

Dynamic Population Health Modeling for Multi-Product Tobacco Environment

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Outline

- Motivation
- Model Description
- Single Product Simulation
- Hypothetical Two Product Simulation
- Summary

A Changing Landscape



electronic cigarettes



traditional cigarettes



Smokeless tobacco



ban on flavored cigarettes



graphic warning labels

**New products, changing demographics and policies
necessitate new health models**

Modeling Needs

- Multiple tobacco products
- Expand transition behaviors: switching, poly-use, etc.
- Flexibility to represent different products and risk models
- Temporal dynamics
 - Impacts may take time to be realized
 - Conclusions can vary depending on analysis time period

Model Framework

- Population consists of individuals that vary by state attributes
 - Age
 - Sex
 - Tobacco product use state for each product: never/current/former
- Markov model of state transition and death
 - Tobacco use transition and death are Markov processes
 - Probability of transition depends only upon current state
- Population size varies due to births, deaths, and net international migration
- Total population model can be represented as a time-variant, linear system of equations

$$Pop(t_{k+1}) = A(t_k) Pop(t_k) + M(t_{k+1}) + B(t_{k+1})$$

State Transition Matrix **Net International Migration Vector** **Birth Vector**

Key Model Input and Output Groups

Inputs:

- Initial population: distribution across states at time 0
- Net international migration, birth and never user death rates
- All-cause mortality risks, relative to never use
- Transition probabilities:
 - Initiation
 - Cessation
 - Switching
 - Relapse

Input parameters are specified by

- Sex, age and multi-product use state

Outputs:

- Prevalence
- Mortality
- Life years lived

By demographic and product use subgroups

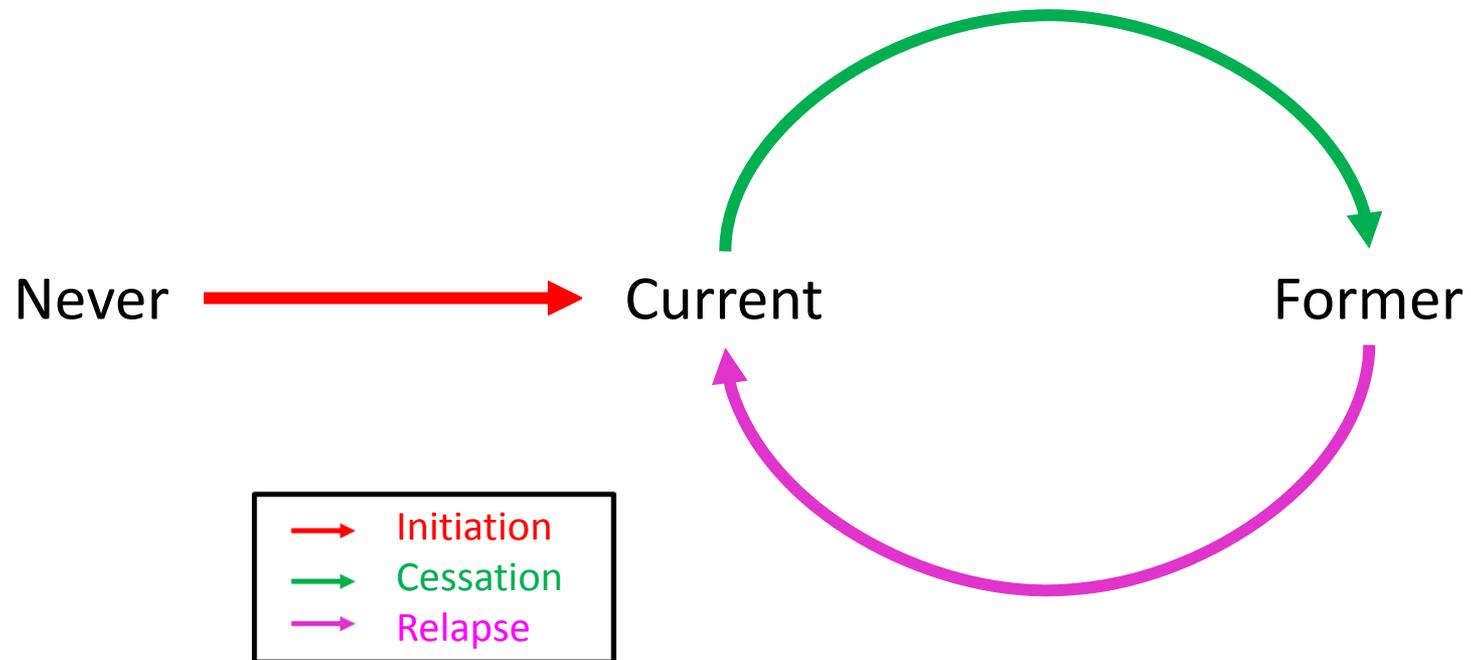
- Sex, age and multi-product use state

Intended Model Use

- Single scenario analysis – project changes to population over time
 - Status quo baseline
 - Project changes in population where there is no change in model parameters from the start
 - Project possible “what if” futures

- Multiple scenario analysis – compare target scenario(s) projection(s) to baseline scenario
 - Side-by-side output comparison
 - Difference between scenario and baseline
 - Changes in mortality

Tobacco Use Transitions: 1 Product



3 tobacco use states & 3 transitions

Single Product Model Inputs

Demographic:

- Initial population by sex, age, and smoking status - (U.S. Census, NHIS)
- Birth rate - (U.S. Census)
- Net international migration rate - (U.S. Census)
- Immigrant smoking prevalence - (NHIS)

