Tobacco-Control Regulatory Policy Modeling and Analysis

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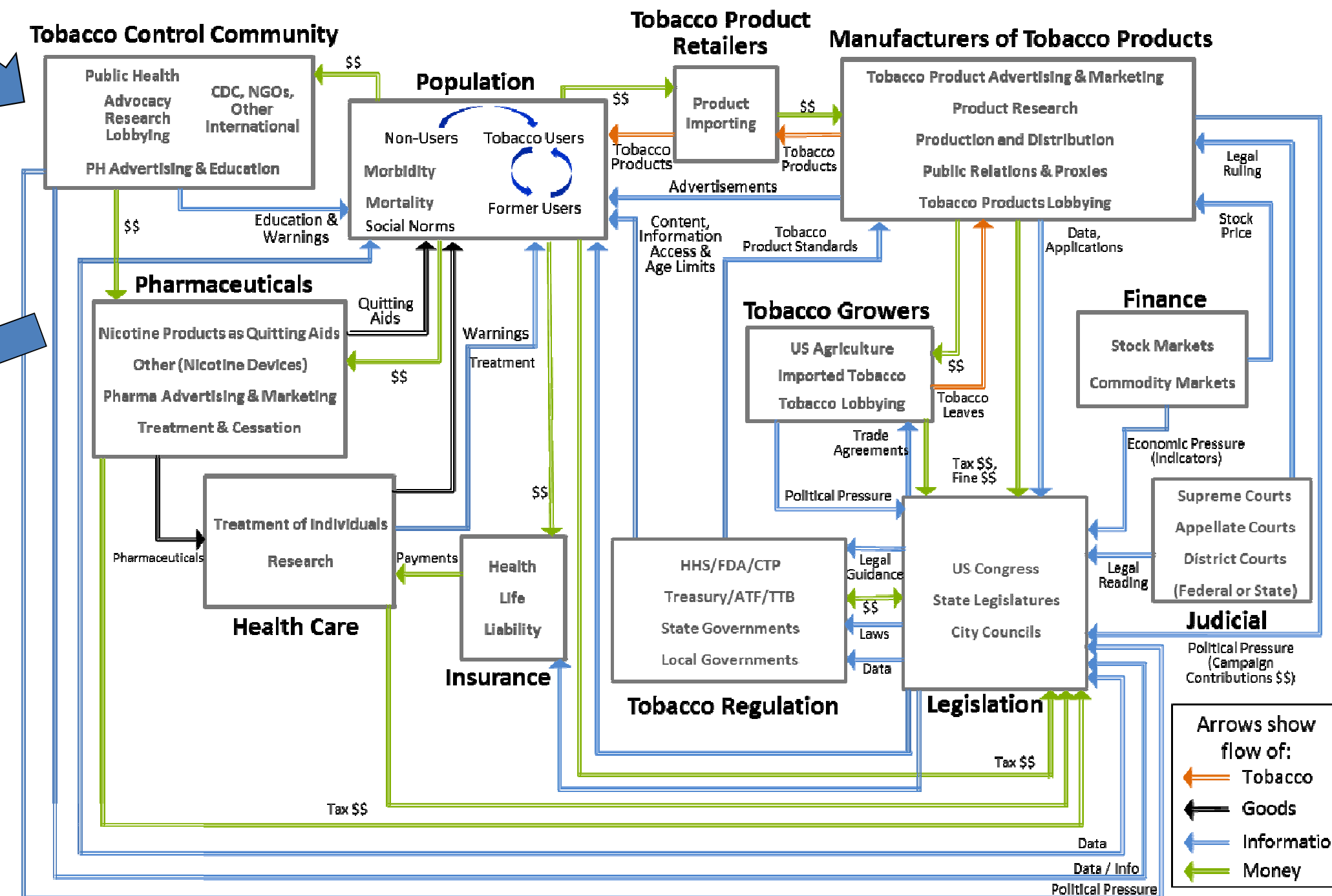
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Background:

Tobacco prematurely kills over 400,000 Americans each year and disables many at an annual cost of over $193 Billion. The Family Smoking Prevention and Tobacco Control Act (FSPTCA), signed into law by President Barack Obama on June 22, 2009:

- Recognizes the FDA as the "primary Federal regulatory authority with respect to the manufacture, marketing, and distribution of tobacco products…"
- FSPTCA authorizes the FDA to:
  - Require disclosure of tobacco product ingredients
  - Require stronger health warnings on packaging and in advertisements
  - Create standards for tobacco products
  - Restrict tobacco sales, distribution, and marketing
- Mandates regulatory decisions be based on the protection of public health, which "shall be determined with respect to the risks and benefits to the population as a whole, including users and nonusers of the tobacco product…"

