Computational Models in Tobacco Control

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Acknowledgment

Many thanks to **Dr. David Levy**, from Georgetown University for providing slides about the SimSmoke model,

and to **Dr. Rafael Meza**, from the University of Michigan for providing the slides about the CISNET models.

Why Model?

- To fully understand the problem
  - Models provide a coherent framework to analyze a situation and integrate different data sets
- To monitor and forecast
- To evaluate the consequences of policies
- To guide data collection

Example of questions that models can help to address

- If current conditions continue, what is the likely trajectory of smoking prevalence?

- If we fully implement all the tobacco control measures known to be effective, what is the likely trajectory of the smoking prevalence?

Example of questions that models can help to address

- What would be the population health impact of removing menthol cigarettes from the market?

- What would be the consequences of increasing the minimum purchasing age for tobacco products?

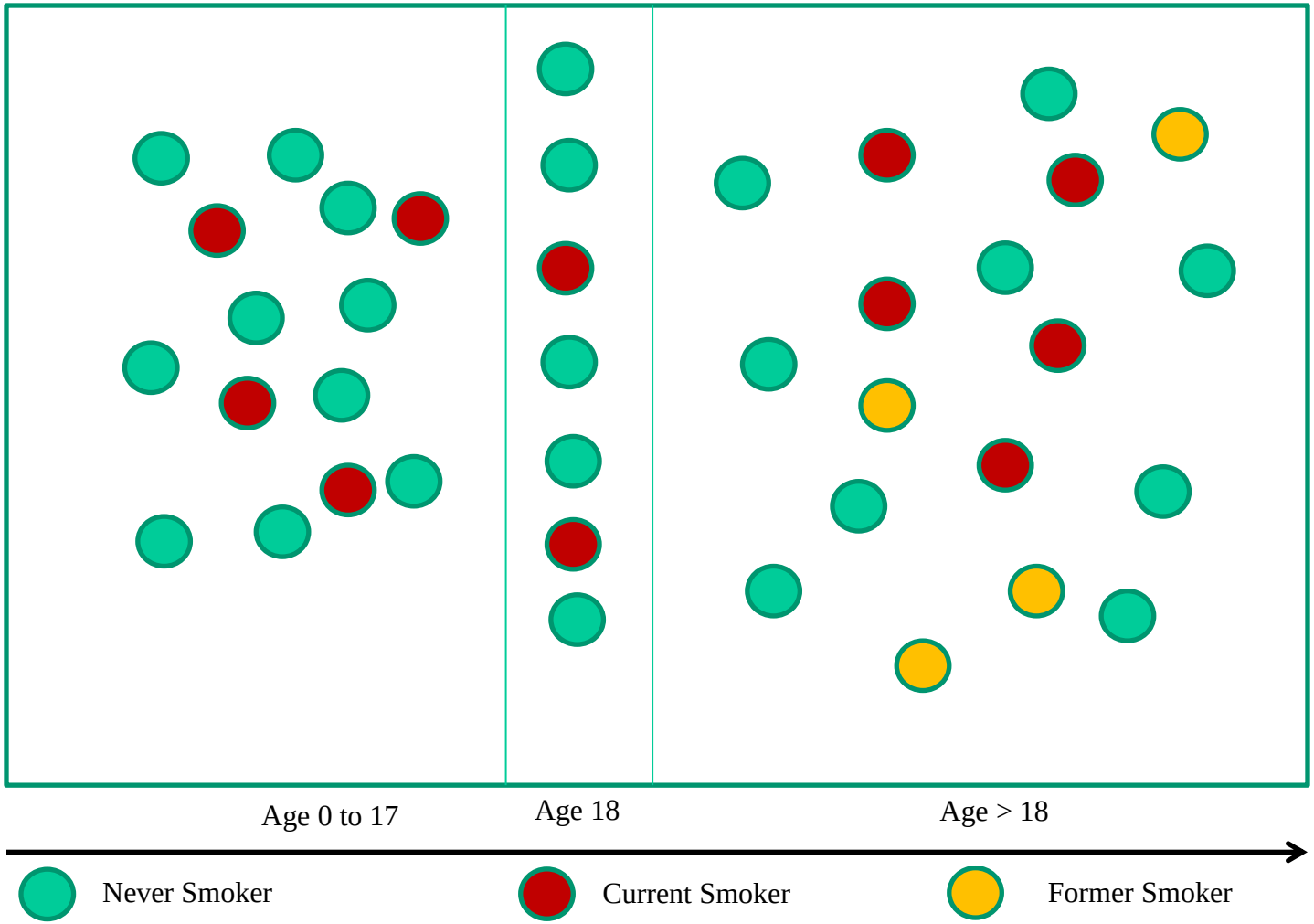
Example of questions that models can help to address

- What would be the impact of reducing nicotine in combustible tobacco products to non-addictive levels?

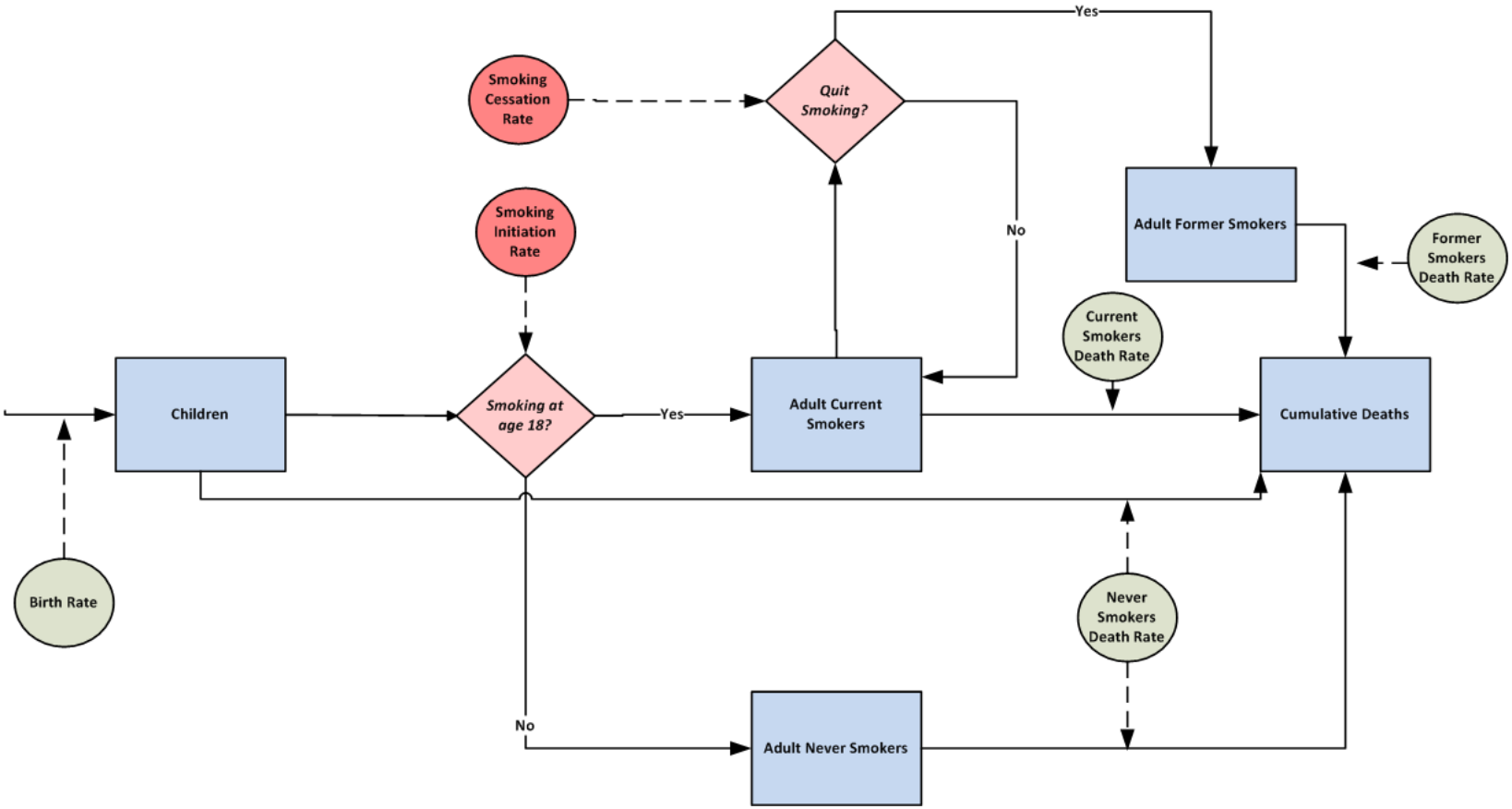
- What is the estimated impact of tobacco control policies on avoided mortality?

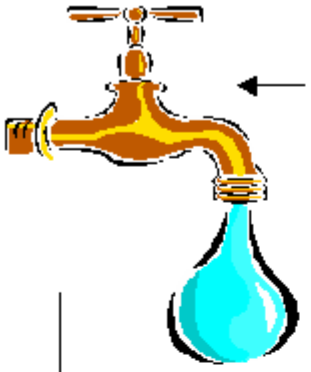
Michigan Model of Smoking Prevalence and Health Effects

Smokers in the Population



Basic Aggregate Model





SMOKING INITIATION

Prob(Initiation)

SMOKING PREVALENCE

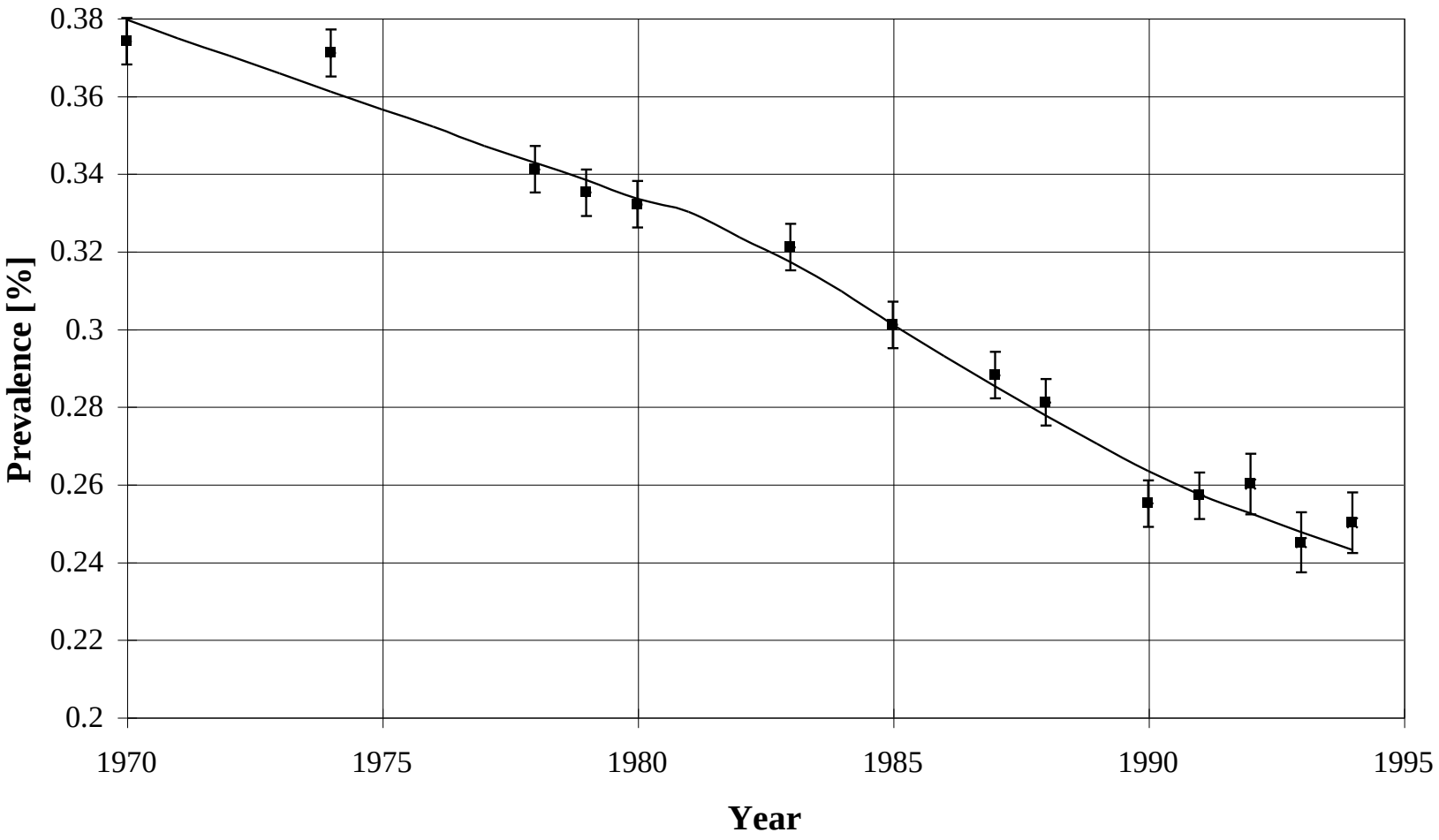
Prob(Cessation)