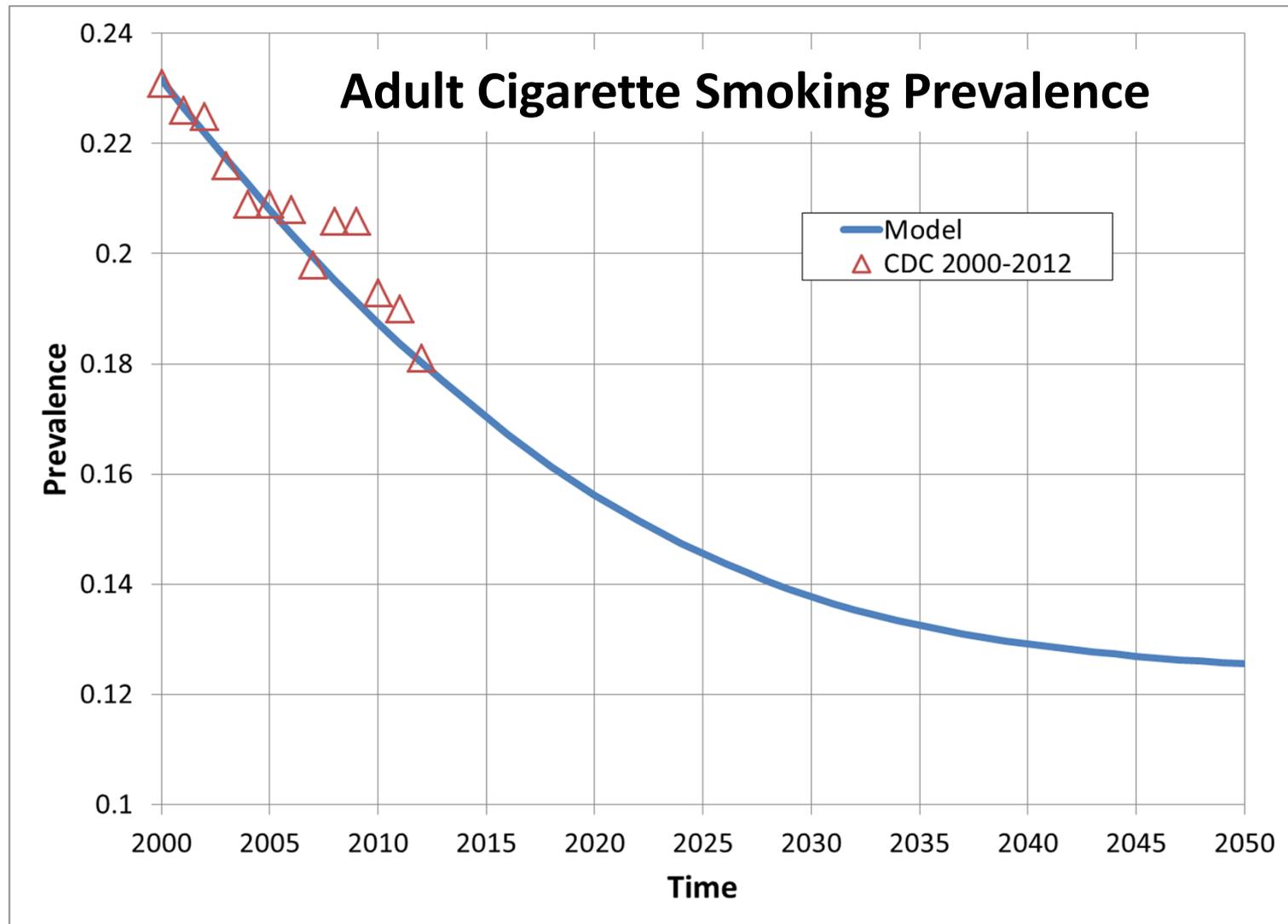
Smoking Initiation and Cessation Rates:

- Sex- and age-specific initiation and cessation rates based on reconstructions of cohort smoking histories from NHIS
 - Generated by NCI-funded Cancer Intervention and Surveillance Modeling Network (CISNET) Lung Working Group.
 - See Feuer et al (2012) for detail on methodology

Death Rates and Relative Risks:

- Never smoker death rates
 - Based on data from U.S. Vital Statistics (under age 35) and NHIS-Linked Mortality Files (ages 35+)
 - Projected future decline in age-specific death rates based on Lee-Carter mortality projection
- Relative risk by sex, age, smoking status, and age at cessation based on NHIS-LMF

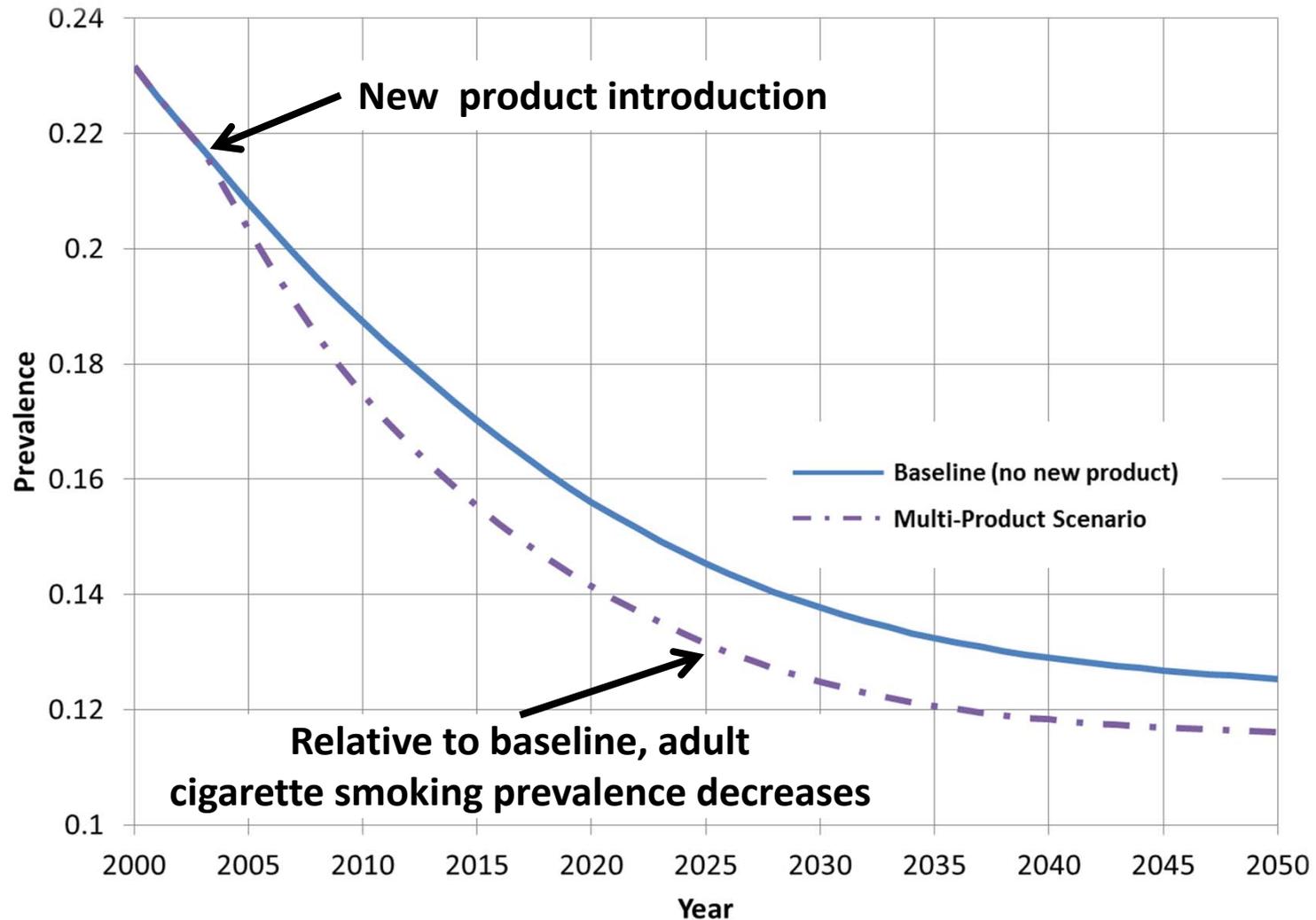
Single-Product Model Validation: Comparison with Observed Data