Family Smoking Prevention and Tobacco Control Act

Our Role: Sandia National Laboratories supports FDA regulators through modeling and analysis of potential effects of tobacco use and related health policies on future population health

Opinion-Driven Behavioral Dynamics

Family/Friends
Products
Information
Individual Opinion
Opinion Dynamics

Barriers to Access
Costs
Addiction
Risk Affinity

Individual Tobacco Use Behavior

Opinion-to-Behavior Mapping

Social Network Modeling:
Captures many components of policy options, and models how these affect movement of opinions, attitudes, behaviors, social norms along social networks. Leverages disease contagion work.

Simplified Conceptual Diagram:
Model leverages opinion dynamics approaches to model movement of opinions, attitudes, views within social network. Apply simplified opinion-to-behavior mapping.

Opinion Dynamics: Approach for analysis of social influences on individual opinions, emergence of community-scale patterns

$$x_i(t+1) = x_i(t) + \frac{1}{k}\sum_{N_i}\mu_{ik}[x_k(t)-x_i(t)]$$

$$N_i \in S_i : |x_k(t)-x_i(t)| \le \varepsilon_i$$

S_i Set of out degree neighbors
ε_i Tolerance (Do you influence me?)
μ Plasticity (How much you influence me)
x Opinion (My integrated view)
$N_i(t)$ Subset of S_i within tolerance bounds at time t
k number of neighbors within tolerance bounds

Update Rule: Adjust individual agent's opinion by mean scaled opinion differences of opinion and neighbors' opinions within tolerance limits
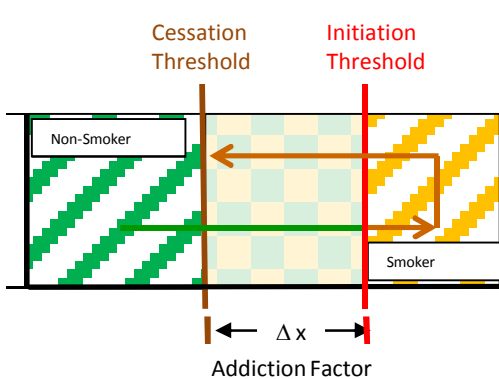
Examples: Applying to Policy

Increase education / counter-marketing efforts: Connect people to educational information, disconnect them from advertising (S_i: connections and connections of connections.)

Sow doubt – skepticism towards advertising/education: Modify tolerance and plasticity

Rotation of warnings on tobacco products: Time-dependent decay of plasticity (decay of influence), resurgence of plasticity with new advertisement.

$\mu_{il} = .1$
$x = 3$
$\mu_{ij} = .1$
$x = 4$, $\varepsilon = 0.3$
$x = 8$
$\mu_{ij} = .1$
$x = 7$

Opinion-to-Behavior Mapping

Cessation Threshold
Initiation Threshold
Non-Smoker
Smoker
Δx
Addiction Factor

Examples: Applying to Policy

Barriers to access (costs, restrict sales, clean air laws): Change initiation threshold

Facilitate cessation (NRTs, quitlines, …): Increase cessation threshold reduce addiction to tobacco products in individuals, addictive ingredients

Different nicotine content: Modify utilitarian component of opinion; modify difference between initiation and cessation thresholds

Alternative / novel products: Modify behavior function by including individual risk affinity, product-specific risk perception.

- Initiate product if: Opinion+(Risk Affinity-Risk Perception)> Initiation threshold
- Quit product if: Opinion + (Risk Affinity-Risk Perception)< Cessation threshold

Example Results

Example Result:
Effects of Introducing an Educational Message on a Social Network

Starting condition
Equilibrium with No Interventions
Educational Intervention Initiated
Following Educational Intervention

Baseline: Networks with No messaging
Networks with Public Health messaging
Networks with Public Health and Pro-Smoking messaging

Example Result:
Effects of Education and Advertising with Decreasing Addiction

Example Result:
Introduction of an Alternative Product

Cigarettes
Lower Perceived Risk Product

Tobacco System Entities, Relationships and Flows

Tobacco Control Community
Public Health Advocacy Research Lobbying
CDC, NGOs, Other International
PH Advertising & Education