SMOKING CESSATION + DEATHS

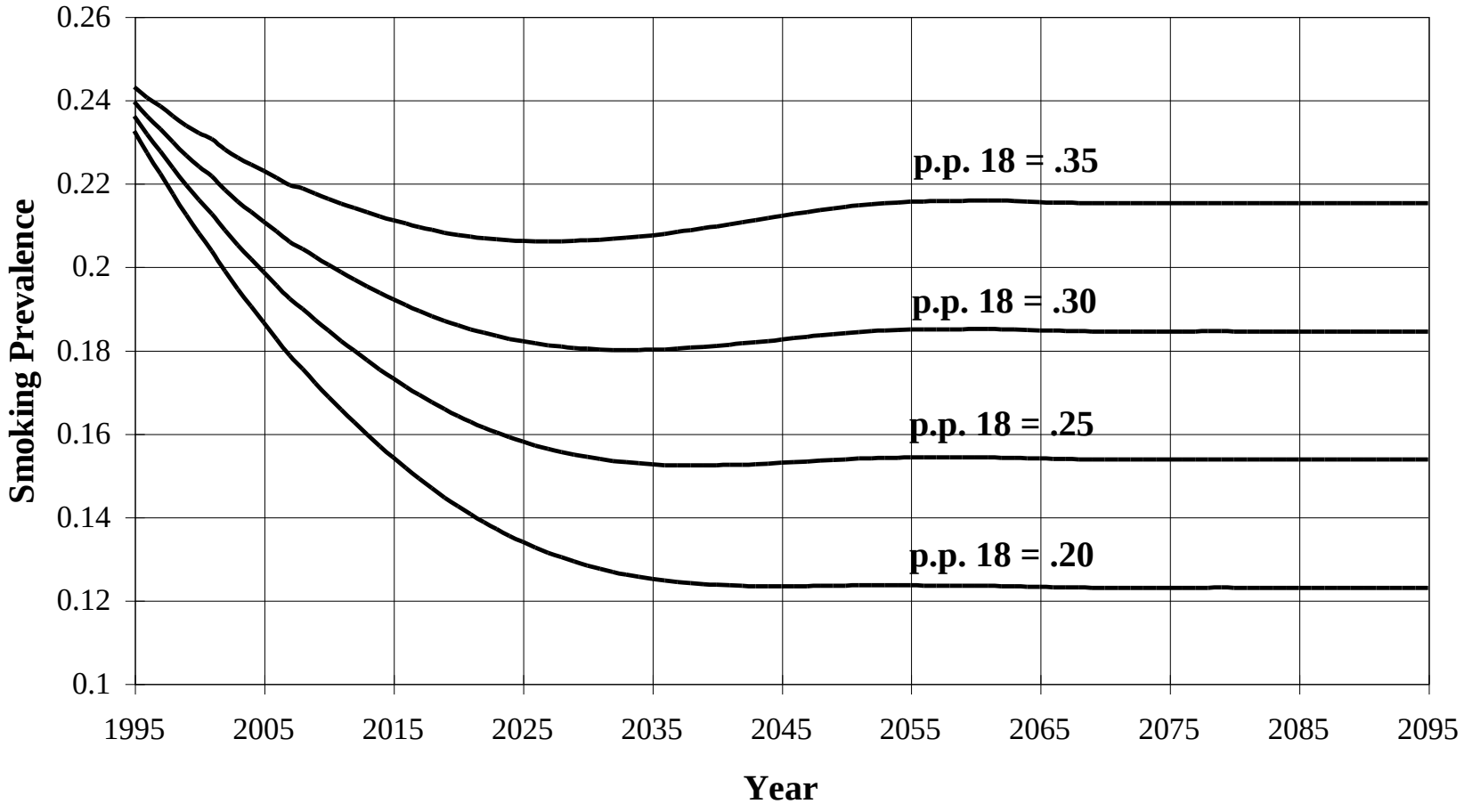
Building Confidence on the Model

- Fitting the model to observed data
- Comparing predictions with observed data

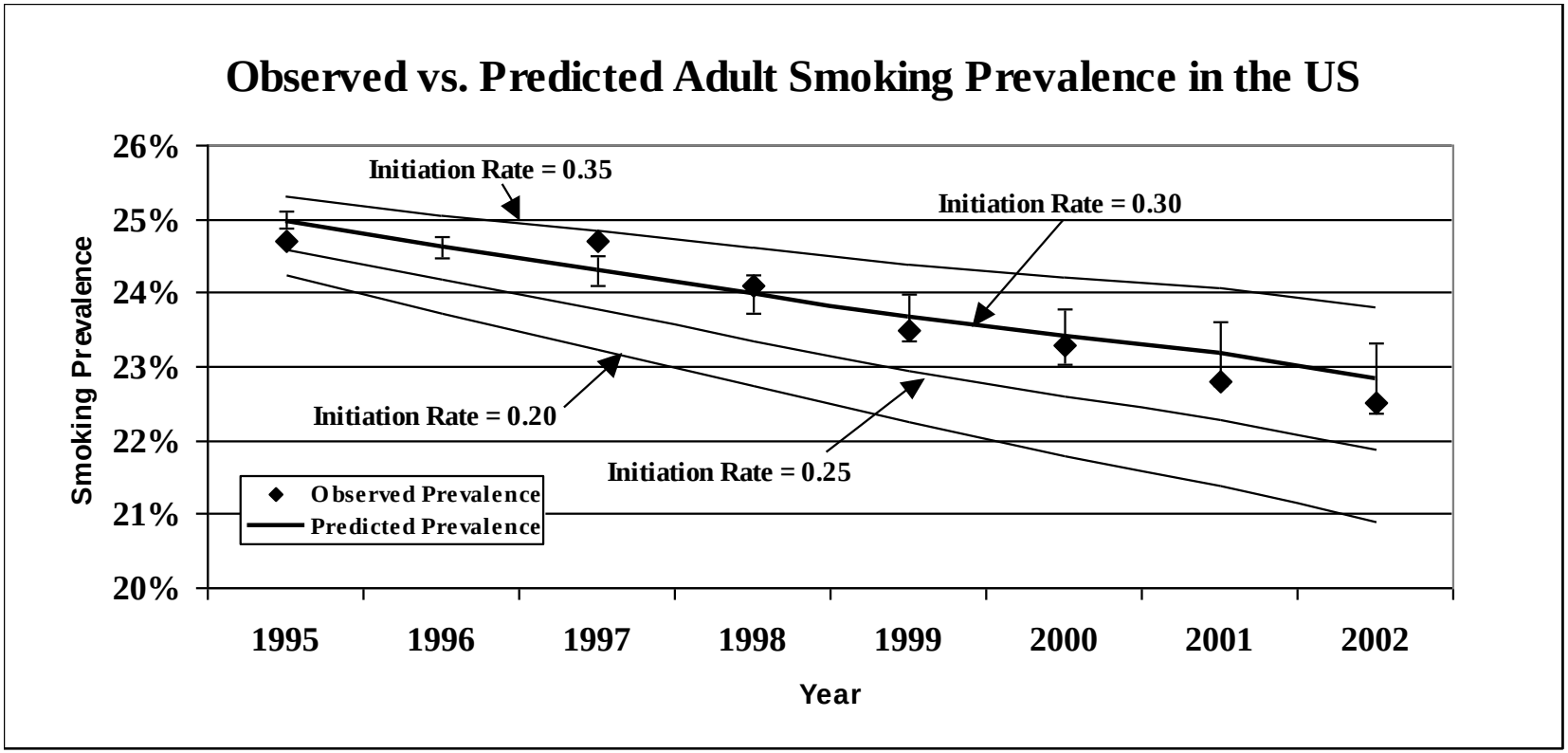
Observed vs Predicted Smoking Prevalence
All Ages

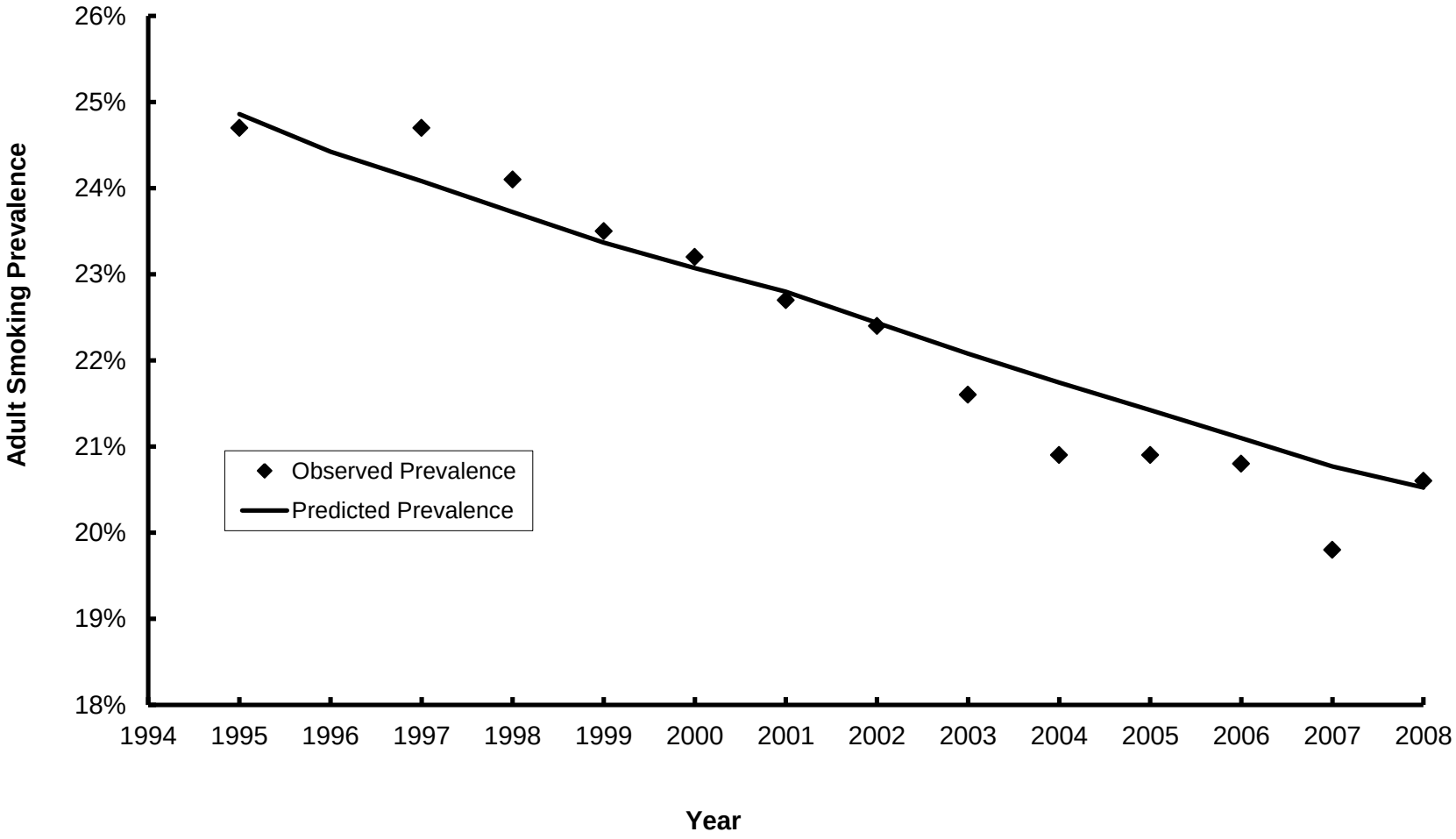


Forecasted Overall Smoking Prevalence by Different Peak Prevalence at 18



Mendez and Warner, *AJPH*, 2004

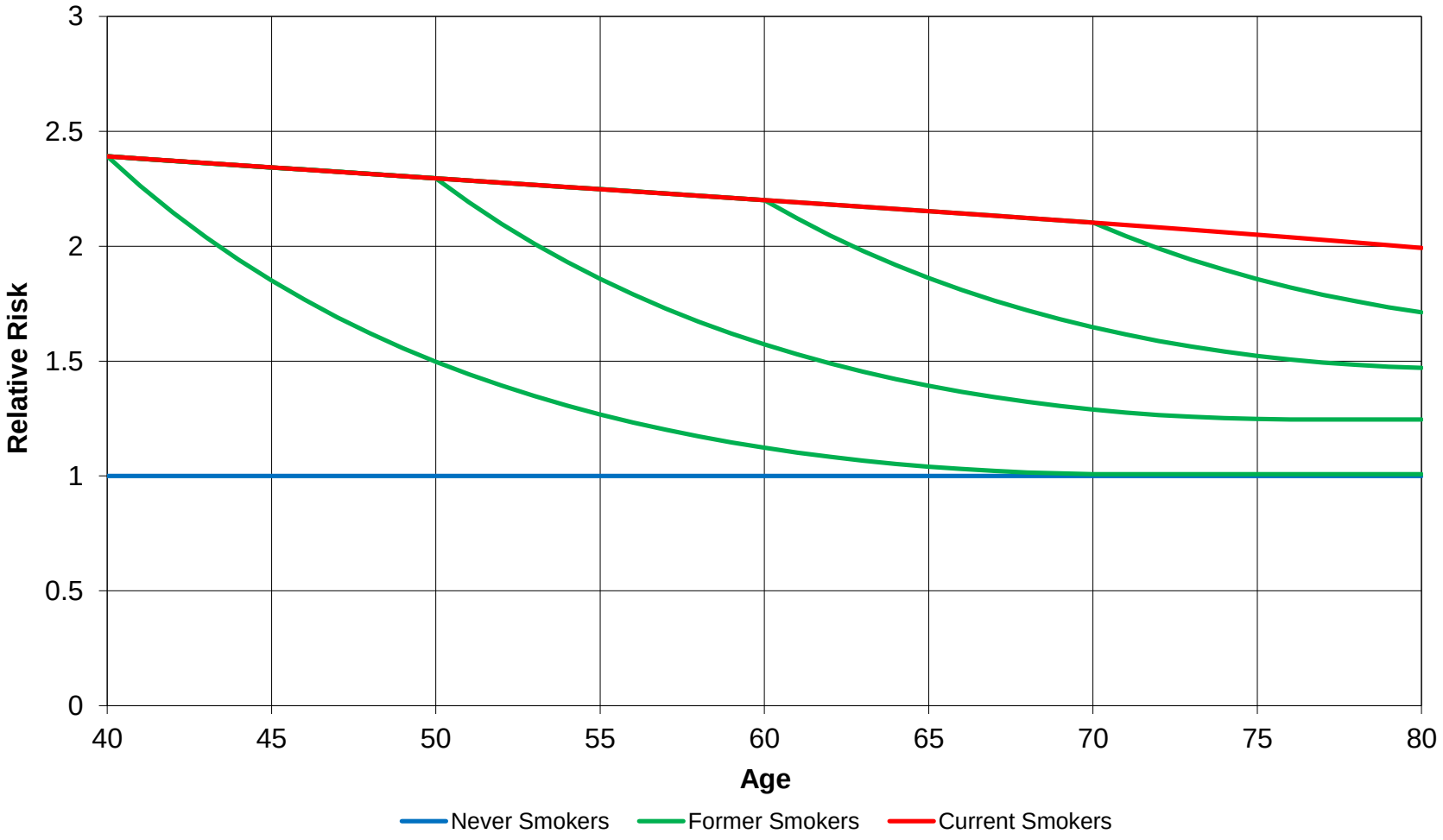



Adult Smoking Prevalence
26%
25%
24%
23%
22%
21%
20%
19%
18%
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year
Observed Prevalence
Predicted Prevalence

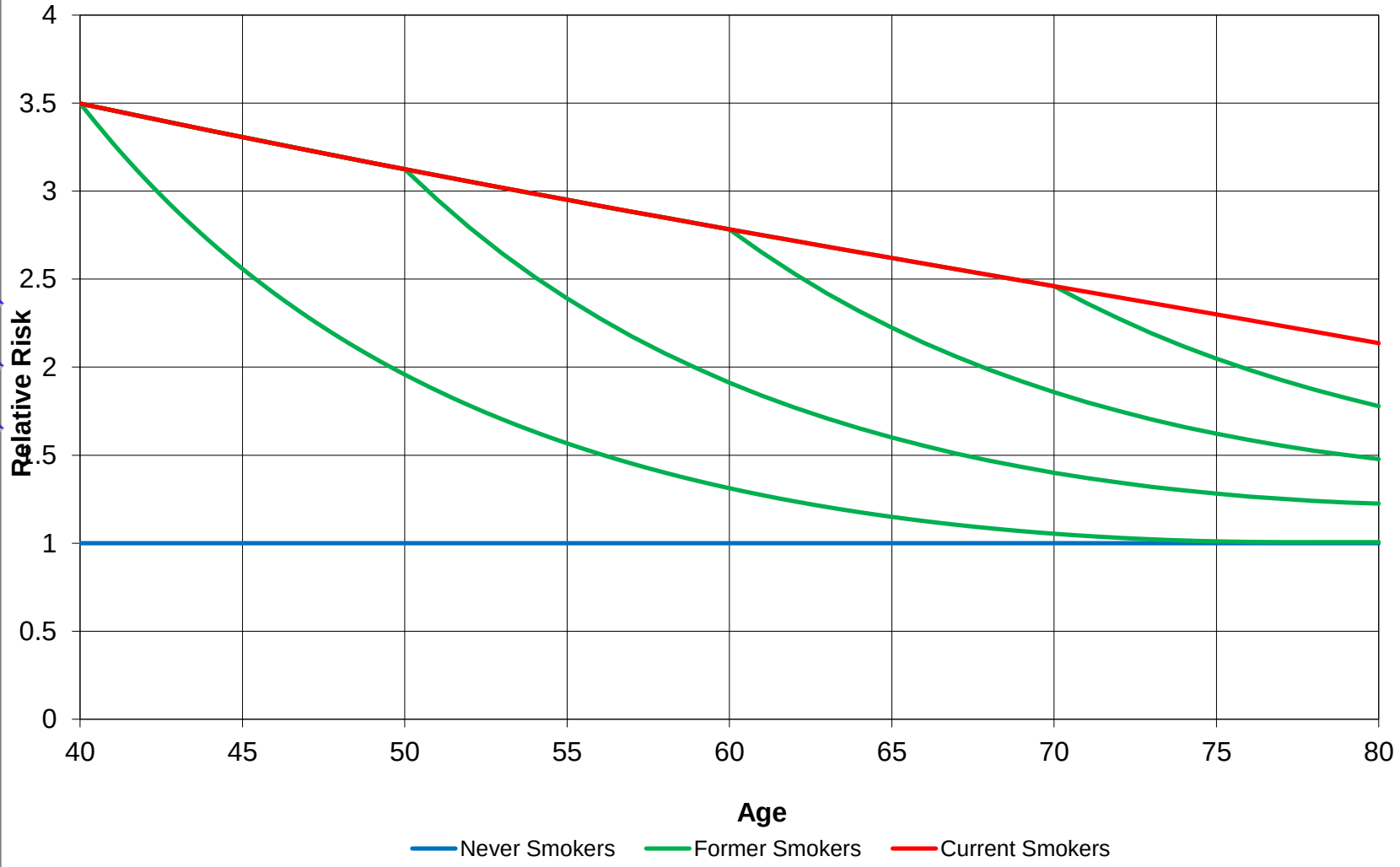
Including Health Effects

- Relative Risks derived from the Cancer Prevention Study II (CPS II) data

Female relative risk of death, current and former smokers, by age and smoking status



Male relative risk of death, current and former smokers, by age and smoking status



Compartment Model of Smoking Prevalence, Health Effects and Medical Costs

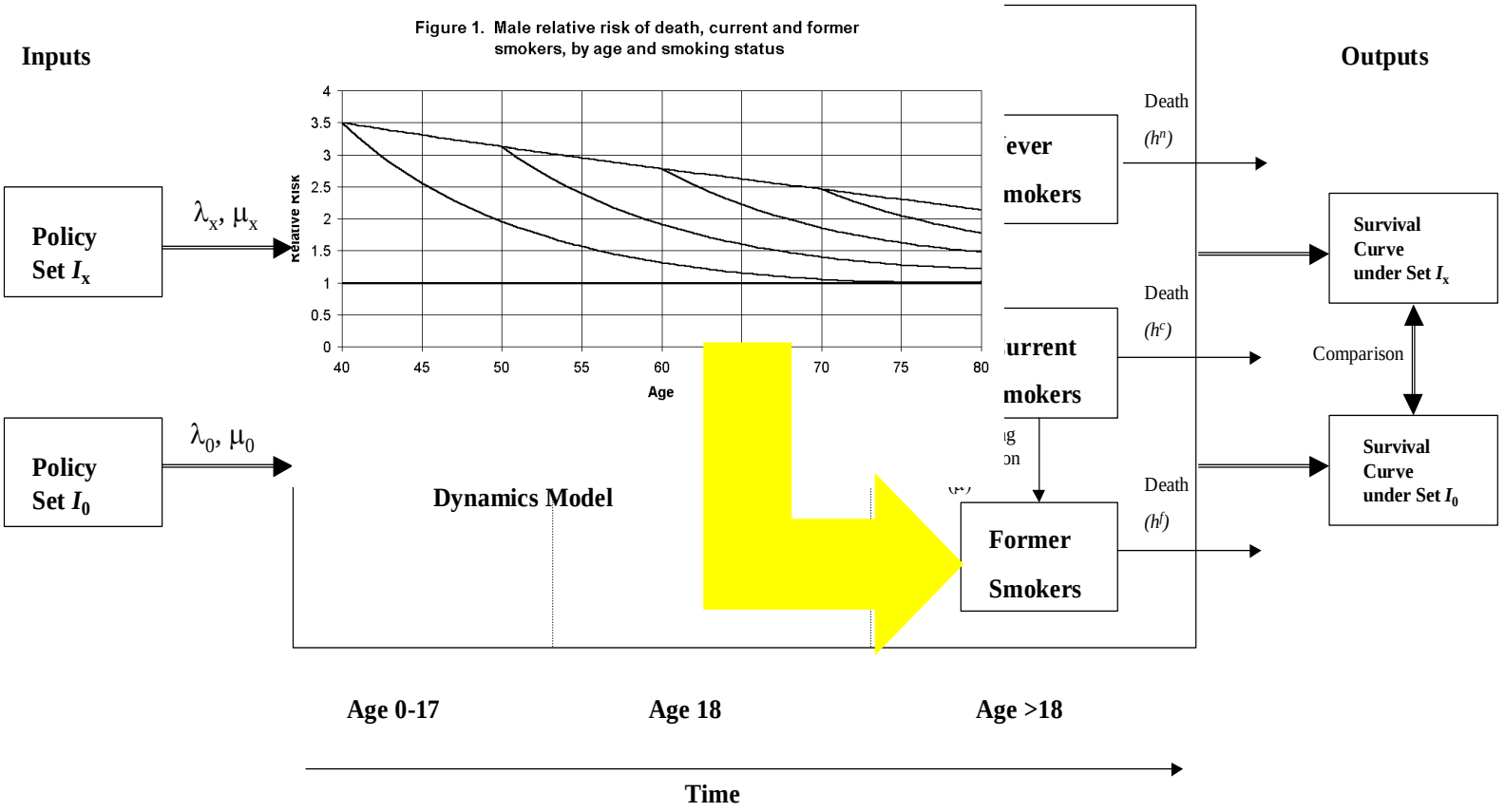


Figure 1. Male relative risk of death, current and former smokers, by age and smoking status

Example of Model Applications

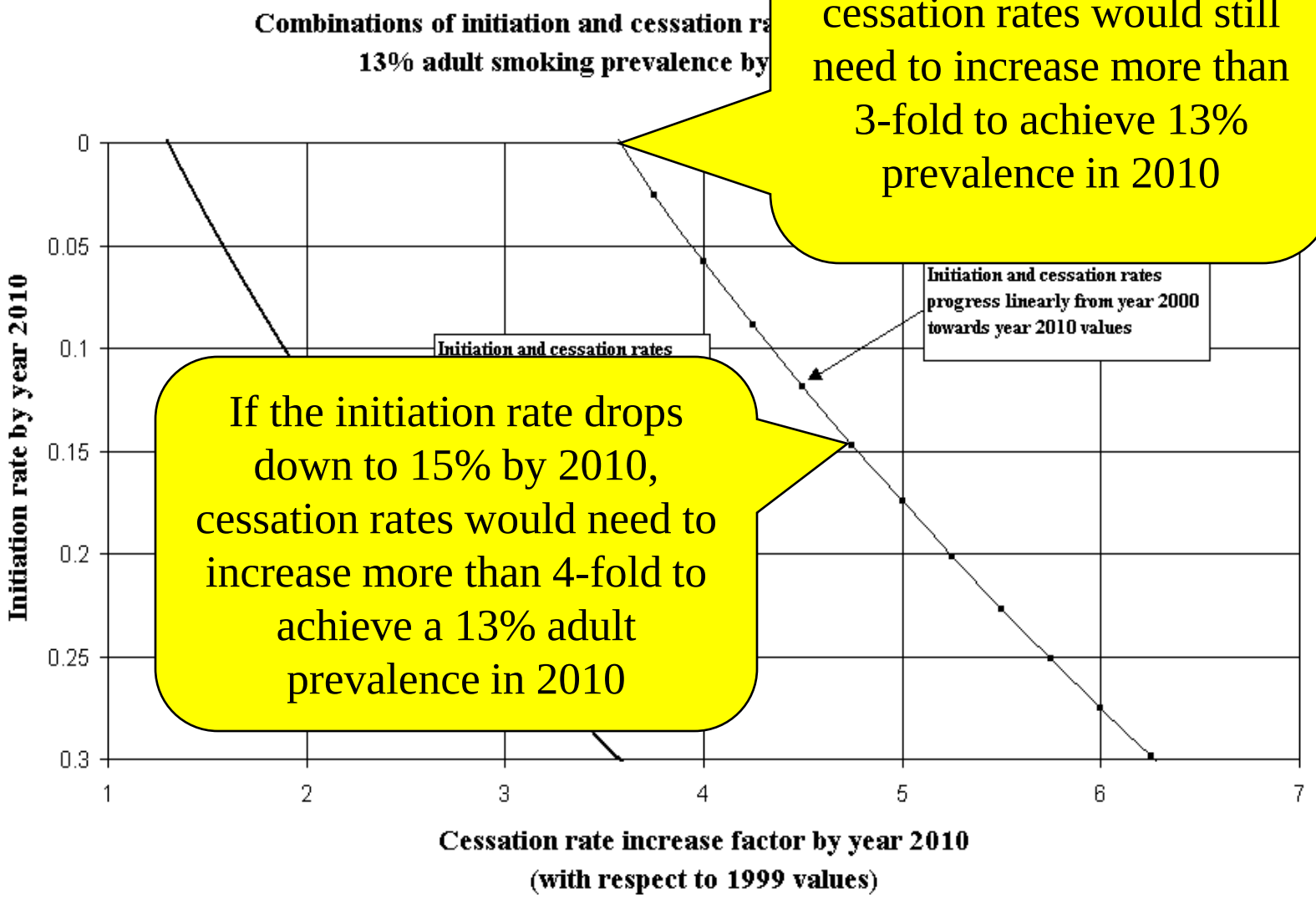
- Assessing smoking prevalence targets
- Offering smoking cessation programs in managed care organizations
- Evaluating the impact of menthol cigarettes on population's health

Example of Model Applications

- Evaluating the effectiveness of radon remediation under declining smoking rates
- Evaluating the effect of control policies on global smoking trends

Smoking Prevalence Targets

Mendez and Warner, *AJPH*, 2000



Even if the initiation rate goes down to zero, cessation rates would still need to increase more than 3-fold to achieve 13% prevalence in 2010

If the initiation rate drops down to 15% by 2010, cessation rates would need to increase more than 4-fold to achieve a 13% adult prevalence in 2010

Actual and projected adult cigarette smoking prevalence, United States, 2005 and 2010

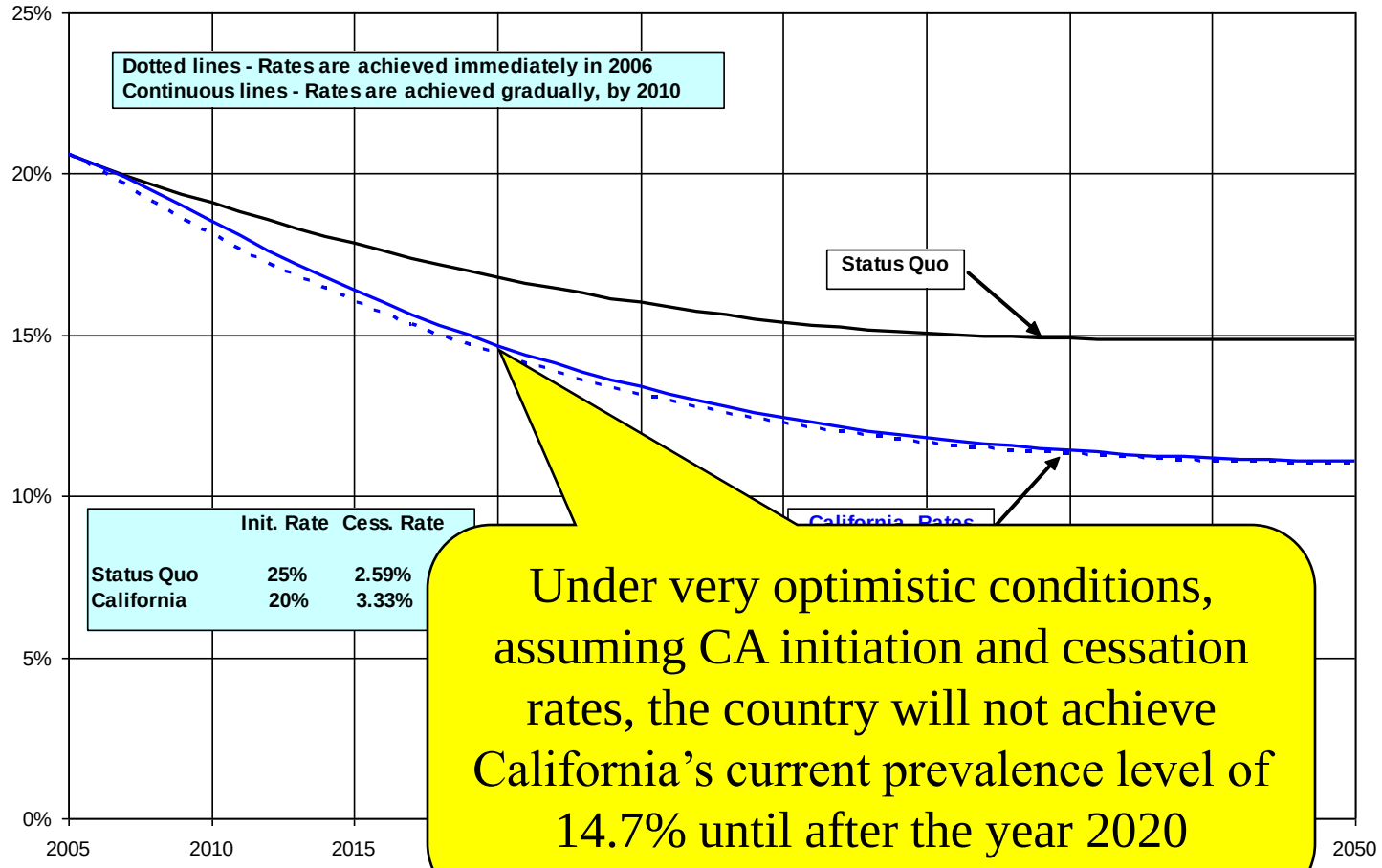
Source	Model calibrated through	Initial year of projection	2005 (%)	2010 (%)
National Health Interview Survey	NA	NA	20.9	19.3
Mendez and Warner [AJPH 2000], assuming continuation of 30% initiation rate	1995	2000	20.9	19.9
Mendez and Warner [AJPH 2000], assuming initiation rate declines from 30% to 15% from 2000-2010	1995	2000	20.5	18.4
Mendez and Warner [AJPH 2008]	2005	2006	NA	19.1

Mendez & Warner, AJPH, 2008

What can the country achieve by emulating best performance?

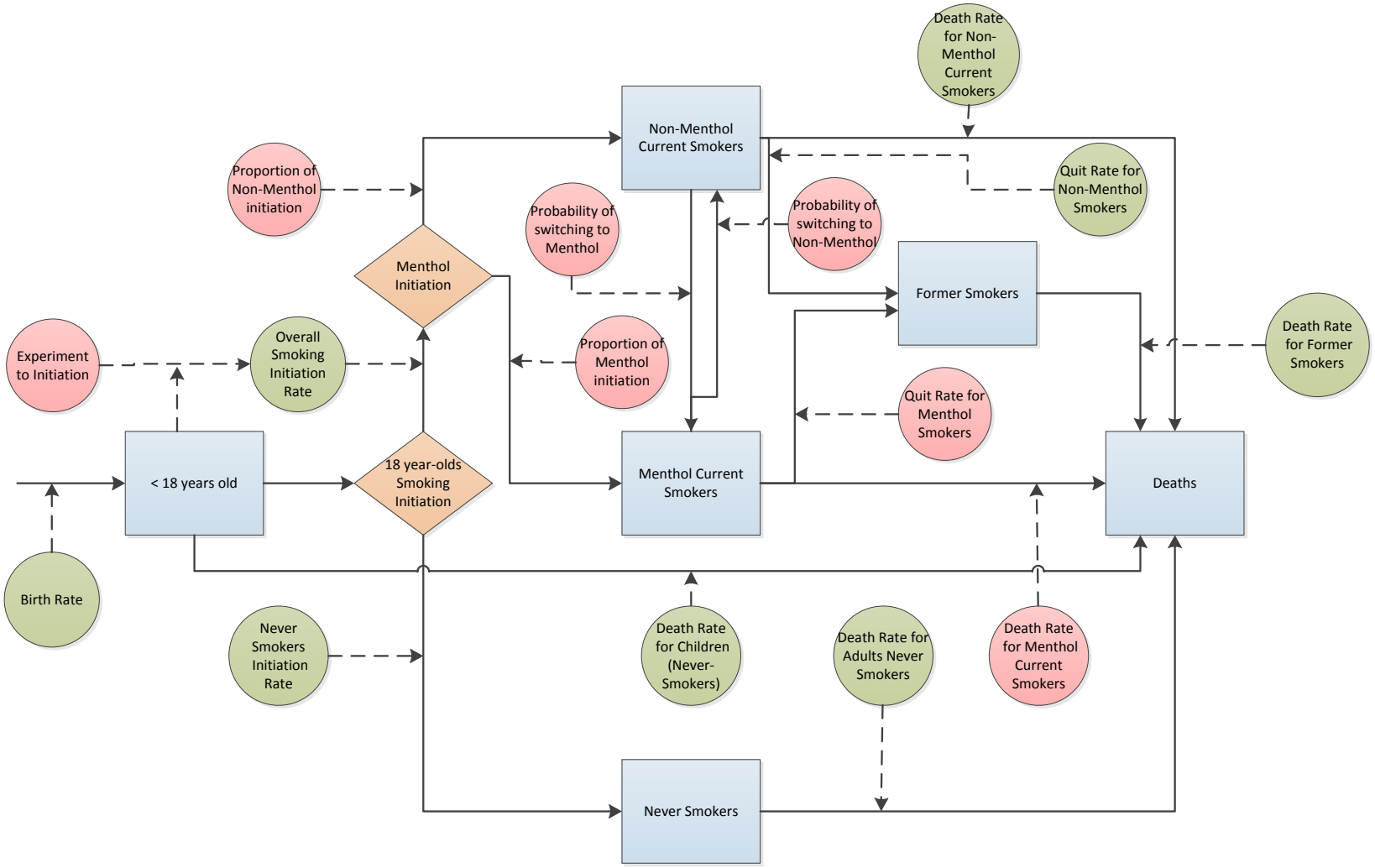
Status Quo vs. Best Performance

Projections of U.S. adult smoking prevalence under status quo and California smoking initiation and cessation rates



Impact of Menthol Cigarettes on the Population

Block Diagram of Menthol Cigarettes Prevalence Model



Input Parameters
General Population

Parameter	Min	TPSAC Estimate	Max
Proportion of Menthol among Initiators	0.35	0.40	0.45
Proportion of Menthol among Experimenters (K_4)	0.38	0.45	0.60
Ratio of "Proportion of Menthol Experimenters that become Established Smokers" / "….Non-menthol….." (K_5)	1.00	1.68	1.85
Cessation Rates Ratio (Menthol/Non-menthol)	0.92	0.95	1.10
Mortality Risk Ratio (Menthol/Non-menthol)	0.80	1.00	1.20
Switching Rate from Menthol to Non-menthol (among Menthol smokers)	0.9%	1.8%	2.7%
Switching Rate from Non-menthol to Menthol (among Non-menthol smokers)	0.4%	0.8%	1.2%

Results for the General Population Model
TPSAC Estimates

General Population	TPSAC Estimates	Counterfactual
Initiation Age	18	18
Initiation Rate	21.8%	16.7%
Proportion of Menthol Initiation	40%	---
Proportion of Menthol Experimentation	45%	---
Experimentation to Initiation Ratio Menthol/Non-Menthol	1.68	---
Background Cessation Rates		
<= 30	0.21%	0.21%
31-49	2.15%	2.15%
50+	5.96%	5.96%
Cessation Ratio Menthol/Non-Menthol	0.95	---
Menthol Mortality Multiplier	1	---
Probability of switching to Menthol	0.8%	---
Probability of switching to Non-Menthol	1.8%	---

	2010	2020	2030	2040	2050
TPSAC - Adult Smoking Prevalence - Menthol	6.8%	5.5%	4.9%	4.6%	4.5%
TPSAC - Adult Smoking Prevalence - Non-Menthol	13.8%	10.5%	8.7%	8.0%	7.8%
TPSAC - Overall Adult Smoking Prevalence	20.5%	16.1%	13.6%	12.5%	12.3%
Counterfactual - Overall Adult Smoking Prevalence	20.4%	15.1%	11.9%	10.3%	9.7%
Cumulative Excess Deaths among Menthol Smokers	172,743	1,601,751	2,777,684	3,804,560	4,696,753
Cumulative Excess Deaths among Non-Menthol Smokers	-172,443	-1,557,225	-2,626,551	-3,479,267	-4,109,077
Cumulative Excess Deaths among Current Smokers	300	44,526	151,132	325,292	587,675
Cumulative Excess Deaths among Former Smokers	0	-16,797	-48,419	-76,392	-70,064
Cumulative Excess Deaths among Never Smokers	-300	-10,547	-34,897	-84,310	-190,047
Total Cumulative Excess Deaths	0	17,182	67,817	164,590	327,565
Cumulative Excess Smoking Initiation - Menthol	387,845	3,920,549	7,580,884	11,480,562	15,609,338
Cumulative Excess Smoking Initiation - Non-Menthol	-165,457	-1,632,015	-3,151,558	-4,770,461	-6,484,471
Total Cumulative Excess Smoking Initiation	222,388	2,288,534	4,429,326	6,710,101	9,124,867

Results from the Menthol Model

- If menthol cigarettes did not exist, an estimated 328,000 premature deaths and 9 million new smokers would be avoided over a 40 year period.

SimSmoke

- ***SimSmoke*** simulates the dynamics of smoking rates and smoking-attributed deaths in a State or Nation, and the effects of policies on those outcomes.
- **Focus on tobacco control policies**
  - Effects vary depending a) on the way the policy is implemented, b) by demographics
  - Dynamic, nonlinear and interactive effects of policies
- **Compartmental (macro) model** with smokers, ex-smokers and never smokers evolving through time by age and gender.
- **Deterministic uni-causal model** with sensitivity analysis

Models

Countries:

Albania, Argentina, Bangladesh, Brazil, China, Czech Republic, Egypt, Finland, France, Germany, Great Britain, India, Indonesia, Ireland, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Pakistan, Poland, Philippines, Taiwan, Russia, Spain, Sweden, Thailand, Turkey, Ukraine, US, Vietnam

States:

Arizona, Calif, Kentucky, Massachusetts, Minnesota, NY, Missouri

Basic Approach

Policy Changes

Taxes

Clean air laws

Media Camp.

Marketing Bans

Warning labels

Cessation Support

Youth Access

Norms, Attitudes, Opportunities

Cigarette Use

Former and current smokers, relative risks

Smoking-Attributable Deaths

Total Mortality and by type:

Lung cancer

Other cancers

Heart disease

Stroke

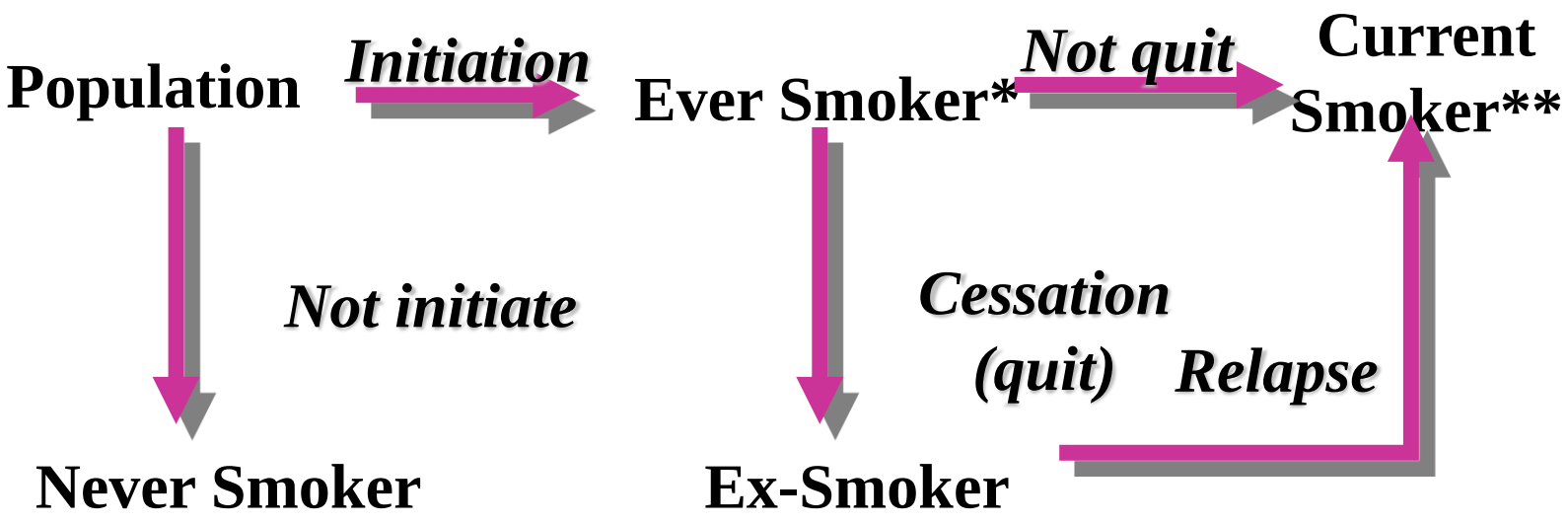
COPD

MCH Outcomes

Basic Structure of Model

- Population model begins with initial year population (by age and gender) and moves through time (by year) with births and deaths (1st order discrete Markov process)
- Smoking model distinguishes population into never smokers, smokers, and ex-smokers and moves through time with initiation, cessation and relapse (Markov)
- Smoking-attributable deaths depend on death rates, smoking rates and relative risks from CPS-II
- Policy modules for each policy with interdependent effects on smoking rates

Smoking Model: Evolution of Smokers



** Usually as smoked 100 cigarettes lifetime ** usually smoked some or all days*

Policies based on FCTC MPOWER

- *Cigarette taxes- through price*
- *Smoke-Free Air Laws*
  - *Worksite*
  - *Restaurant and bars*
  - *Other public places*
- *Tobacco control/media campaigns*
- *Marketing Bans*
- *Health Warnings*

MPOWER policies (cont)

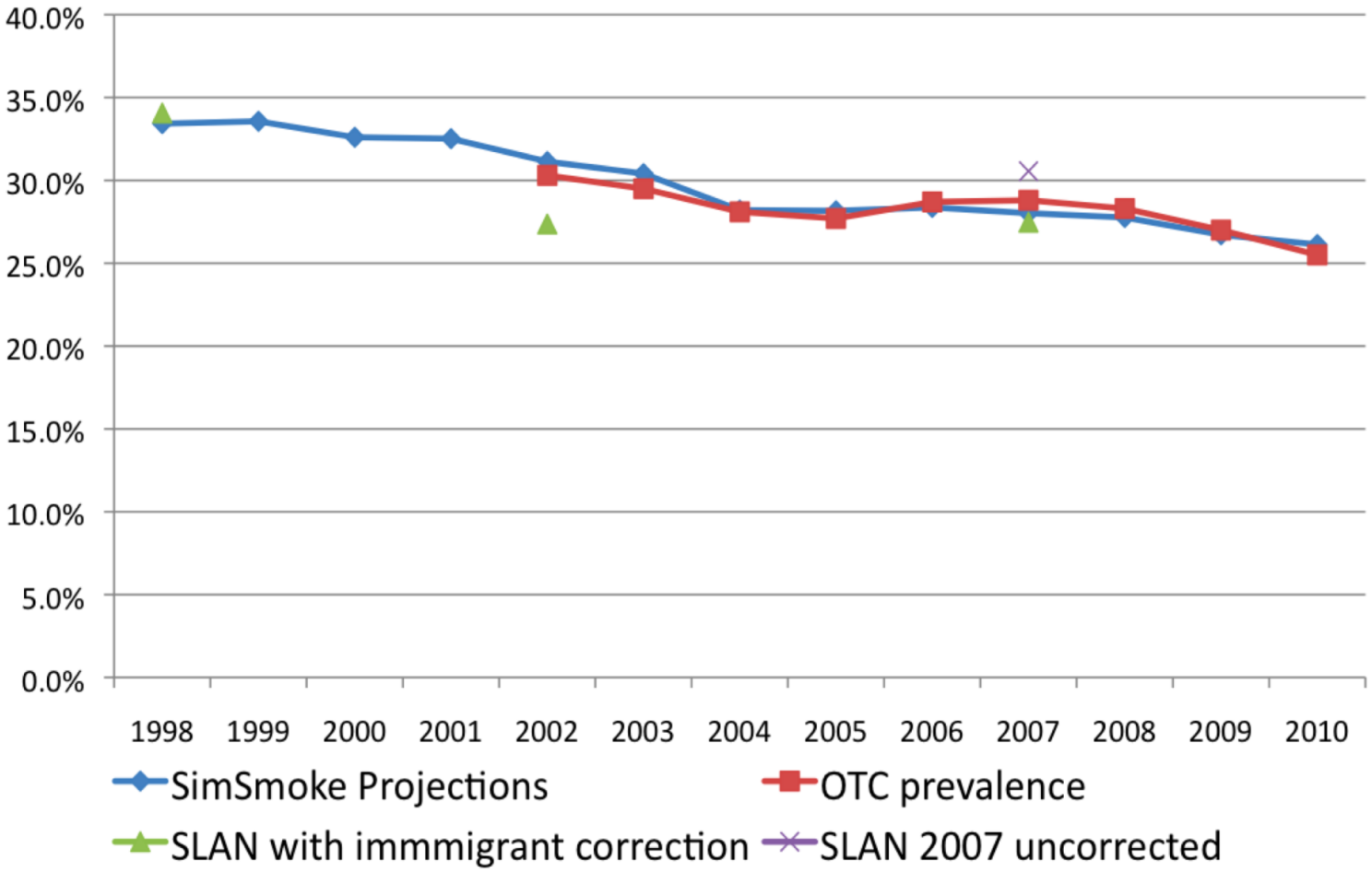
- *Cessation Treatment*
  - Availability of pharmacotherapy
  - Cessation treatment access (hospital etc)
  - Quitlines (and web-based treatment)
  - *Health care provider involvement (not in MPOWER)*
- *Youth access policies*

includes enforcement, and vending AND self-service bans

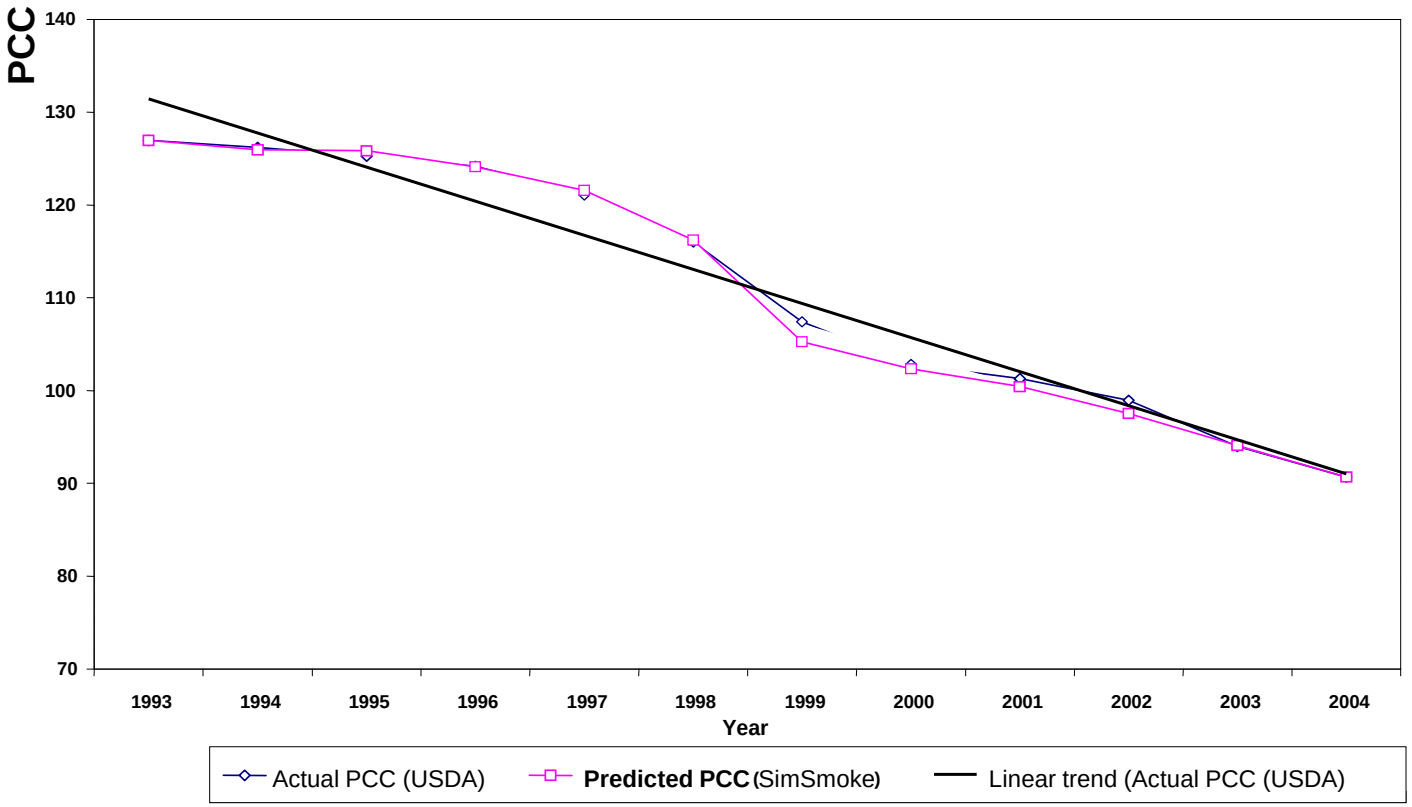
Interactions of Publicity through media campaigns on health warnings and cessation treatment.

Ireland Male Smoking Prevalence,1998-2010

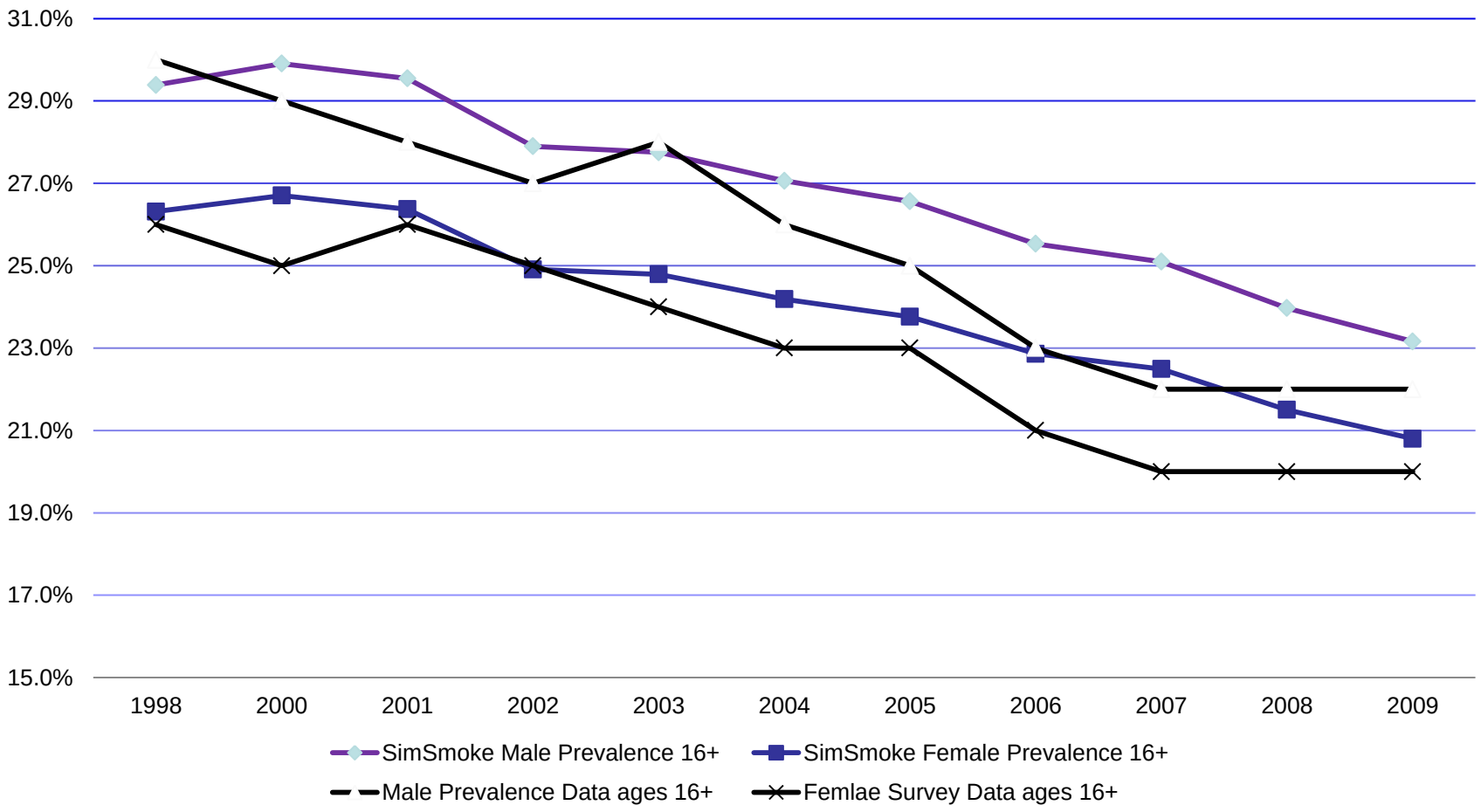
data, data, data



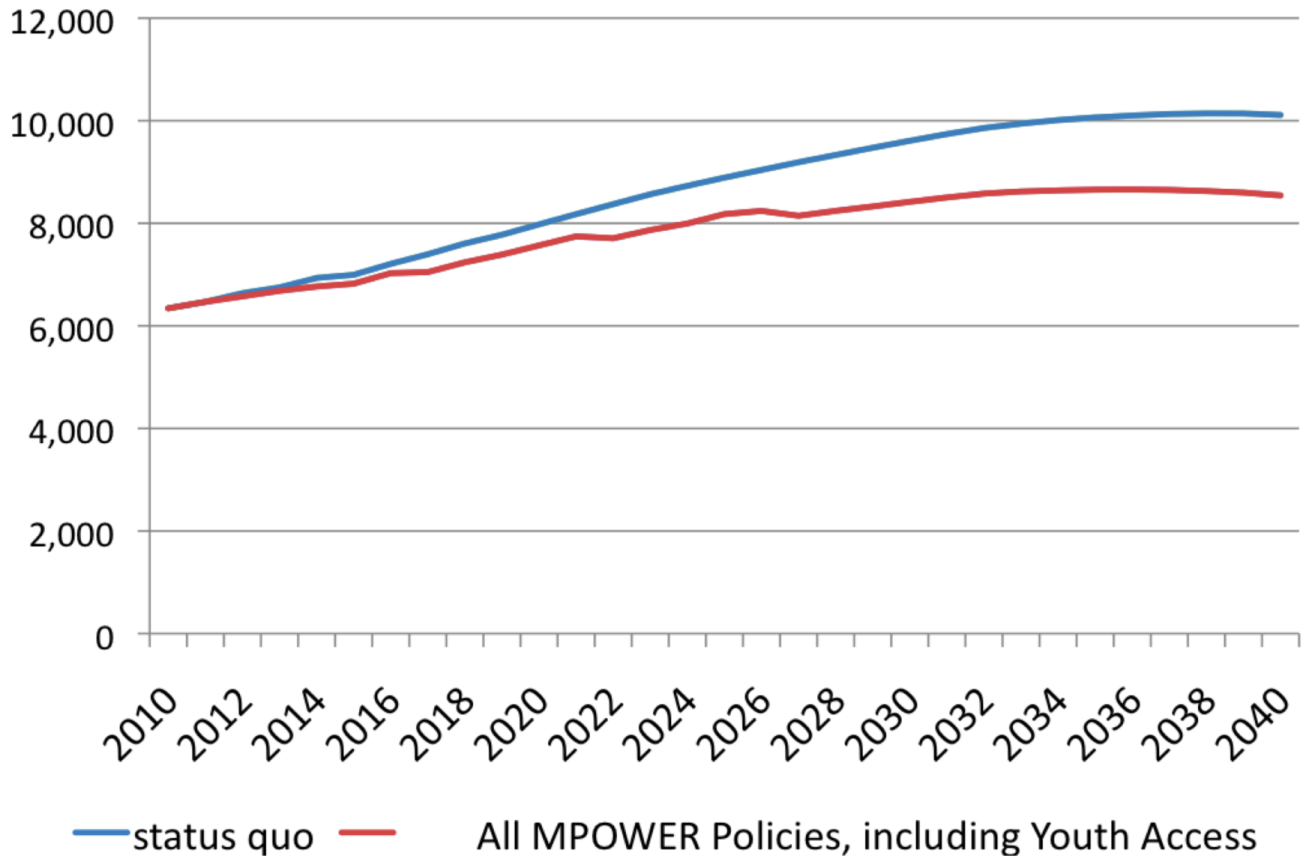
U.S. Model Validation: Actual Vs Predicted Per Capita US Consumption Vs Trend Line



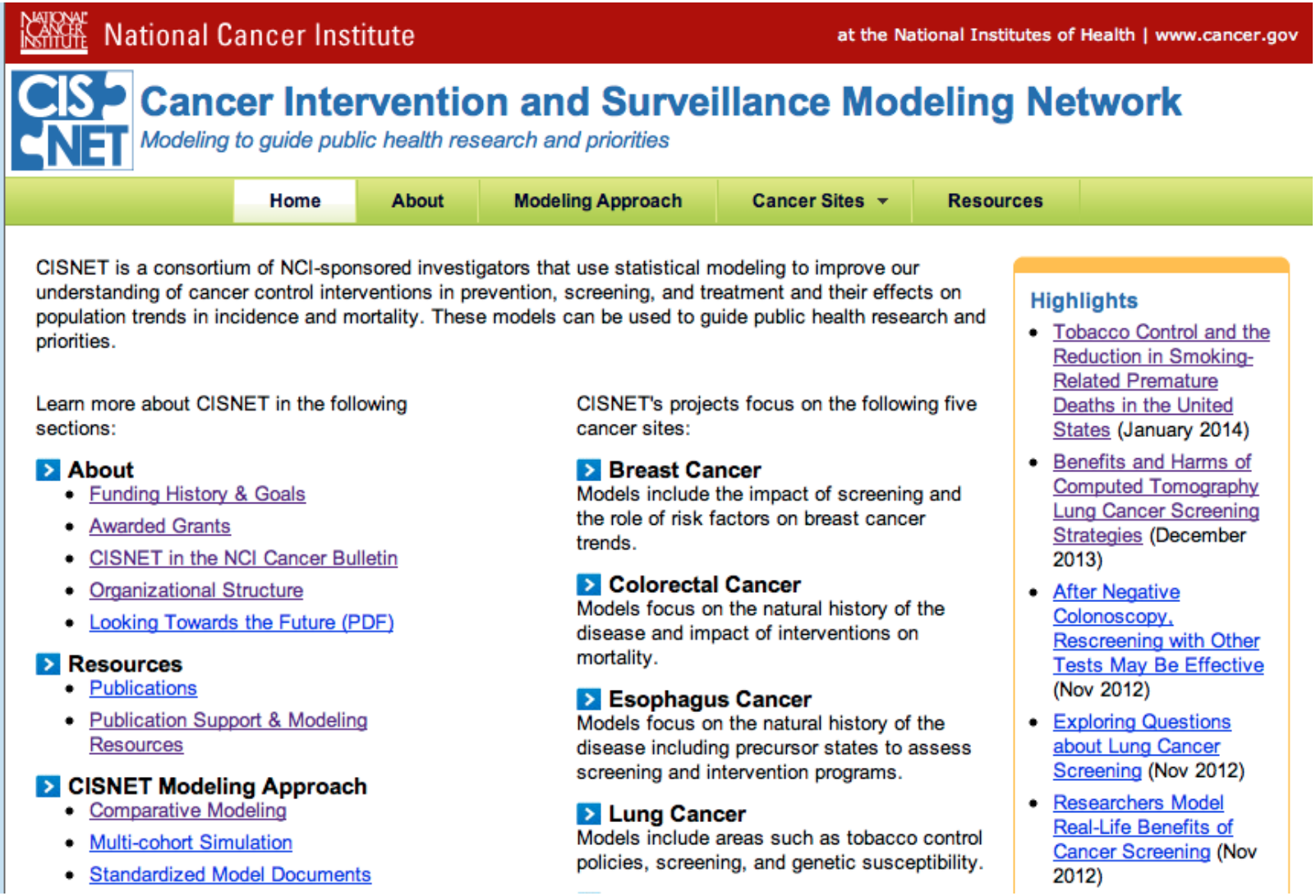
Great Britain SimSmoke, Predicted vs Survey, 1999-2009



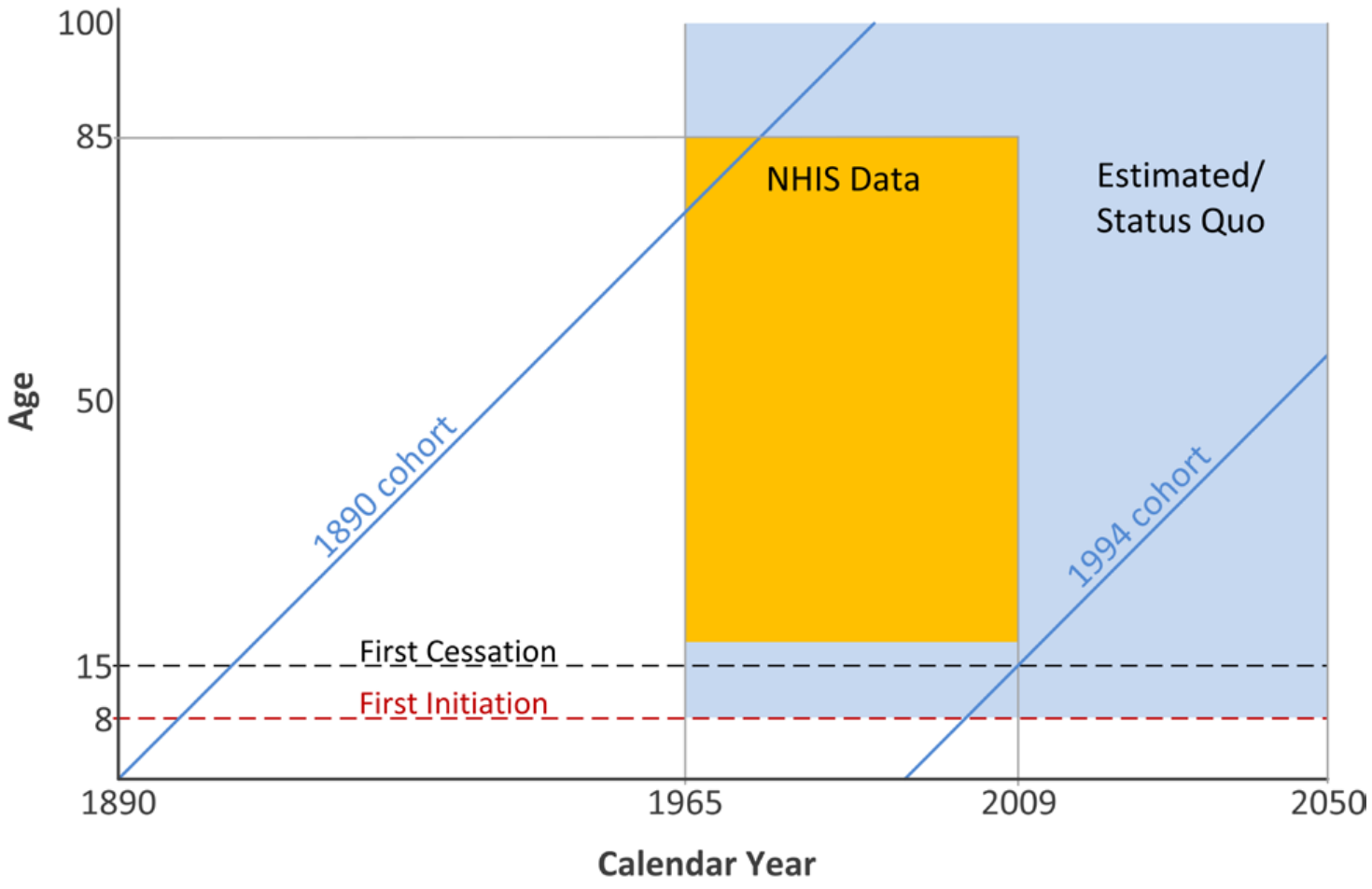
SimSmoke Projections Male and Female Smoking-Attributable Deaths 2010-2040
Status Quo vs. All MPOWER Policies

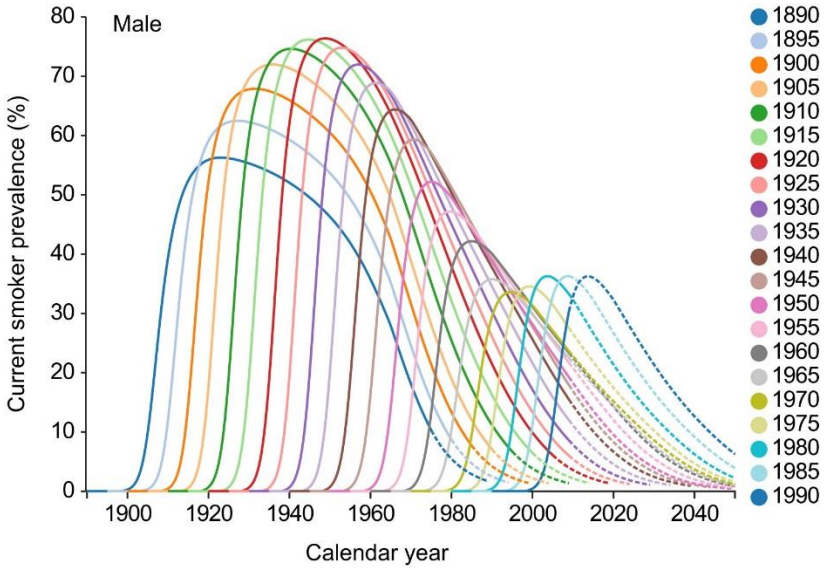


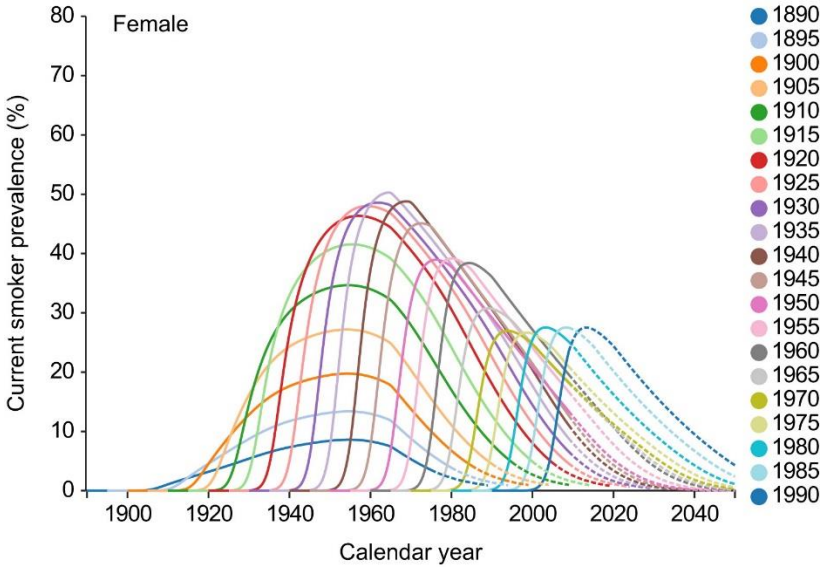
CISNET


National Cancer Institute
at the National Institutes of Health | www.cancer.gov
CIS NET
Cancer Intervention and Surveillance Modeling Network
Modeling to guide public health research and priorities
Home
About
Modeling Approach
Cancer Sites
Resources
CISNET is a consortium of NCI-sponsored investigators that use statistical modeling to improve our understanding of cancer control interventions in prevention, screening, and treatment and their effects on population trends in incidence and mortality. These models can be used to guide public health research and priorities.
Learn more about CISNET in the following sections:
About
Funding History & Goals
Awarded Grants
CISNET in the NCI Cancer Bulletin
Organizational Structure
Looking Towards the Future (PDF)
Resources
Publications
Publication Support & Modeling Resources
CISNET Modeling Approach
Comparative Modeling
Multi-cohort Simulation
Standardized Model Documents
CISNET's projects focus on the following five cancer sites:
Breast Cancer
Models include the impact of screening and the role of risk factors on breast cancer trends.
Colorectal Cancer
Models focus on the natural history of the disease and impact of interventions on mortality.
Esophagus Cancer
Models focus on the natural history of the disease including precursor states to assess screening and intervention programs.
Lung Cancer
Models include areas such as tobacco control policies, screening, and genetic susceptibility.
Highlights
Tobacco Control and the Reduction in Smoking-Related Premature Deaths in the United States (January 2014)
Benefits and Harms of Computed Tomography Lung Cancer Screening Strategies (December 2013)
After Negative Colonoscopy, Rescreening with Other Tests May Be Effective (Nov 2012)
Exploring Questions about Lung Cancer Screening (Nov 2012)
Researchers Model Real-Life Benefits of Cancer Screening (Nov 2012)

CISNET Smoking History Generator




Male
Current smoker prevalence (%)
0
10
20
30
40
50
60
70
80
1900
1920
1940
1960
1980
2000
2020
2040
Calendar year
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990


Female
Current smoker prevalence (%)
0
10
20
30
40
50
60
70
80
1900
1920
1940
1960
1980
2000
2020
2040
Calendar year
1890
1895
1900
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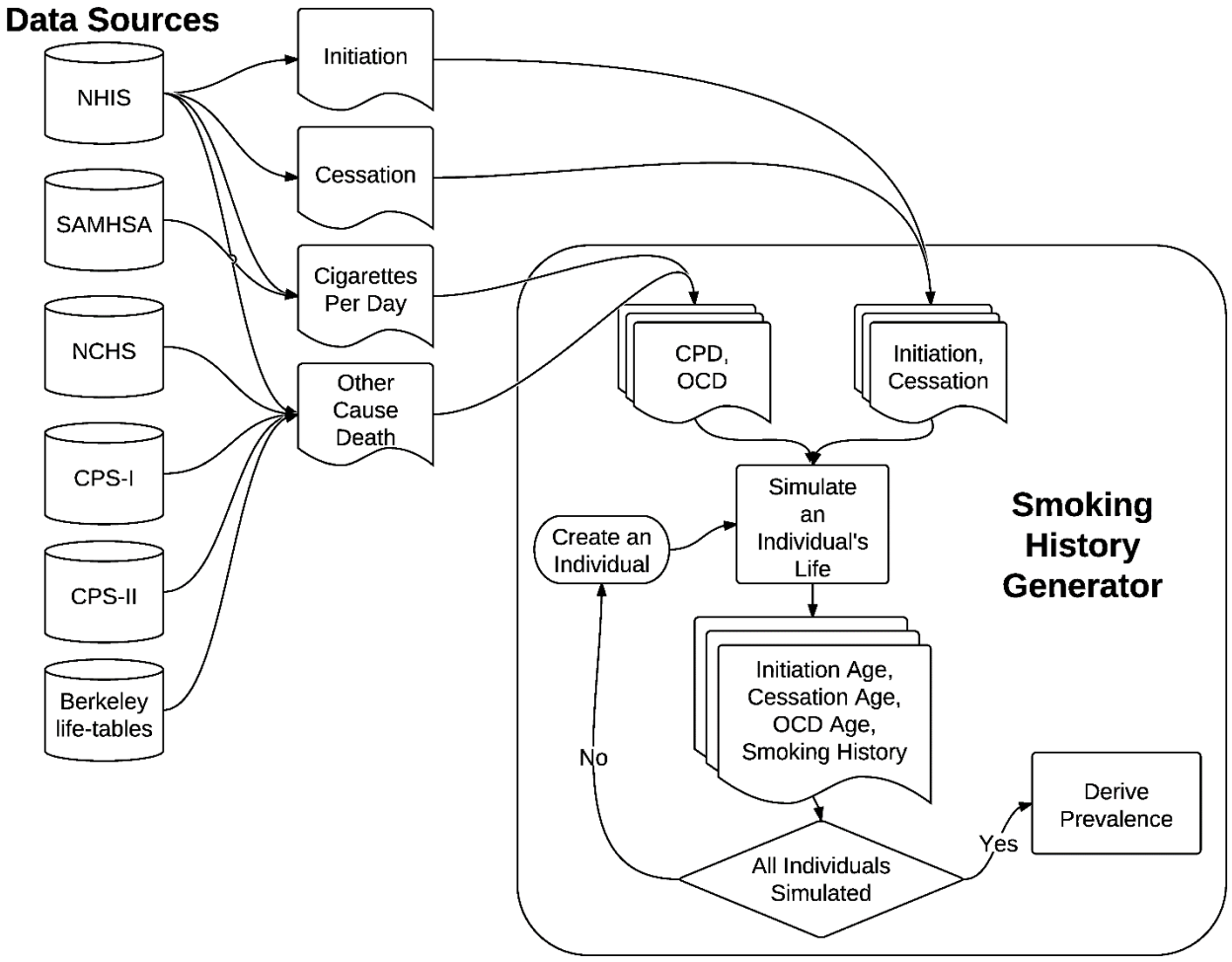
Data Sources
NHIS
SAMHSA
NCHS
CPS-I
CPS-II
Berkeley life-tables
Initiation
Cessation
Cigarettes Per Day
Other Cause Death
CPD, OCD
Initiation, Cessation
Simulate an Individual's Life
Create an Individual
Smoking History Generator
Initiation Age, Cessation Age, OCD Age, Smoking History
No
Yes
All Individuals Simulated
Derive Prevalence

Tobacco Control and the Reduction in Smoking-Related Premature Deaths in the United States, 1964-2012

Theodore R. Holford, Rafael Meza; Kenneth E. Warner, Clare Meernik, Jihyoun Jeon, Suresh H. Moolgavkar, David T. Levy

JAMA. 2014;311(2):164-171

Approach

- Reconstruct smoking experience in the US from 1864-2012
  - By gender, age, birth-cohort
- Simulate counterfactual assuming no reductions in smoking due to tobacco control since 1964
- Model attributed smoking mortality under “actual” and “counterfactual” scenarios
  - Mortality rates by smoking status

Impact of Tobacco Control in the US since 1964

- In 1964-2012, an estimated **17.7 million deaths** were related to smoking
- Tobacco control was estimated to be associated with **avoidance of 8 million** premature deaths and an estimated **extended mean life span of 20 years (two decades of life)**
- Although tobacco control represents an important public health achievement, efforts must continue to reduce the effect of smoking on the US' death toll

Models in Tobacco Control
Areas for further Development

- Increasing complexity and heterogeneity of the tobacco landscape
- Interaction among individuals is important in determining tobacco use behavior
- Need to develop models that account for the effects of those unique individual interactions.

Thank you