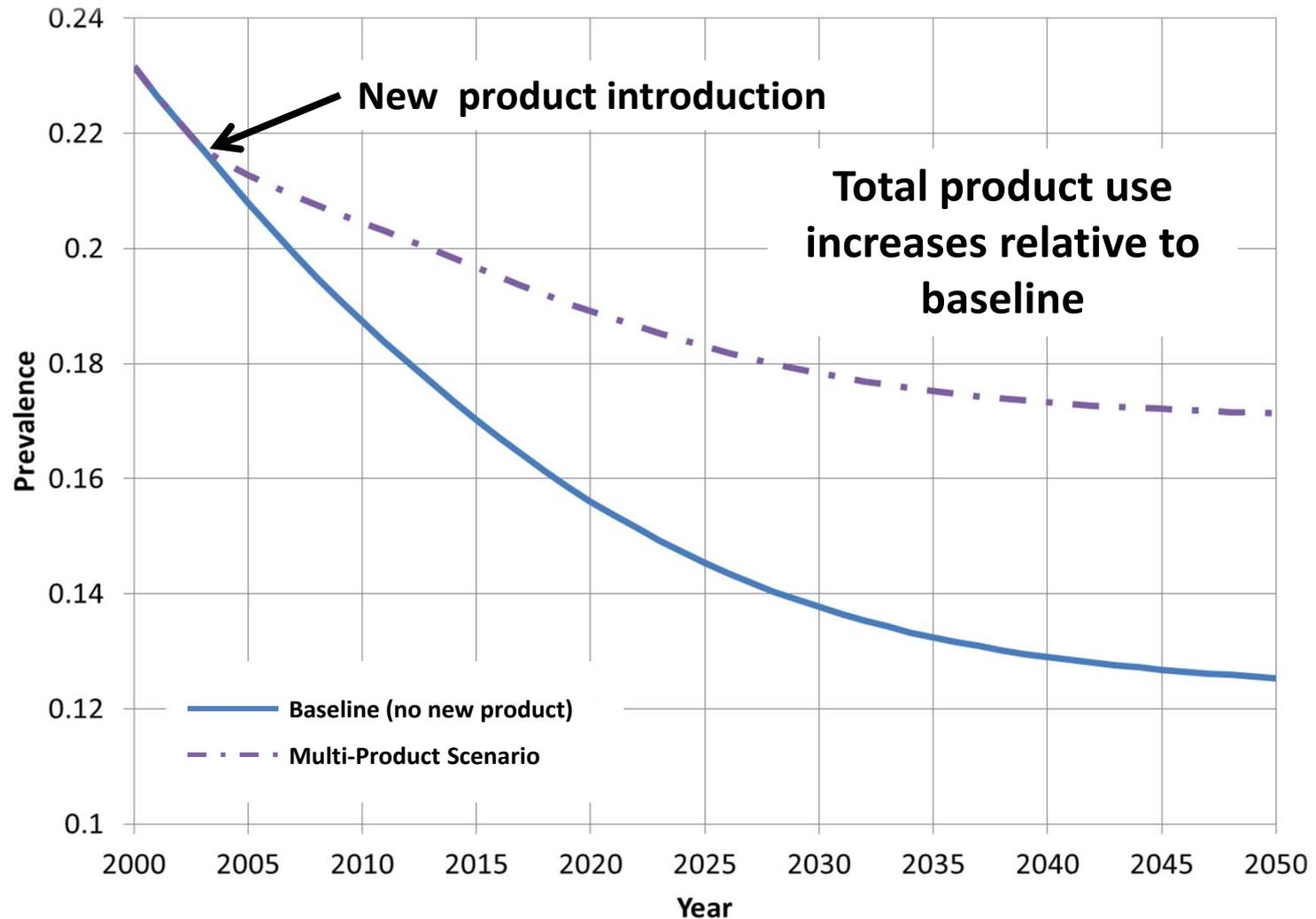
An Illustrative Two-Product Scenario Analysis