Population
Non-Users
Tobacco Users
Former Users
Morbidity
Mortality
Social Norms

Education & Warnings

Tobacco Product Retailers
Product Importing

Manufacturers of Tobacco Products
Product Research
Production and Distribution
Public Relations & Proxies
Tobacco Products Lobbying

Tobacco Products
Advertisements
Content, Information Access & Age Limits
Tobacco Product Standards

Pharmaceuticals
Nicotine Products as Quitting Aids
Other (Nicotine Devices)
Pharma Advertising & Marketing
Treatment & Cessation

Quitting Aids

Warnings
Treatment

Tobacco Growers
US Agriculture
Imported Tobacco
Tobacco Lobbying

Finance
Stock Markets
Commodity Markets

Legal Ruling
Stock Price
Data, Applications

Economic Pressure (indicators)
Trade Agreements
Political Pressure

Treatment of Individuals
Research

Health Care
Health
Life
Liability

Insurance

Payments

HHS/FDA/CTP
Treasury/ATF/TTB
State Governments
Local Governments

Tobacco Regulation

US Congress
State Legislatures
City Councils

Legislation

Supreme Courts
Appellate Courts
District Courts (Federal or State)

Judicial

Legal Guidance
Legal Reading
Laws
Data

Political Pressure (Campaign Contributions $$)

Tax $$
Data
Data / Info
Political Pressure

Arrows show flow of:
Tobacco
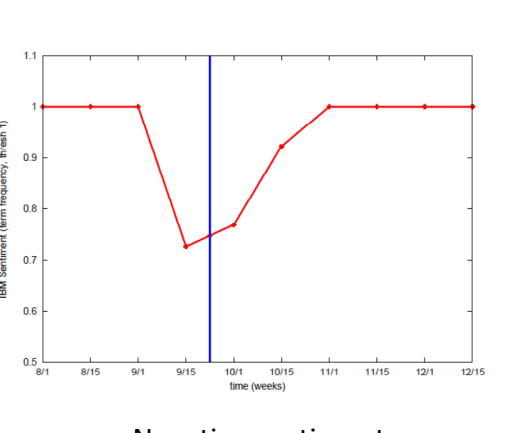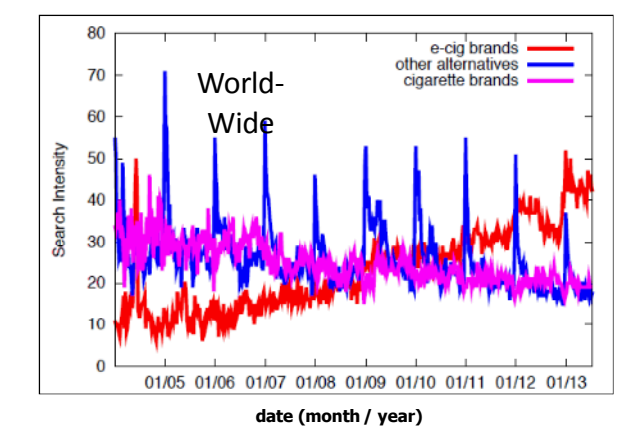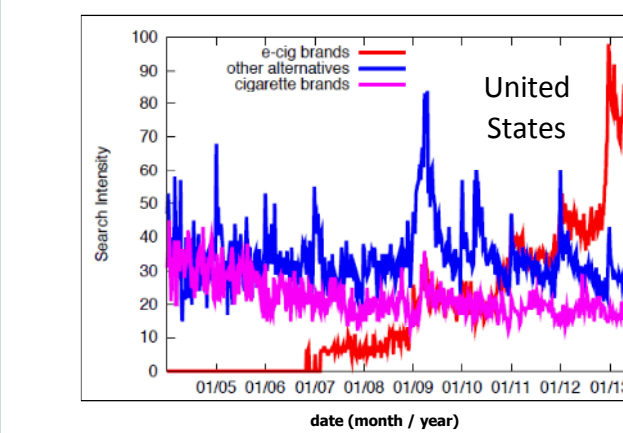Goods
Information
Money

Test and Collect Data

Survey Data
- Data sets available for focused for piece-wise validation
  - Add Health* provides behavior and possible network topology
  - NYTS** shows changes in adolescent opinions but lacks connectivity
- **Modeling requires integrated data set for comprehensive validation. New data sources needed for network topologies, opinion and behavior.**
- Valente et al. 2014*** collected three-year longitudinal data on 1,200 students in five LA High Schools
  - Final year surveys included questions on tobacco opinion from SnapDragon team
  - Preliminary data providing critical information on network topologies, assortativity patterns and opinion-to-behavior mapping

