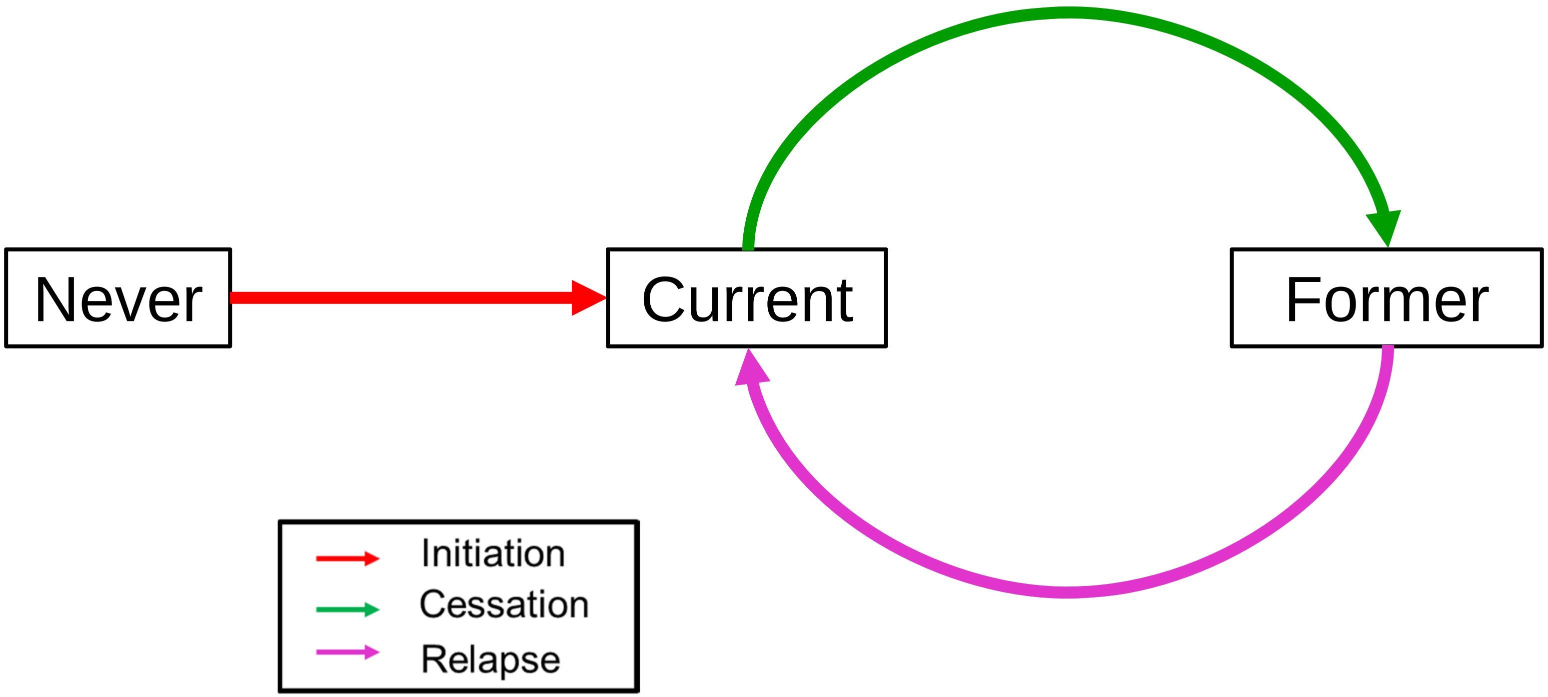
- Markov model of state transition
- State is unique combination of:
  - Age
  - Sex
  - Tobacco product use: never/current/former user status for each product considered
  - Mortality status (alive or dead)
- Transition from one state to another is a stochastic process
  - Probability of transition 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