- Initial population uses 2000 U.S. demographics with cigarettes only
- Introduction of a lower risk, hypothetical new tobacco product in Year 3
 - Hypothetical new product has excess relative risk (ERR) = 0.25 x cigarette ERR
 - Hypothetical new product initiation*
 - Never smokers may take up alternative (0.5 x smoking initiation rate)
 - Hypothetical new product users may switch to cigarettes or become poly-users (0.05 annual rate)
 - *Only allowed for individuals under age 30.
 - Smokers taking up hypothetical new product (0.03 annual rate)
 - Half switch completely
 - Half become dual users

Adult Cigarette Smoking Prevalence



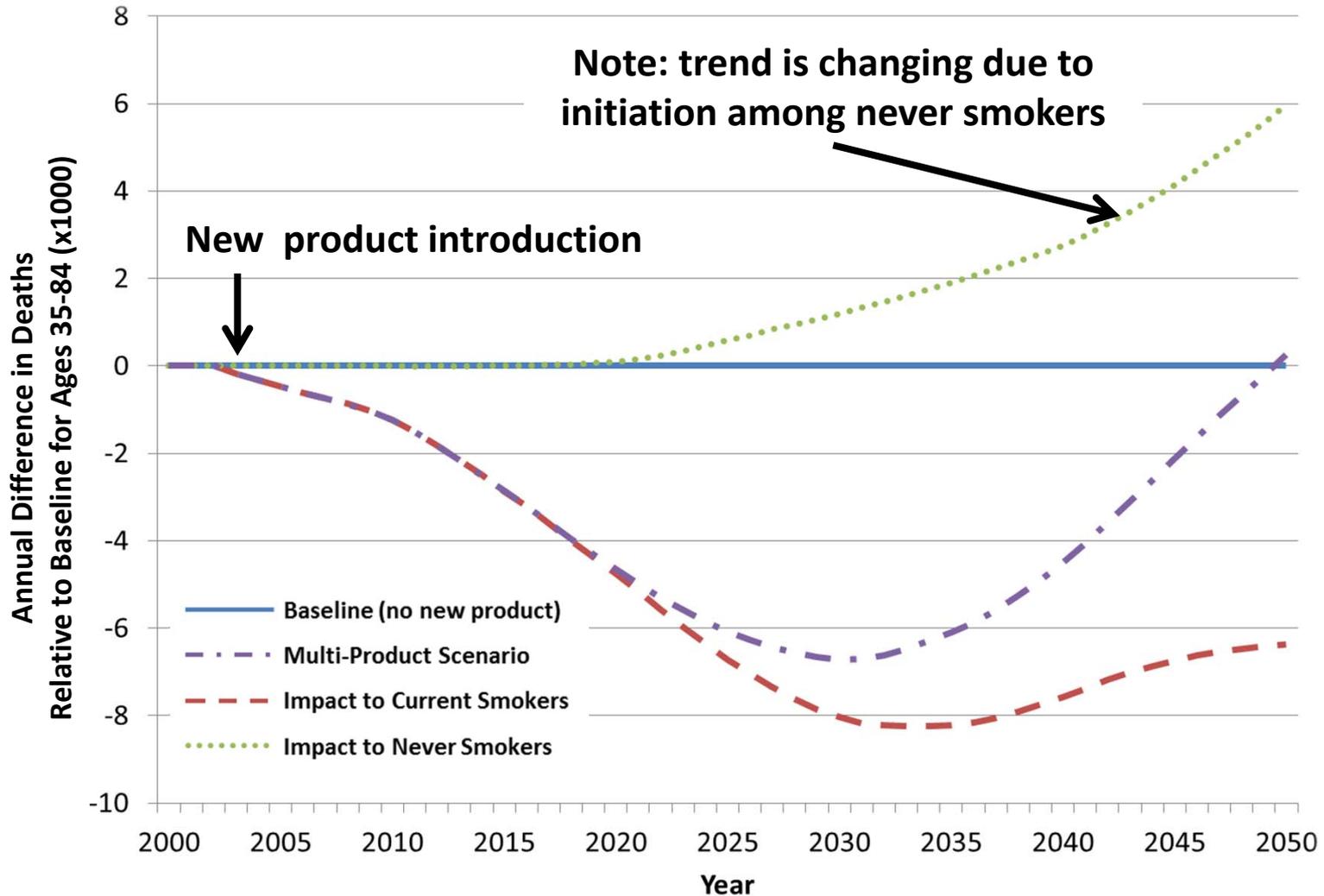
Adult Prevalence: Total Product Use



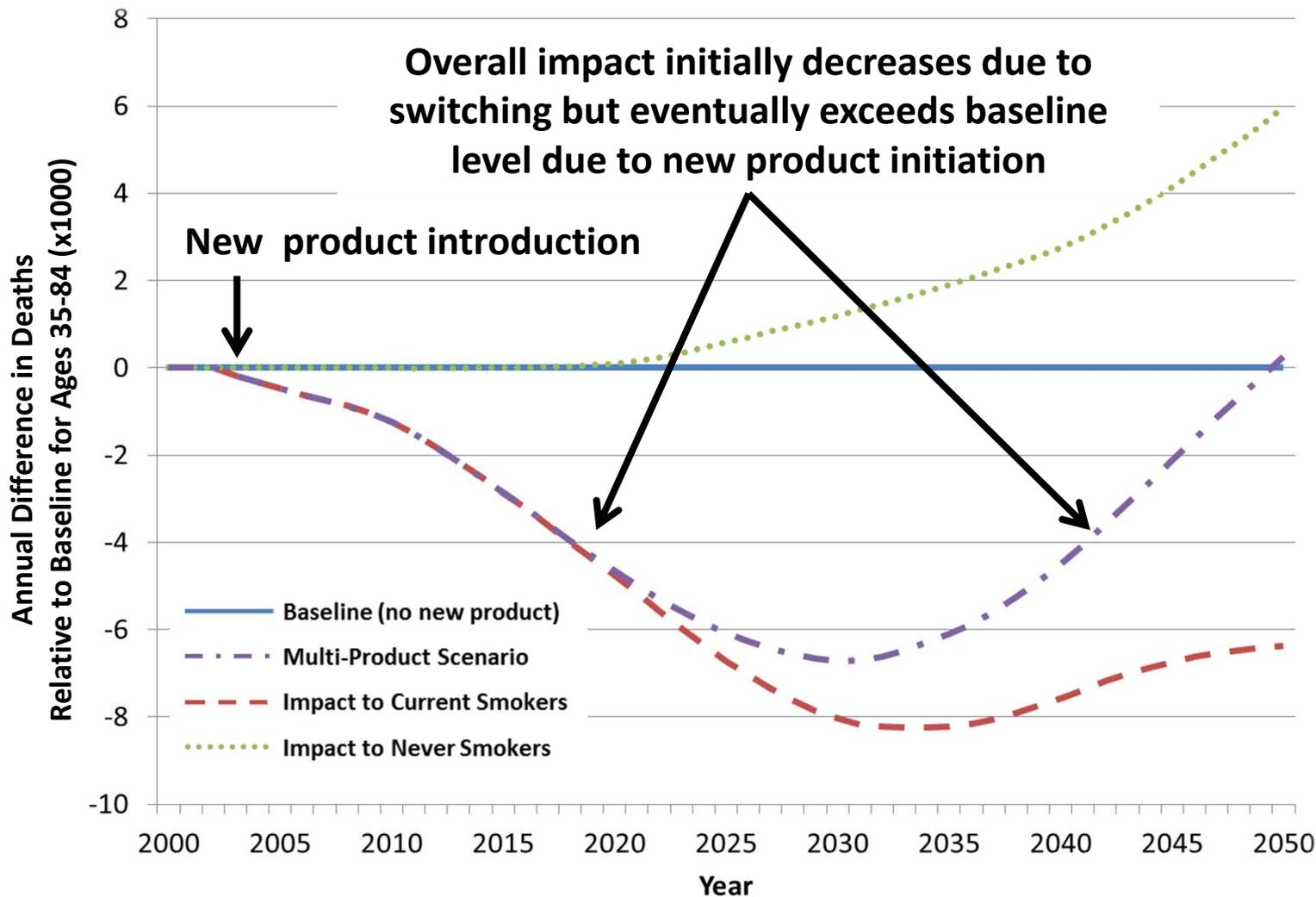
Scenario Legend

- **Baseline** —
 - No new tobacco product
- **Multi-Product Scenario** — . — .
 - **Impacts to current smokers** — — —
 - Allow current smokers to switch or become poly-users
 - No new product initiation among never smokers
 - **Impacts to never smokers** •••••
 - Never smokers may initiate and switch to smoking or become poly-users
 - No switching or poly-use from current smokers

Annual Change in Deaths due to Alternative Product Use



Annual Change in Deaths due to Alternative Product Use

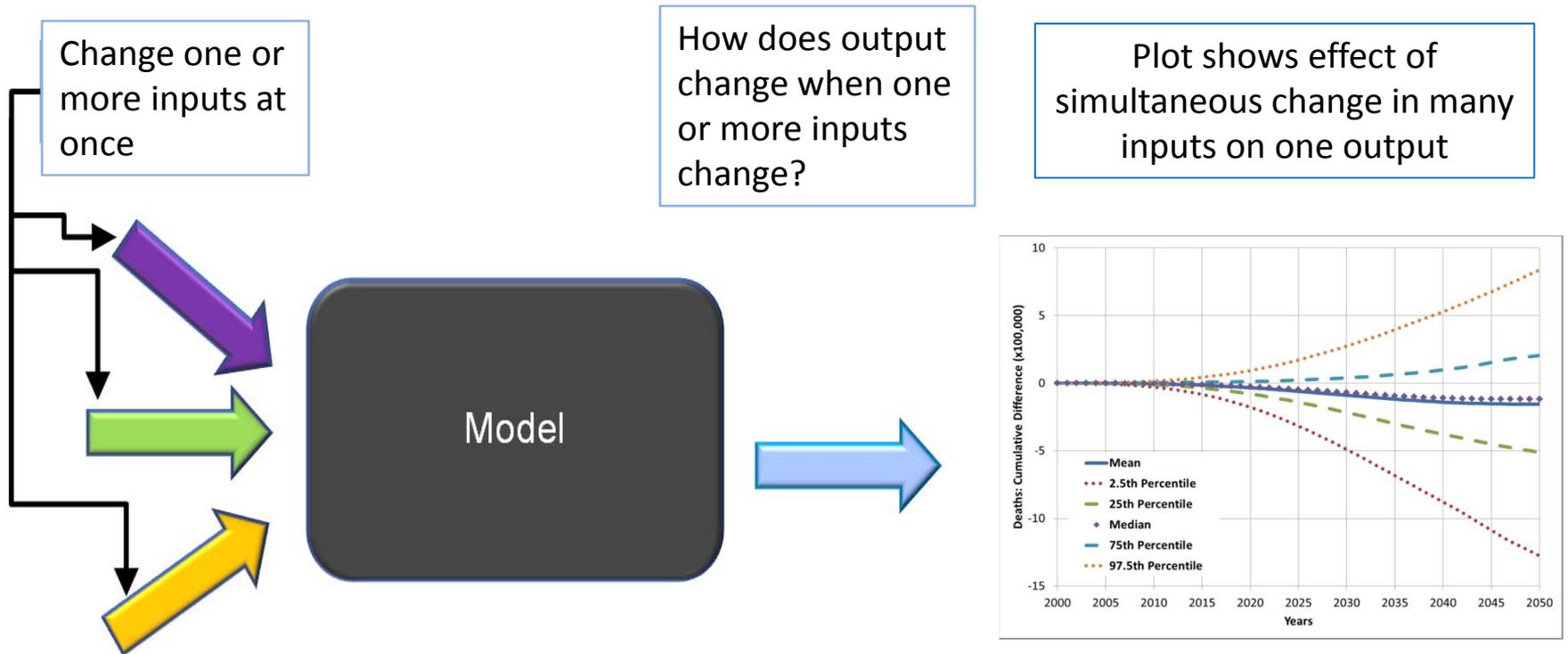


Uncertainty

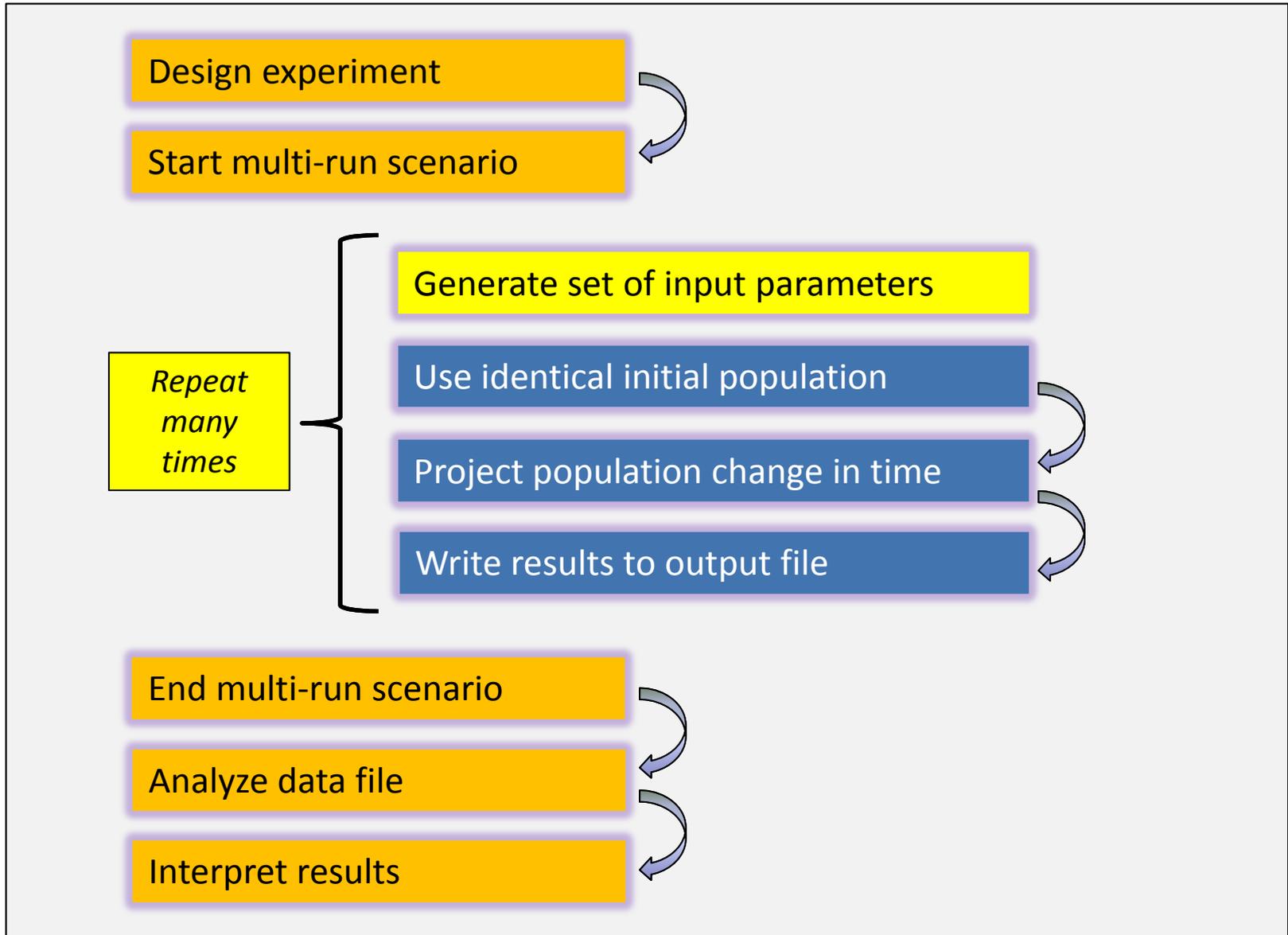
- We do not know exact parameters for future products
 - Previous results have not accounted for parameter uncertainty
- Including uncertainty
 - Single parameter sweep
 - Multiple variables (Latin hypercube design)

Sensitivity Analysis

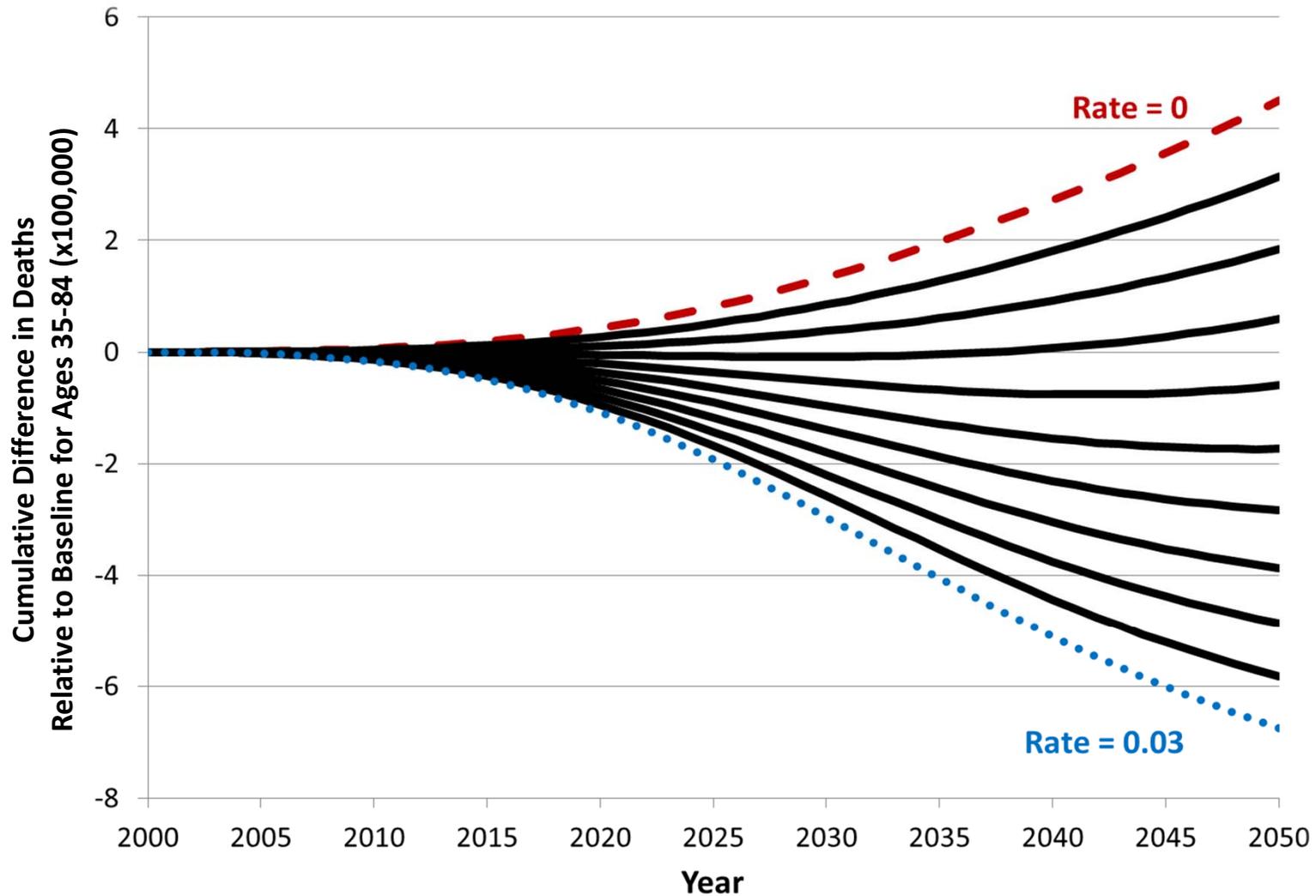
Analyze effect of one or more uncertain inputs on output values*



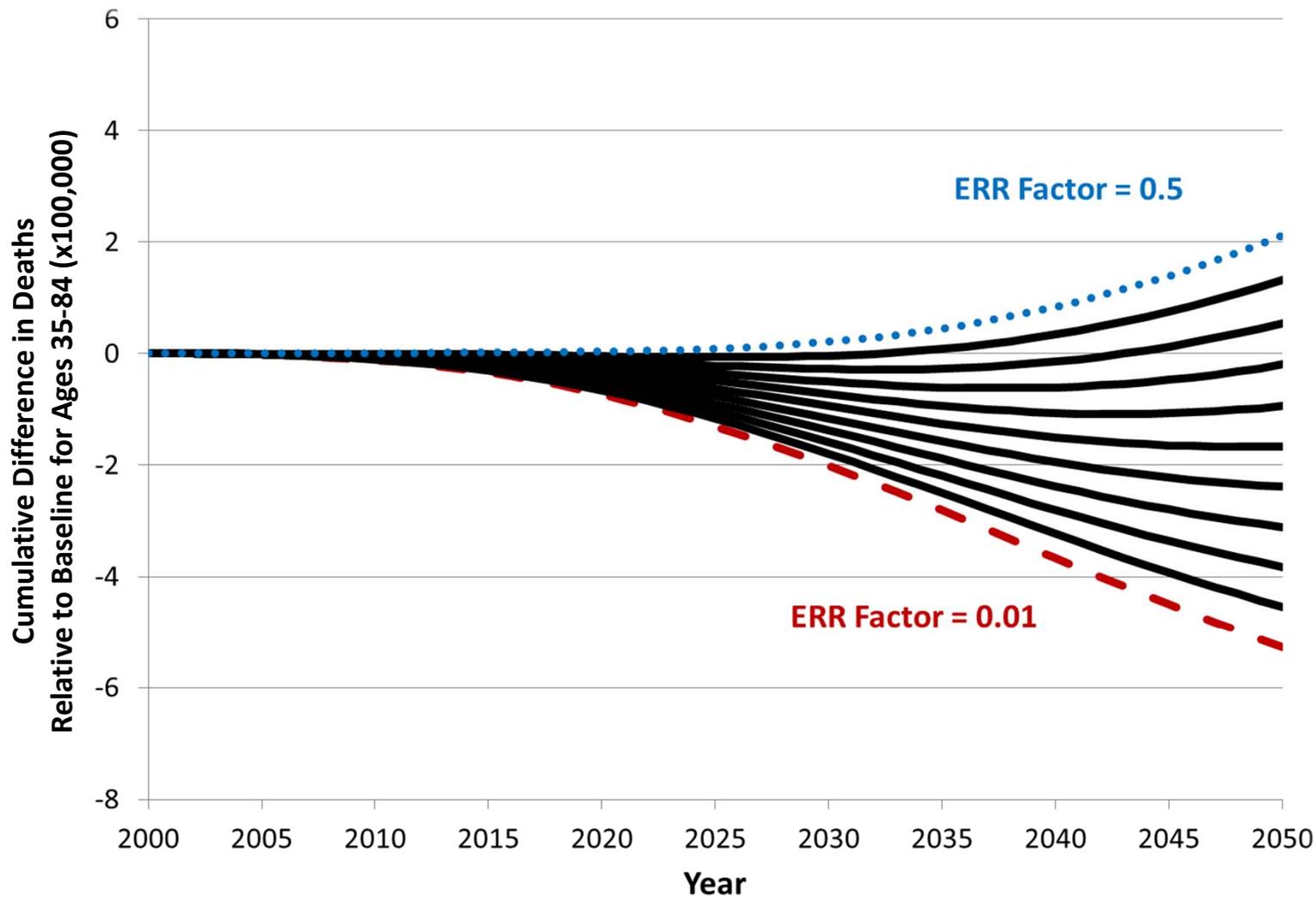
Uncertainty Analysis Process



Change in Deaths: Cigarette-to-New Product Annual Switching Rate



Change in Deaths: New Product Excess Relative Risk

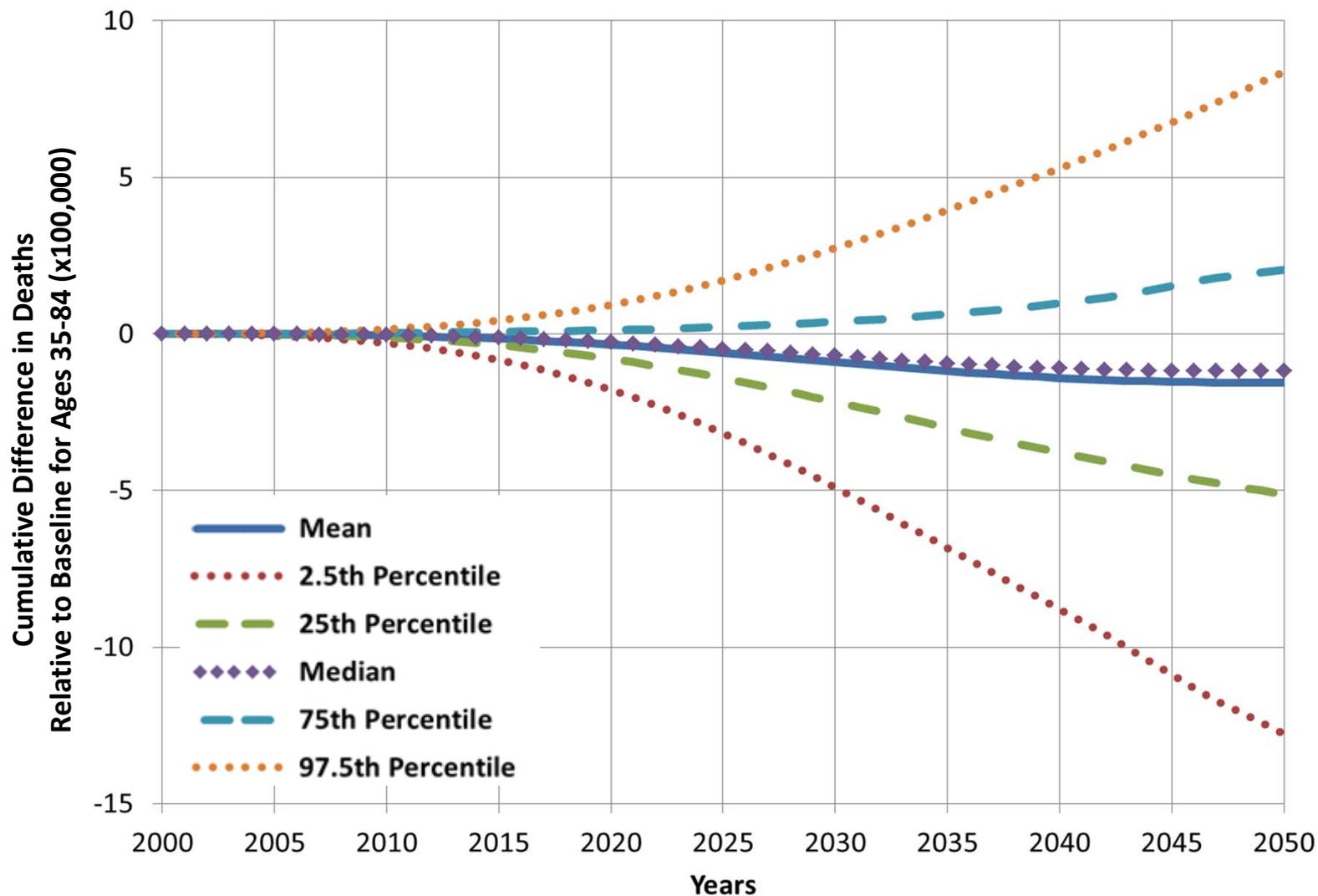


Hypothetical Parameter Values and Ranges for Monte Carlo Simulation

Parameter Description*	Base Value	Distribution Range
Health Risk of the New Product		
New product excess relative risk (RR-1) factor - ERR_{Factor}	0.25	(0.01, 0.5)
Impact on Current Smokers		
Annual proportion switching from cigarettes to new product	0.015	(0, 0.03)
Annual proportion transitioning from cigarettes only to dual use	0.015	(0, 0.03)
Proportion of switchers and new dual users who would have otherwise quit smoking that year	0.25	(0, 0.5)
Impact on Never Smokers		
New product initiation rate scaling factor	0.5	(0.25, 0.75)
Proportion of new product initiates that would have otherwise initiated cigarettes	0.5	(0.25, 0.75)
Annual proportion switching from new product to cigarettes	0.05	(0, 0.1)
Annual proportion transitioning from new product to dual use	0.05	(0, 0.1)

**All other parameters are held at fixed values.*

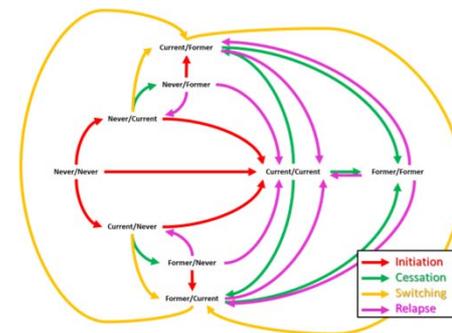
Change in Deaths: Multivariate Monte Carlo with LHS Design



These scenarios were created using hypothetical values to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.

Summary

- Multi-product models are needed to assess a changing marketplace
- Previous cigarette-centric models provide an effective technical foundation for multi-product model development
- Our approach provides a flexible framework for multi-product analysis
- Future challenges
 - Need to shift focus to multi-product analyses – reflecting current market conditions
 - Data challenges: data needs increase exponentially
 - Multi-product transitions
 - Cause-specific mortality
 - Morbidity



Questions