* Add Health: National Adolescent Health Survey
** NYTS: National Youth Tobacco Survey
***From Variations in network boundary and type: A study of adolescent peer influences, Thomas W. Valente et al., [in press: Social Networks, an international journal of structural analysis]. Support for this research was provided by NIH/NCI grant #CA157577-02S1 (Valente, PI)

Example Influence Network (School 3)
Smoking helps calm an angry person
Colors:
Strongly Disagree
Strongly Agree
Shapes: Square -> Smoker
Triangle -> Occasional
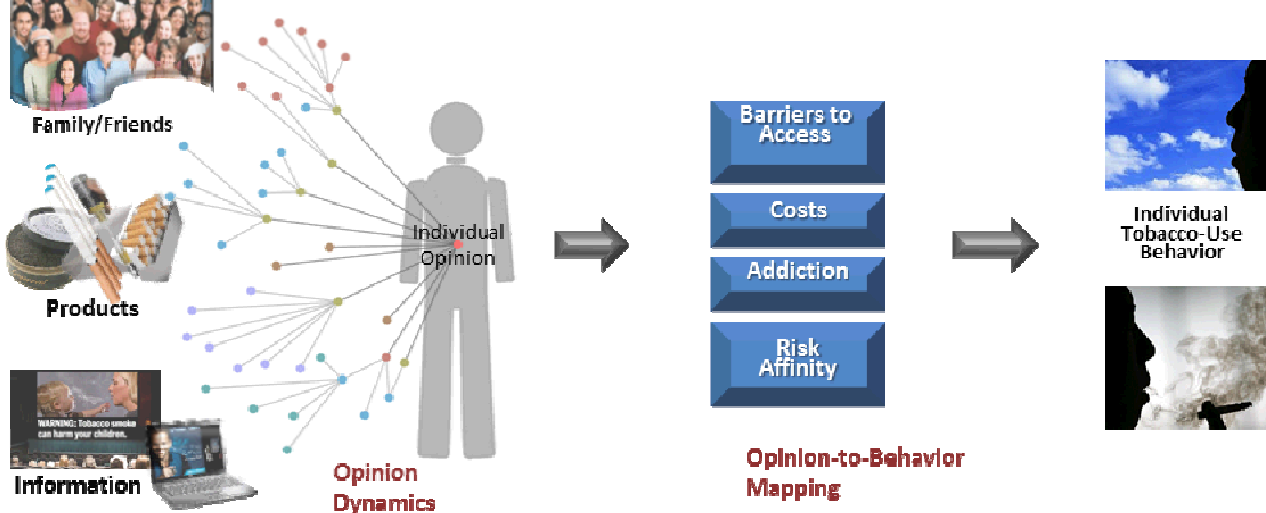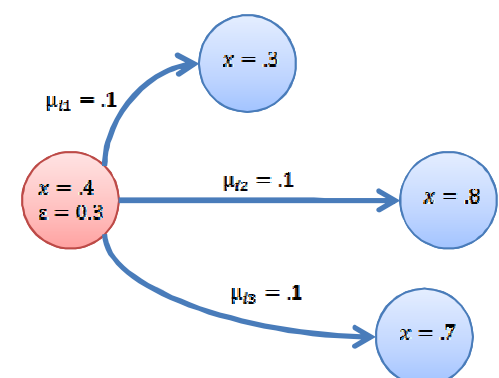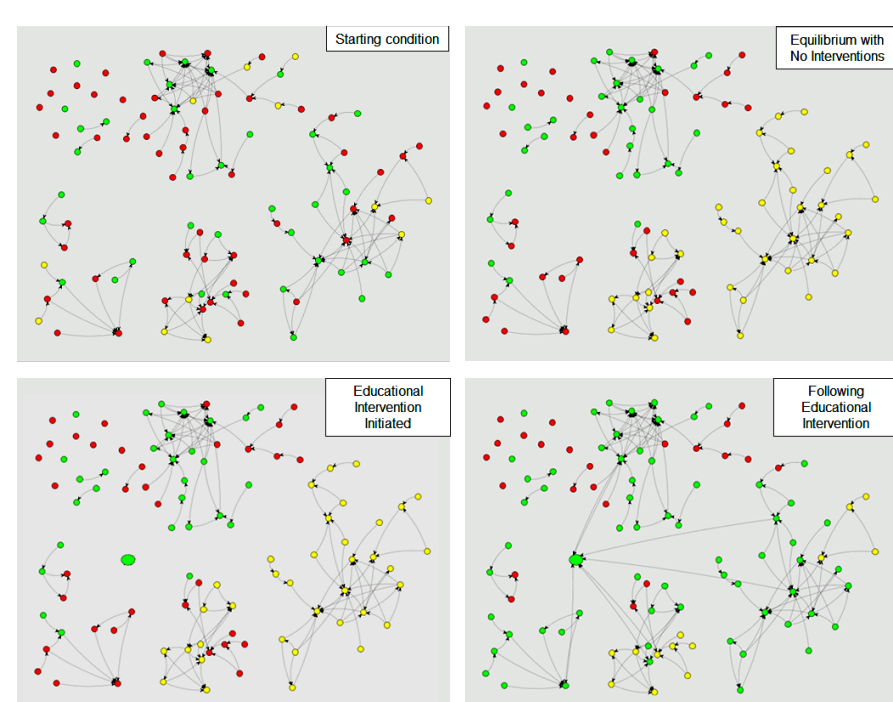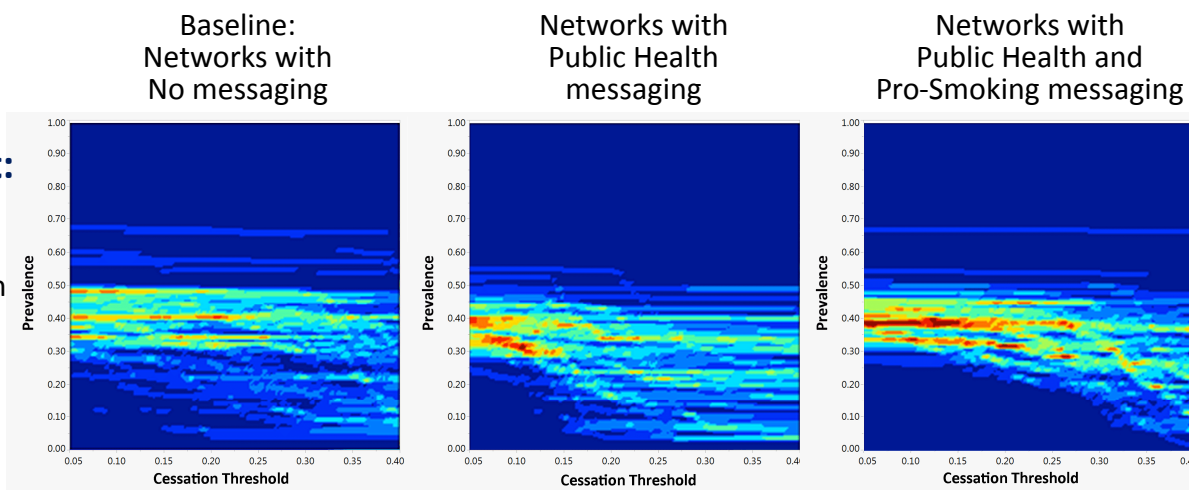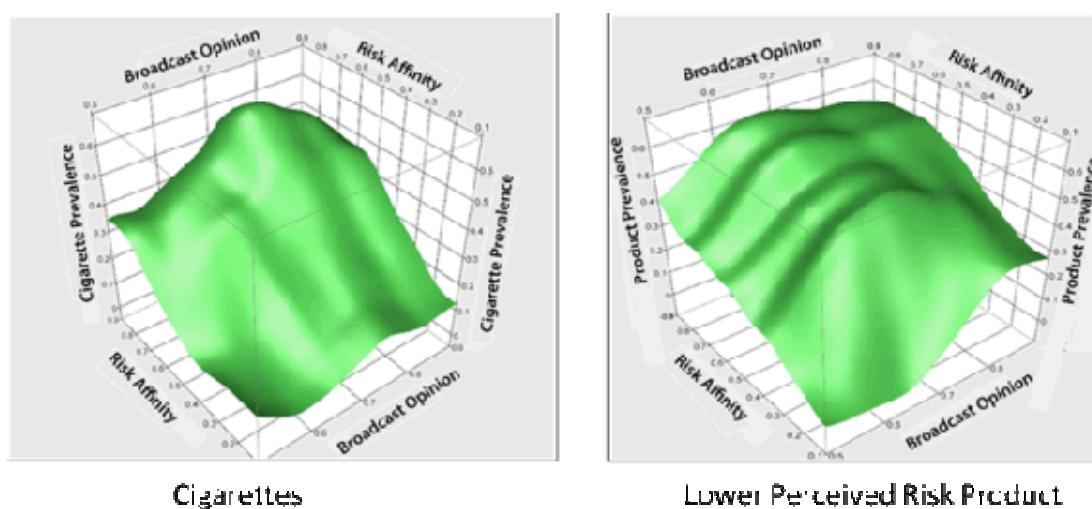Circle -> Nonsmoker

Web Sensor Analysis Data
- Network Structure
- Sentiment / emotion analysis
- Traffic volume
- Communities, sentiment and traffic - Distribution of traffic among communities – Echo chambers or wide distribution of ideas?