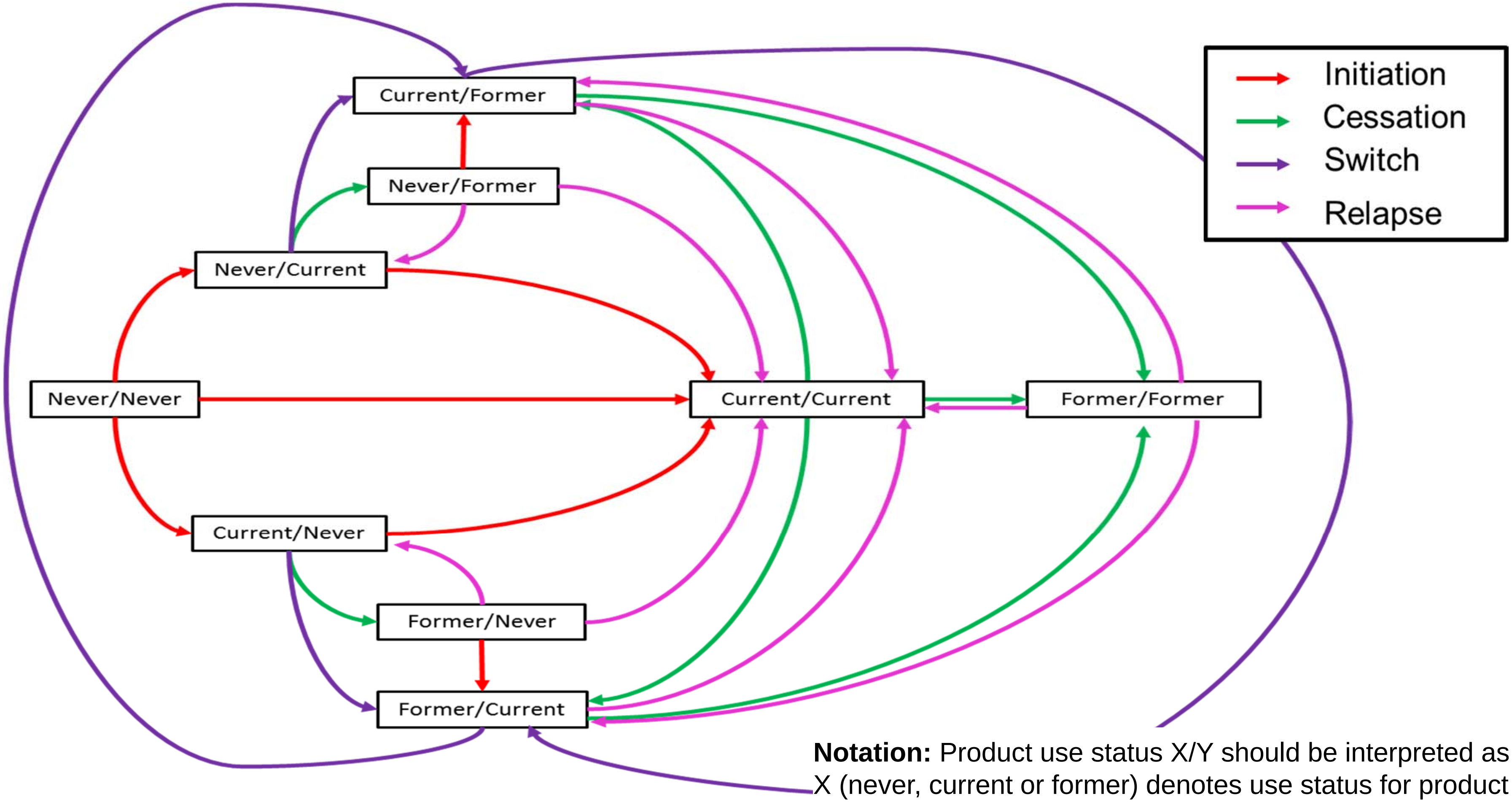
$$RR = \frac{prob\left(dying \mid tobacco\ product\ use\right)}{prob\left(dying \mid never\ used\ tobacco\ products\right)}$$

# Product Use Transition: 1 Products




**3 product use statuses & 3 product use transitions**

# Product Use Transition: 2 Products




**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

**9 product-use statuses & 27 product use transitions**

# Mathematical Model: 2 product example

$$prob_{s_1 \to s_2}(t_i) = prob\left(N/C \to C/F \,\middle|\, state = s_1,\ t = t_i\right) \times \left[1 - prob\left(dying \,\middle|\, state = s_2,\ t = t_i\right)\right]$$

$$s_1 = \{sex = male,\ age = 24,\ use\ status = N/C,\ alive\}$$
$$s_2 = \{sex = male,\ age = 25,\ use\ status = C/F,\ alive\}$$

**State transition probability = probability of changing tobacco-use status x probability of not dying**

# Mathematical Model

Average # of people that
transition into state $s_j$

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

$$+M_{s_j}(t_{i+1})$$

Migration rate
(from census)

$$+B_{s_j}(t_{i+1})$$

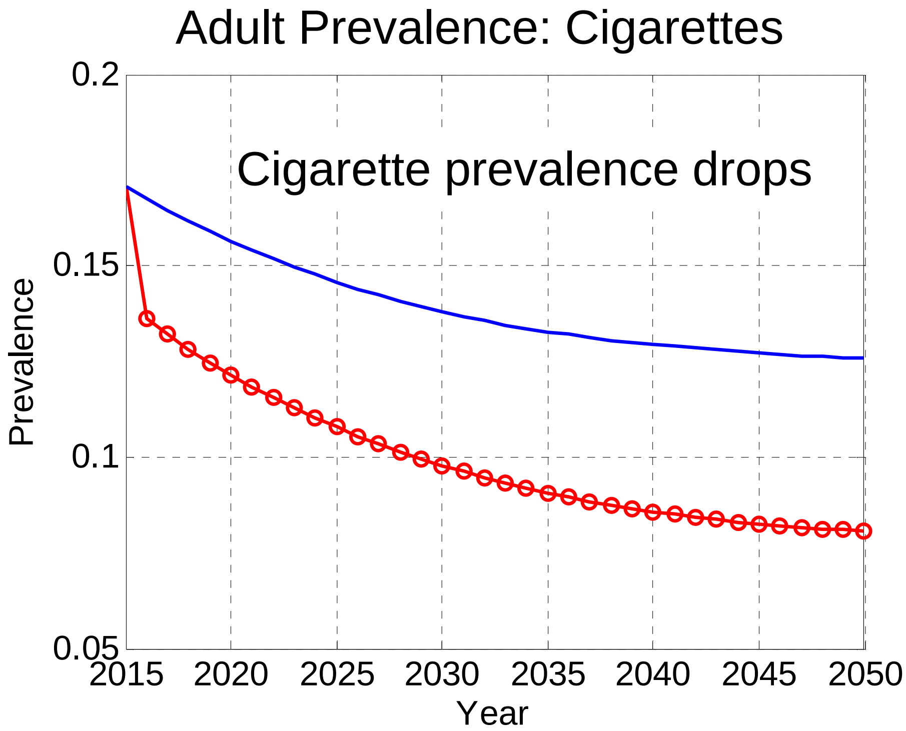
Birth rate
(from census)

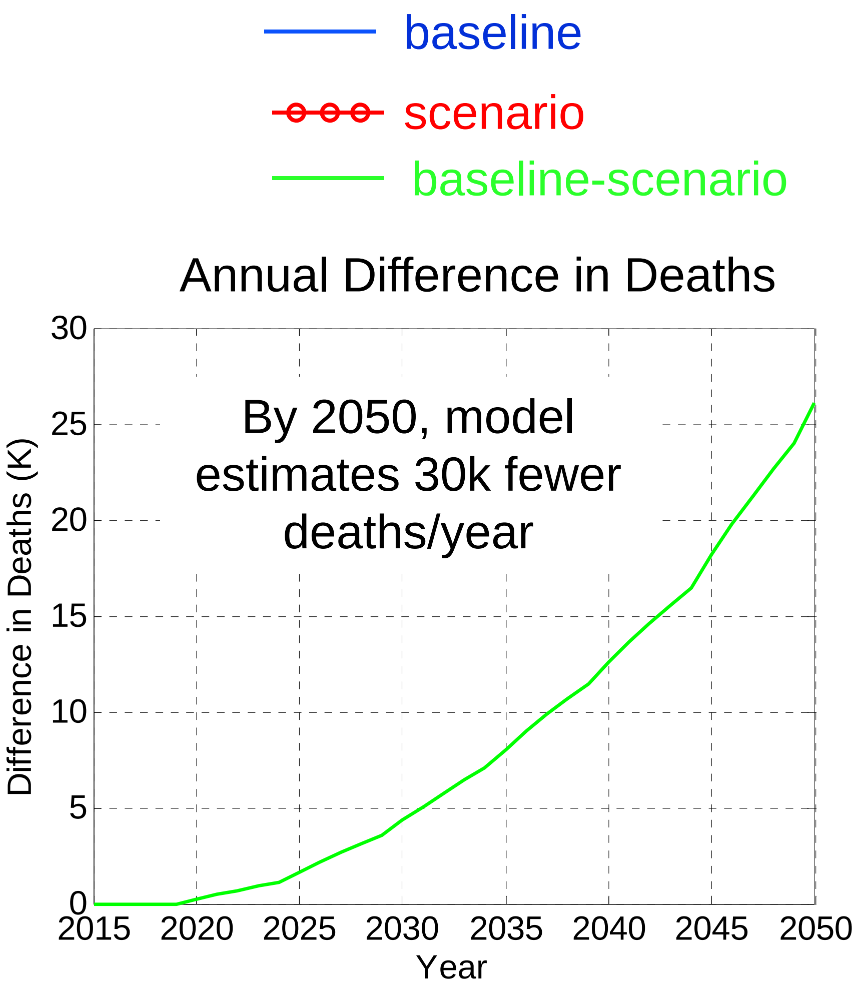
# Example Scenario

- 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

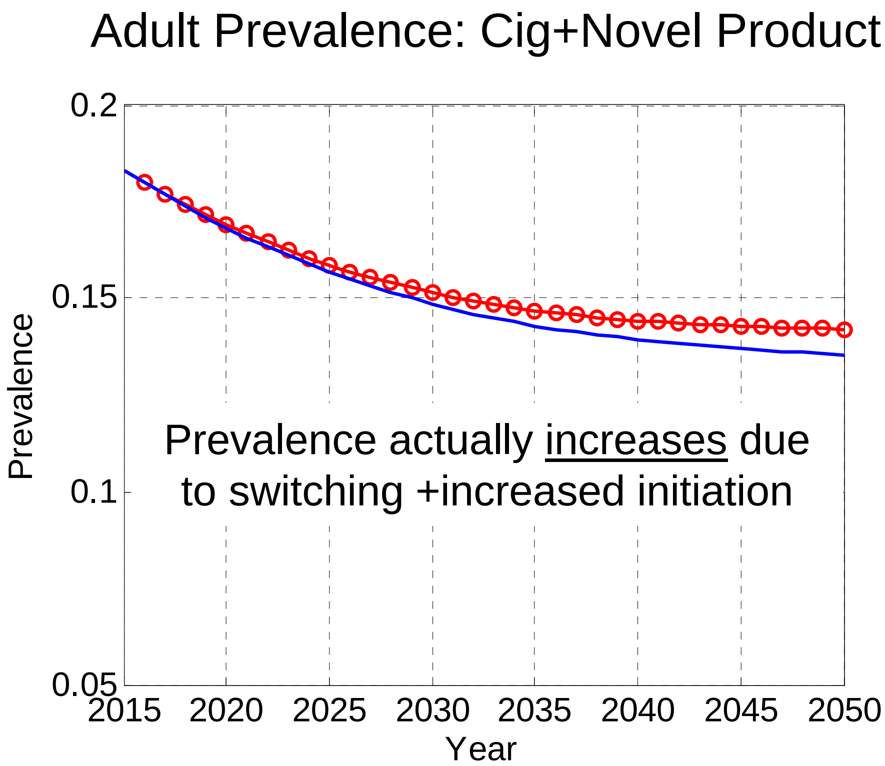
# Results: Single Product (Cigarettes) Model

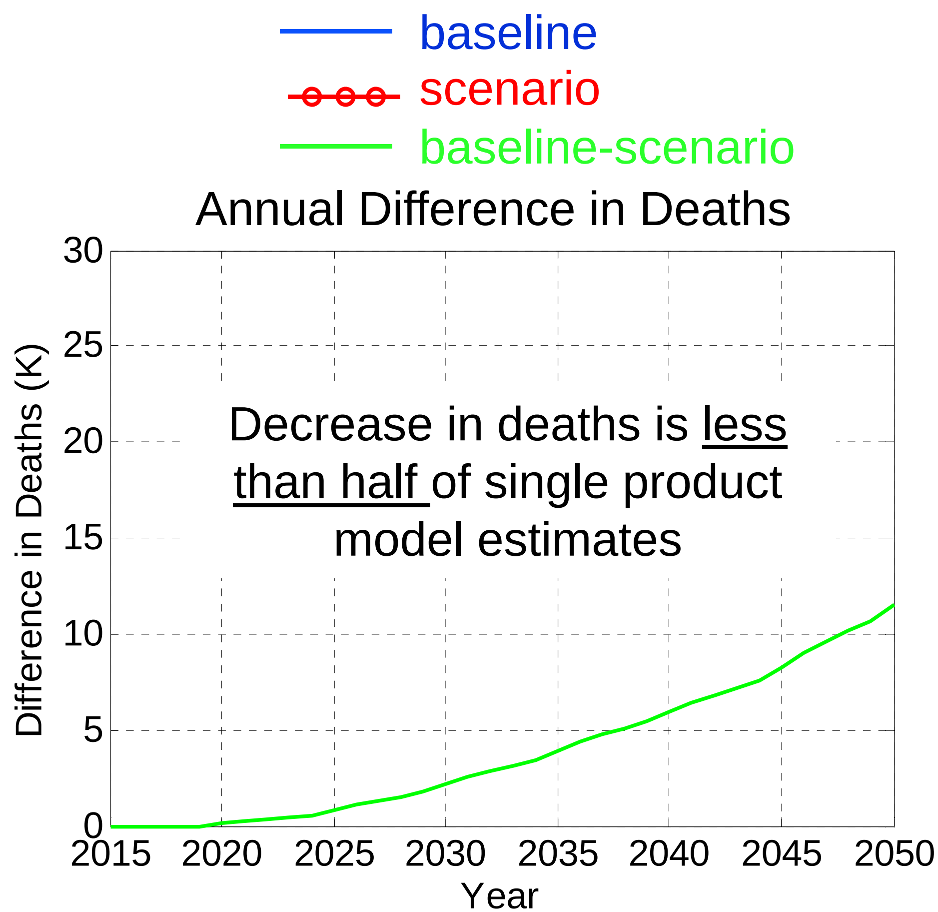



**Increase in novel product popularity appears to decrease deaths**

# 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"