United States
World-Wide

Growing interest in electronic cigarettes vs other alternatives
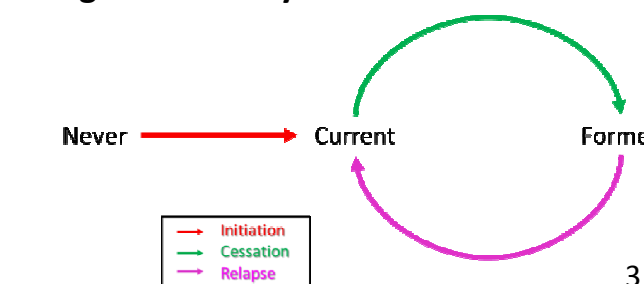(SCHIP tax increase on cigarettes, other tobacco products passed Jan. 2009, signed into law Feb. 2009)

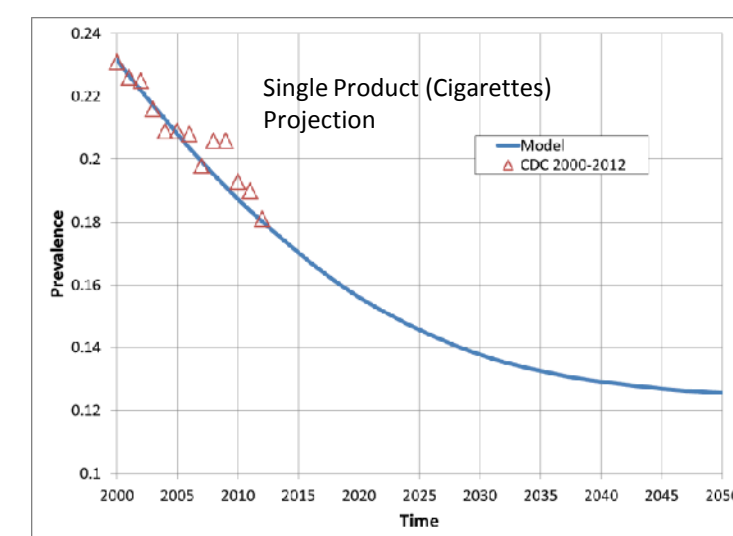Negative sentiment surrounds flavor ban

Dynamic Population Structure Models, Sensitivity and Uncertainty Analysis

How do changes in tobacco use modify US population health in the decades to come?

Single Product System
Never → Current → Former
Initiation
Cessation
Relapse
3 tobacco use states, 3 transitions

Single Product (Cigarettes) Projection
Model
CDC 2000-2012

Comparison with Observed Data: Results consistent with empirical data. Prevalence drops over time due to historical decreases in initiation and increases in cessation.
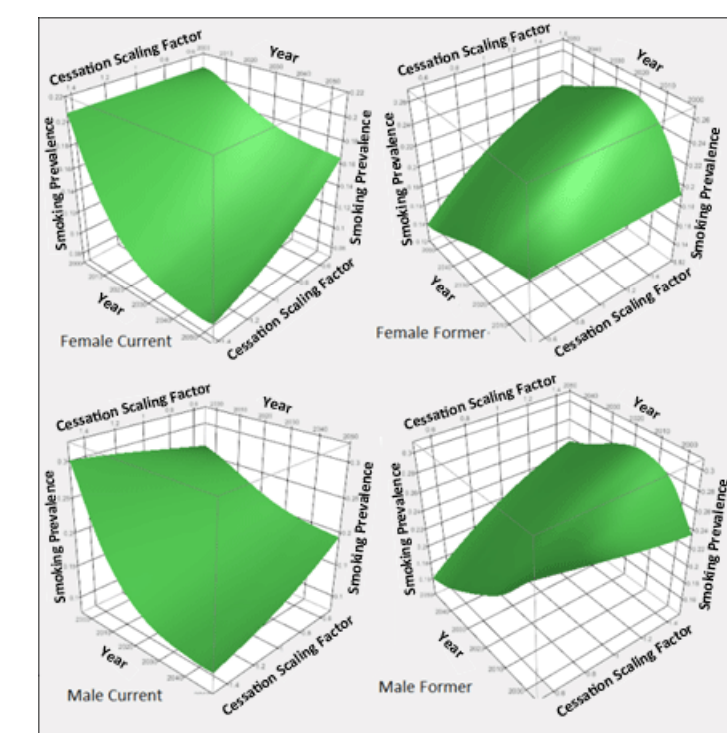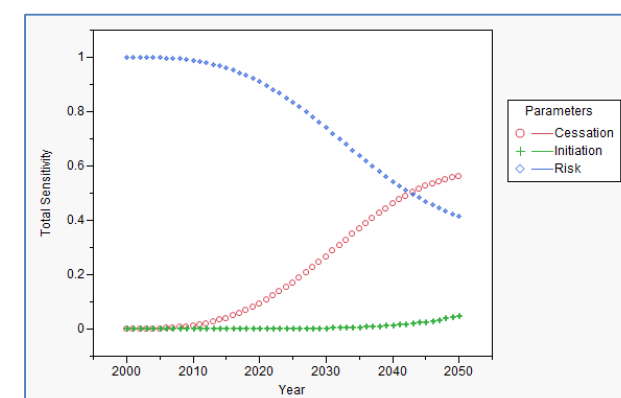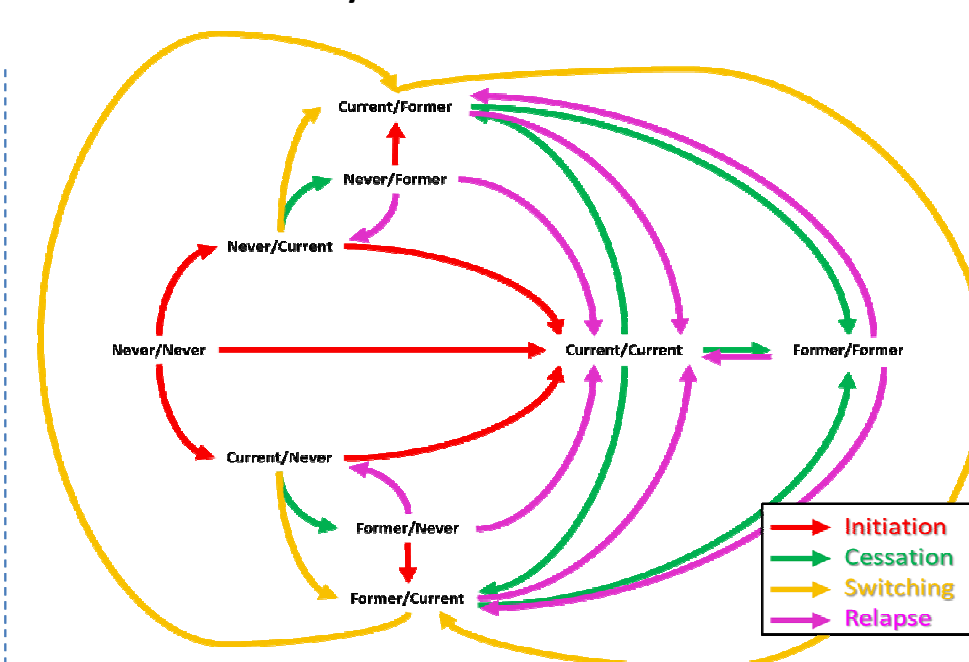
Effect of Varying Cessation Scaling Factor on Smoking Prevalence
Female Current
Female Former
Male Current
Male Former

Sensitivity Analysis
Sensitivity indices show relative contribution of each parameter to calculated attributable death.

Two-Product System
Current/Former
Never/Former
Never/Current
Never/Never
Current/Current
Former/Former
Current/Never
Former/Never
Former/Current

Initiation
Cessation
Switching
Relapse

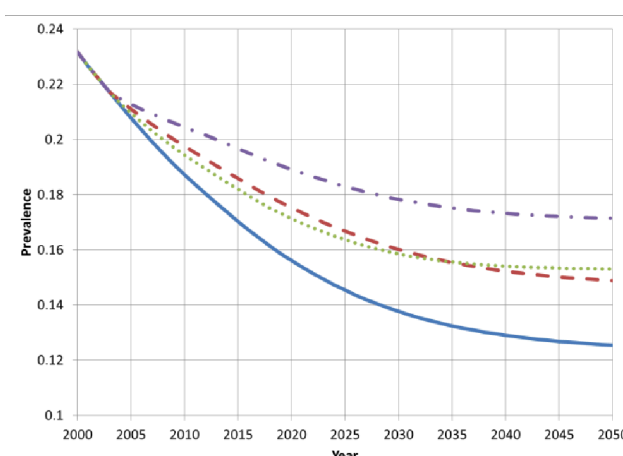9 tobacco use combinations, 27 transitions

Hypothetical 2-product Scenario for Model Illustration
- Initial population designed to represent U.S. 2000 demographics (age, sex, cigarette usage)
- Year 3: introduction of a lower risk, hypothetical new tobacco product
  - Excess relative risk (ERR)=0.25 x cigarette ERR)
- Switching and poly-use
  - Switching (0.03-0.05 annual proportion of current smokers)
  - Poly-use transition (smoking to smoking + new product; 0.005 annually)
- Alternative product initiation
  - Non-smokers may take up alternative (0.25x smoking initiation rate)
  - Alternative users may switch to cigarettes or become poly-users (0.05 annual rate)
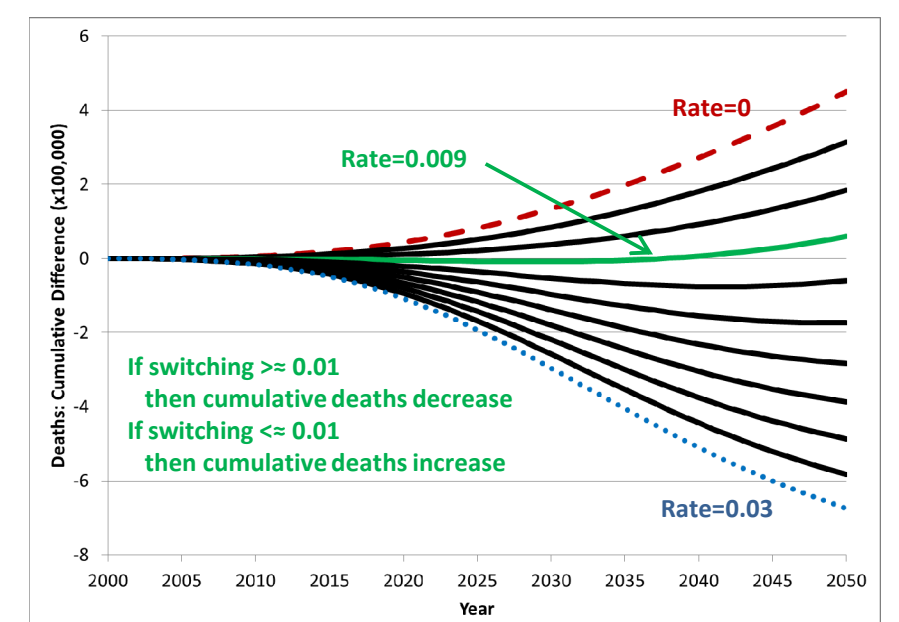
Illustrative Hypothetical Scenario Results
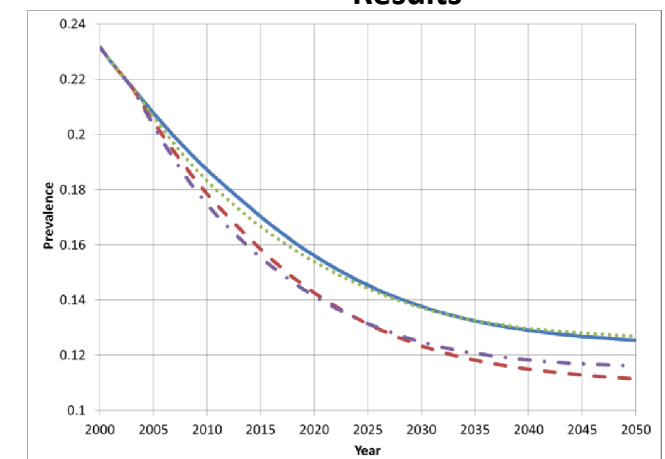
Effect of hypothetical scenario on adult smoking prevalence

Effect of hypothetical scenario on adult two-product prevalence

Rate=0
Rate=0.009
Rate=0.03
If switching >= 0.01 then cumulative deaths decrease
If switching <= 0.01 then cumulative deaths increase

Cumulative Difference in Deaths relative to baseline for Ages 35-84 for Range of Cigarette-to-New Product Annual Switching Rates

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U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration