“A hands-on, case-study demonstration of the modeling process, from problem definition to policy implications”

International Conference of the SDS

July 25, 2012

Sacrificed for the sake of feasibility:

- State of the art in simulation models on cigarette smoking
- Discussion of the **modeling process**
- Ingredients to **problem definition**
- Model development (**model building** and formulation)
- Deriving the parameter values such that the model is initialized in **analytical equilibrium**
- **Automation** tools and procedures for sensitivity analysis and calibration
- **Monte Carlo** simulations and **Latin Hypercube** sampling techniques
- Calculation and interpretation of **Theil statistics** used in behavioral reproduction tests (BRTs)
- Other forms of **model testing and evaluation**

“Four lessons from hands-on exercises based upon a case study”

Sensitivity simulations

calibration to empirical data

story telling and

policy implications

What you will get out of this workshop:

1. How to distinguish pattern (*vs*. numerical) sensitivity
    - Types of sensitivity analysis
2. Calibration does not equate with validation
    - Model testing; confidence building
    - Exercising judgment and choice
3. The importance of having a theory and being consistent in telling a story
    - Dynamic hypothesis
    - Shifting loop dominance
4. Extracting policy implications (vs. making forecasts)

Plan for the day

Morning

8:30 – 10:00:

- Get started
- Single parameter sensitivity simulations
- Interpret results

10:30 – 12:00:

- Two-parameters S.S.
- Types of sensitivity analysis

Afternoon

1:00 – 2:30:

- Calibration
- Model testing, confidence building (*vs.* validation)

3:00 – 4:30:

- Story telling (societal lifecycle of smoking)
- Story verification (PPM)
- Policy implications

Brief introductions

Instructors:

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Participants:

…

Simulation software

Vensim PLE (Personal Learning Edition) is free for educational use. You can read about it at:

http://www.vensim.com/venple.html

We included the installation file of version 6.0 (both for Windows XP/Vista/7 and for Macintosh OSX 10.4+) in the thumb drive that is being circulated with the rest of the workshop materials.

It can also be downloaded from:

http://www.vensim.com/freedownload.html

Lesson 1

Sensitivity simulations

Base run for sensitivity simulations

Using the model SLCCS v.1:

- Simulate the model in equilibrium

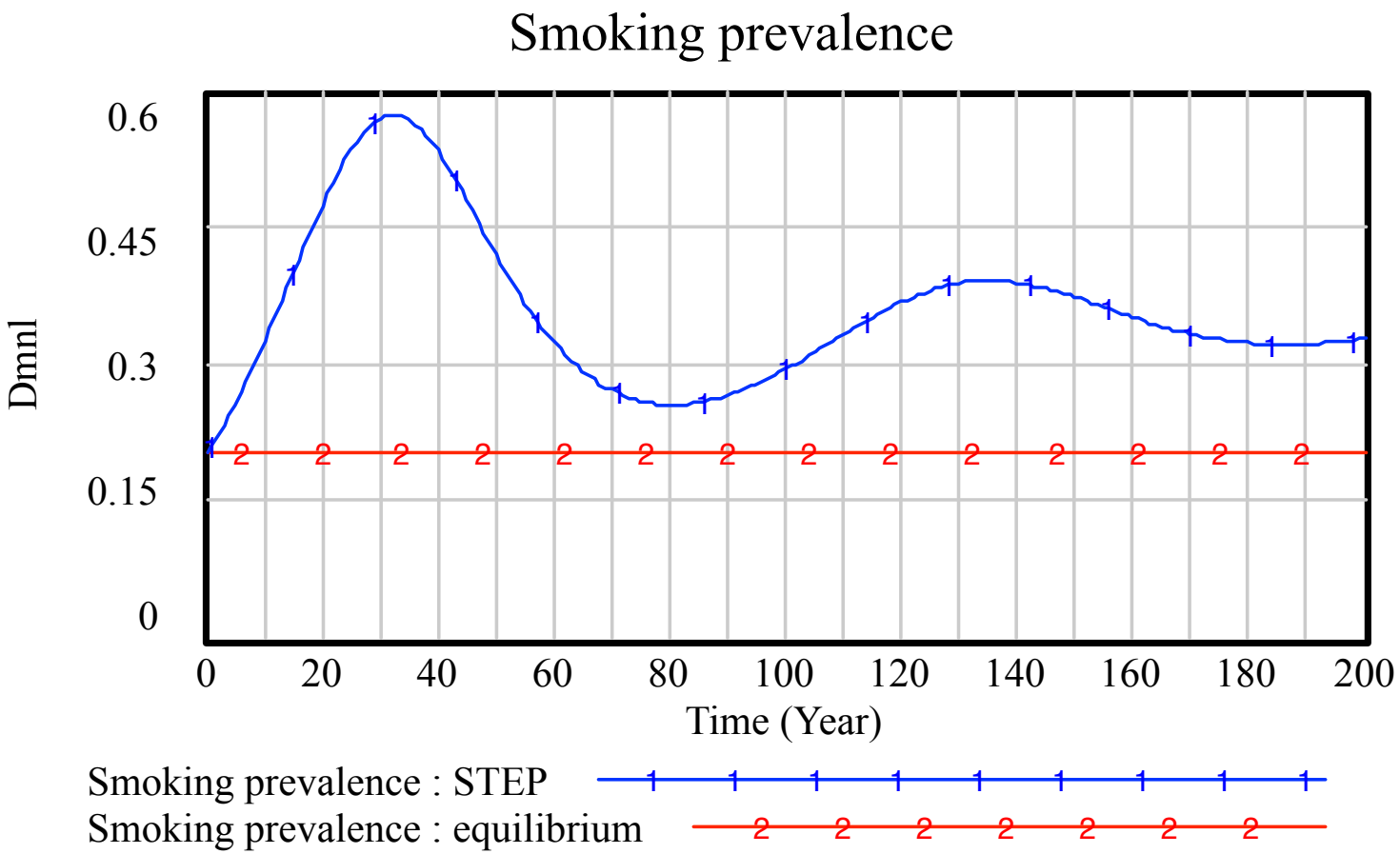
  STEP = 0

- Simulate the model with a disturbance from equilibrium

  STEP = 0.2

- Verify that your results are similar to the results in the following slide

Equilibrium *versus* STEP



Parameter values derived for analytical equilibrium

Parameters	Values in analytical equilibrium	"Arbitrary" ranges (half & double)
Initial P (smoking prevalence)	20%	10% – 40%
Initial K (awareness of health consequences)	0.28	0.14 – 0.56
Normal IR (initiation rate)	0.1389	0.07 – 0.28
Normal CR (cessation rate)	0.072	0.036 – 0.144
Time to manifest health consequences	25 years	12 – 50 years
Time to forget	35 years	17 – 70 years
"Elasticity" of initiation	1	0.5 – 2
"Elasticity" of cessation	1	0.5 – 2

Mechanics for manual sensitivity simulation

1. Give the run a name, e.g., "Initial P min"
2. Use *Sinthesim* button ("Automatically simulate on change") 
3. Slide parameter lever to extreme range value, e.g., minimum value for "Initial P"
4. While in *Sinthesim* mode, move your mouse over the variables in the model to see the pattern of behavior resulting from this parameter change
5. Click on "Stop" 
6. Change the run name, e.g., "Initial P max"
7. Click on *Sinthesim* button ("Automatically simulate on change") 
8. Slide parameter lever to the opposite extreme range value for the given parameter, e.g., maximum value set "Initial P"
9. Again, move your mouse over the variables in the model to see the changes in the pattern of behavior
10. Click on "Stop" 
11. Click on the parameter changed, then click on the "Graph" button, to check if the changes were captured correctly 
12. Click on a variable of interest (e.g., "Smoking prevalence") and use the "Graph" button to display the patterns resulting from your sensitivity simulations 

Summary table of the sensitivity of prevalence to each of the parameters, varied one at a time

Parameters	Amplitude of oscillations	Frequency of oscillations	Final value	Pattern of behavior
Initial P	Not sensitive	Not sensitive	Not sensitive	Not sensitive
Initial K				
Normal IR				
Normal CR				
TTMHC				
TTF				
Initiation ε				
Cessation ε				

How sensitive is prevalence to parametric changes?

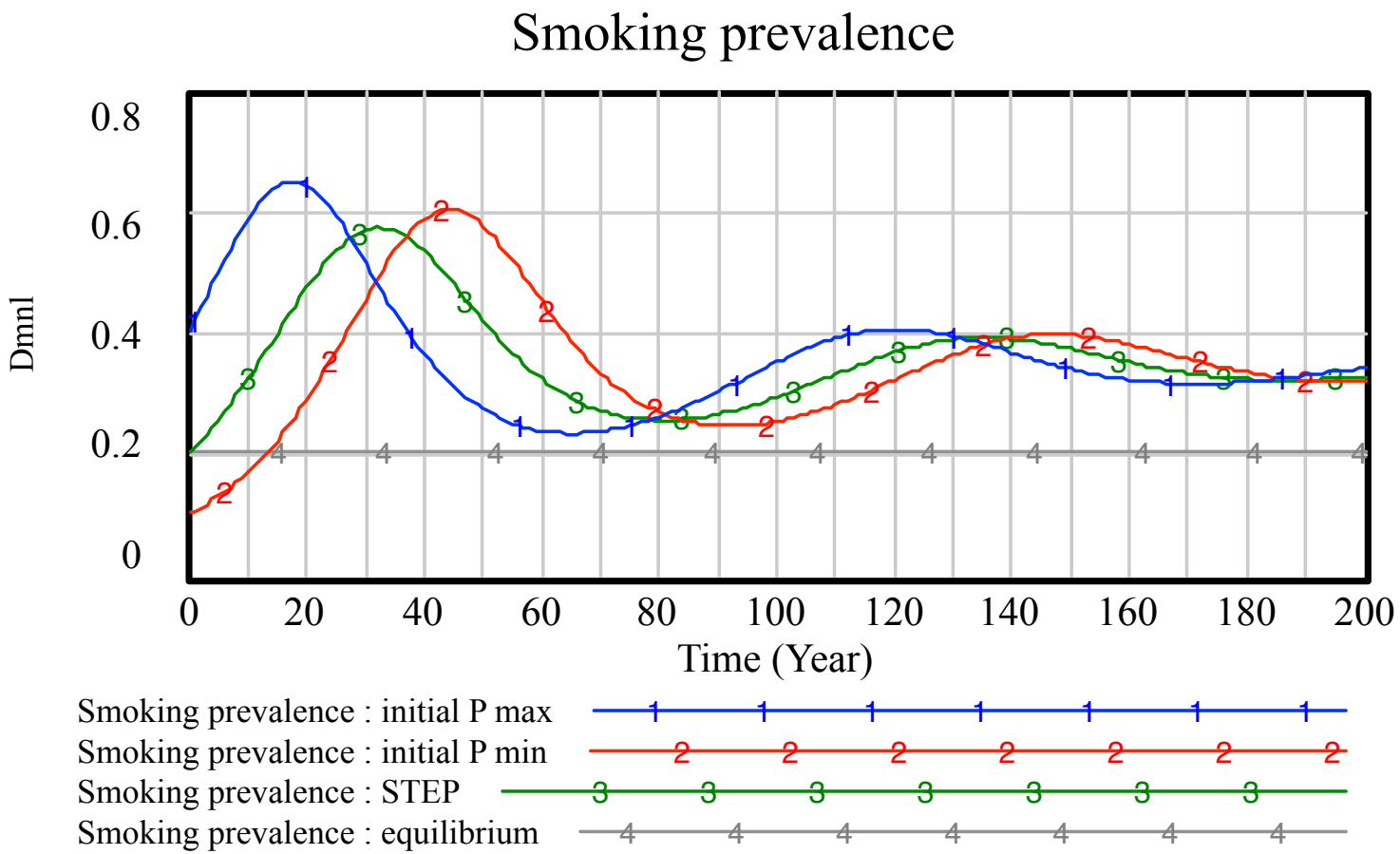
- Remember to base your sensitivity simulations in the simulation of the model that contains the disturbance from equilibrium! **STEP = 0.2**

Testing, evaluation and refinement

Keep in mind that sensitivity simulations are one form of model testing:

- In doing these simulations, what anomalies do you observe? Under what conditions?
- Is the model robust in the parameter space specified?
  - Awareness of model limitations
  - Perhaps, refinements are needed

Initial P (smoking prevalence)
Value = 20 %, Range 10-40 %



Two-parameters sensitivity simulations

Varying two parameters simultaneously:

- Min (A), Min (B)
- Min (A), Max (B)
- Max (A), Min (B)
- Max (B), Max (B)

Contrast a favorable scenario against an unfavorable scenario with respect to:

- Degree of instability during the transition period
- Value of prevalence in the new equilibrium state
- Resulting pattern(s) of behavior for prevalence

Types of sensitivity analysis

Sensitivity analysis is used for the following reasons:

- **Explore and test model behaviors during model building and refinement, to associate sensitivity in key variables to variation in parameter values**
- In formal model testing and analysis, it is used to explore the impact of the uncertainty that exists in the estimation of the parameter values upon:
  - The numerical results of the simulated variables
  - The patterns of behaviors of the variables of interest
  - The insights and practical implications extracted from the analysis, such as the robustness of the policy recommendations resulting from model-based analysis

Sensitivity analysis is key to testing simulation models, for the purpose of understanding model behavior, limitations and conducting refinements

- **In feedback-rich models (placing emphasis upon an endogenous treatment of phenomena), it is critical to distinguish pattern-sensitivity from numerical-sensitivity**

Lesson 2

Calibration to empirical data

Using model **SLCCS v2**

Following the instructions for manual calibration:

- Establish the values and ranges that you consider "appropriate" for the parameters
- Execute manual calibration using your intuition and the knowledge that you developed doing sensitivity simulations
- Present your results:
  - Your group's table with the chosen values and ranges
  - Label your manual calibration with your group name and copy onto thumb drive for comparison with other groups
  - Discuss:
    1. Do you agree with the simulated prevalence prior to 1970?
    2. Are the deviations between the simulation and the empirical data after 1970 of significance and import? Why? Why not?
    3. The process (Fun? Frustrating? Why?)
    4. The results (Is the fit good or bad? Why?)

Values of the parameters to execute manual calibration using empirical data (1900-2010)

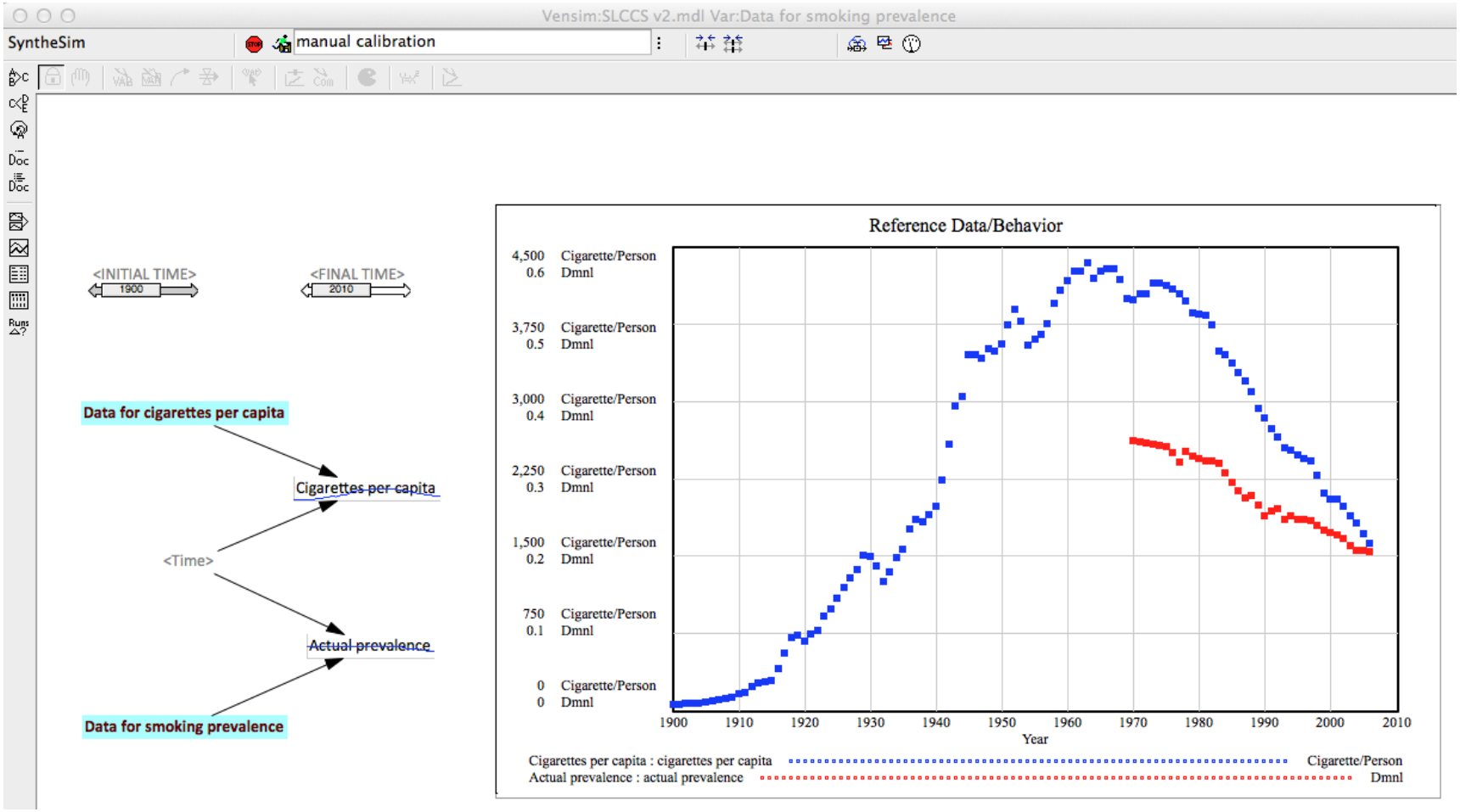
Parameters	Estimated value	"Appropriate" interval (degree of uncertainty)
Initial P (smoking prevalence)	…%	…% – …%
Initial K (awareness of health consequences)	…	… – …
Initial IR (initiation rate)	…	… – …
Initial CR (cessation rate)	…	… – …
Time to manifest health consequences	… years	… – … years
Time to forget	… years	… – … years
"Elasticity" of initiation	…	… – …
"Elasticity" of cessation	…	… – …

Procedures for manual calibration

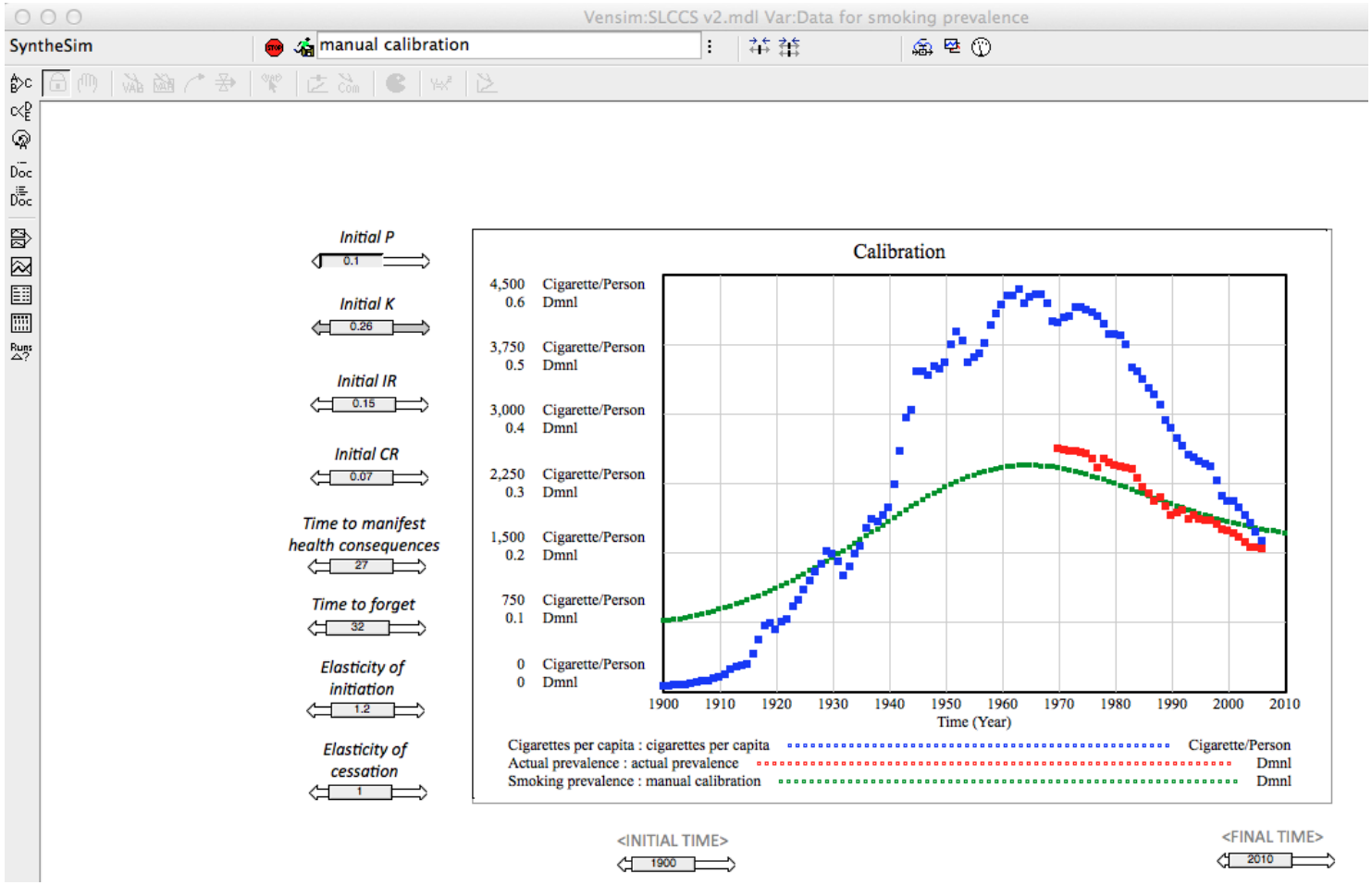
1. Introduce the empirical data in the model (see View "Reference Data/Behavior" in the model **SLCCS v2**)
   - Time series data for "Cigarettes per capita" (1900-2006)
   - Time series data for "Actual prevalence" (1970-2006)

   ➢ "Simulate" the empirical data
2. Establish the values and ranges for each of the parameters
   - It is important to estimate the values for the parameters and the degree of uncertainty using "appropriate" ranges!
3. Build a view in the model to execute and observe the results (see View "Calibration"):
   - Containing graph(s) with the simulated vs. empirical data
   - Containing the list of parameters that will be manipulated
4. Search for the best "fit" that can be obtained manipulating the set of parameters within the ranges established:
   - Use your intuition aided by
   - Your knowledge about the behavior of the model
   - Considering what you learned doing sensitivity simulations

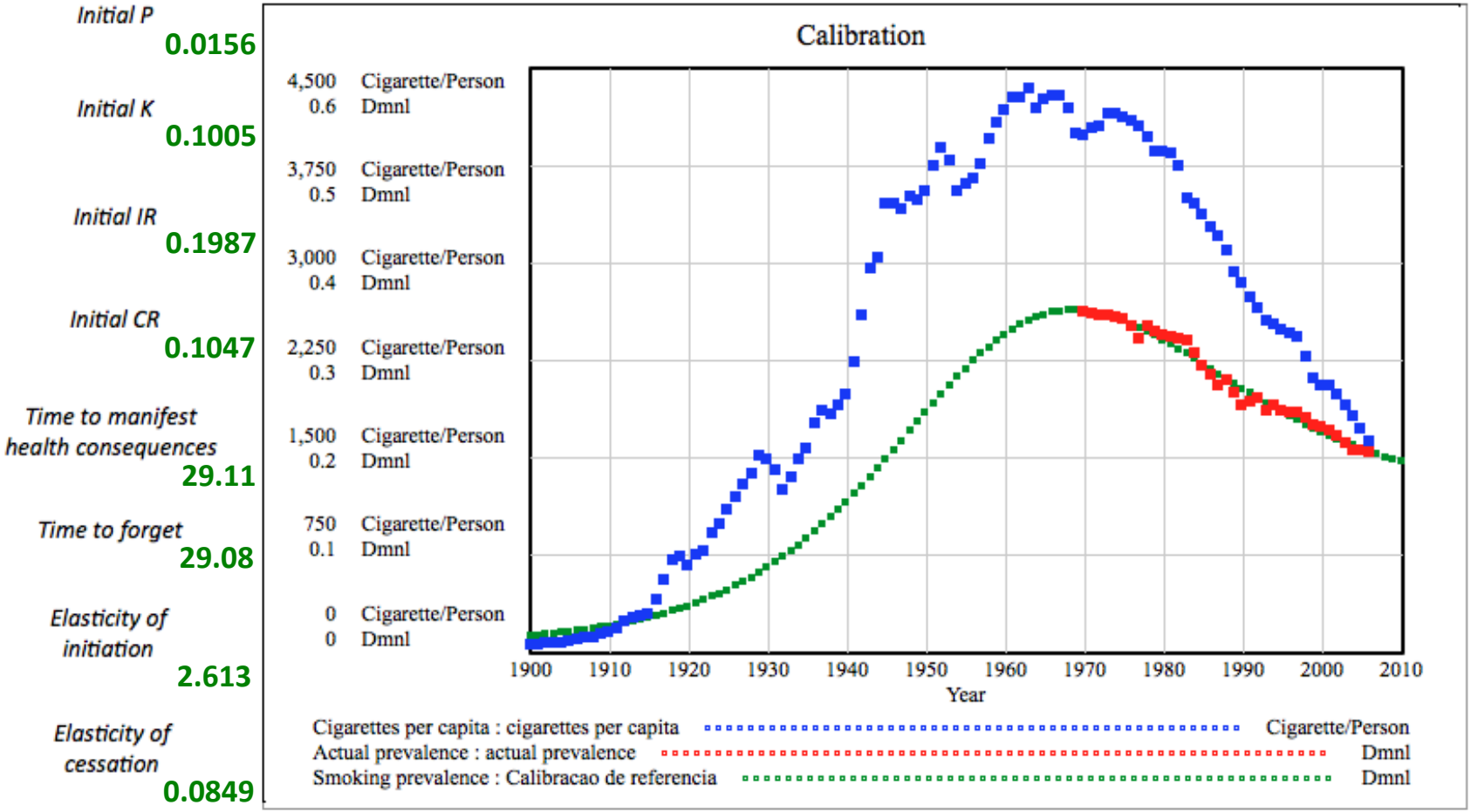
View “Reference Data/Behavior”



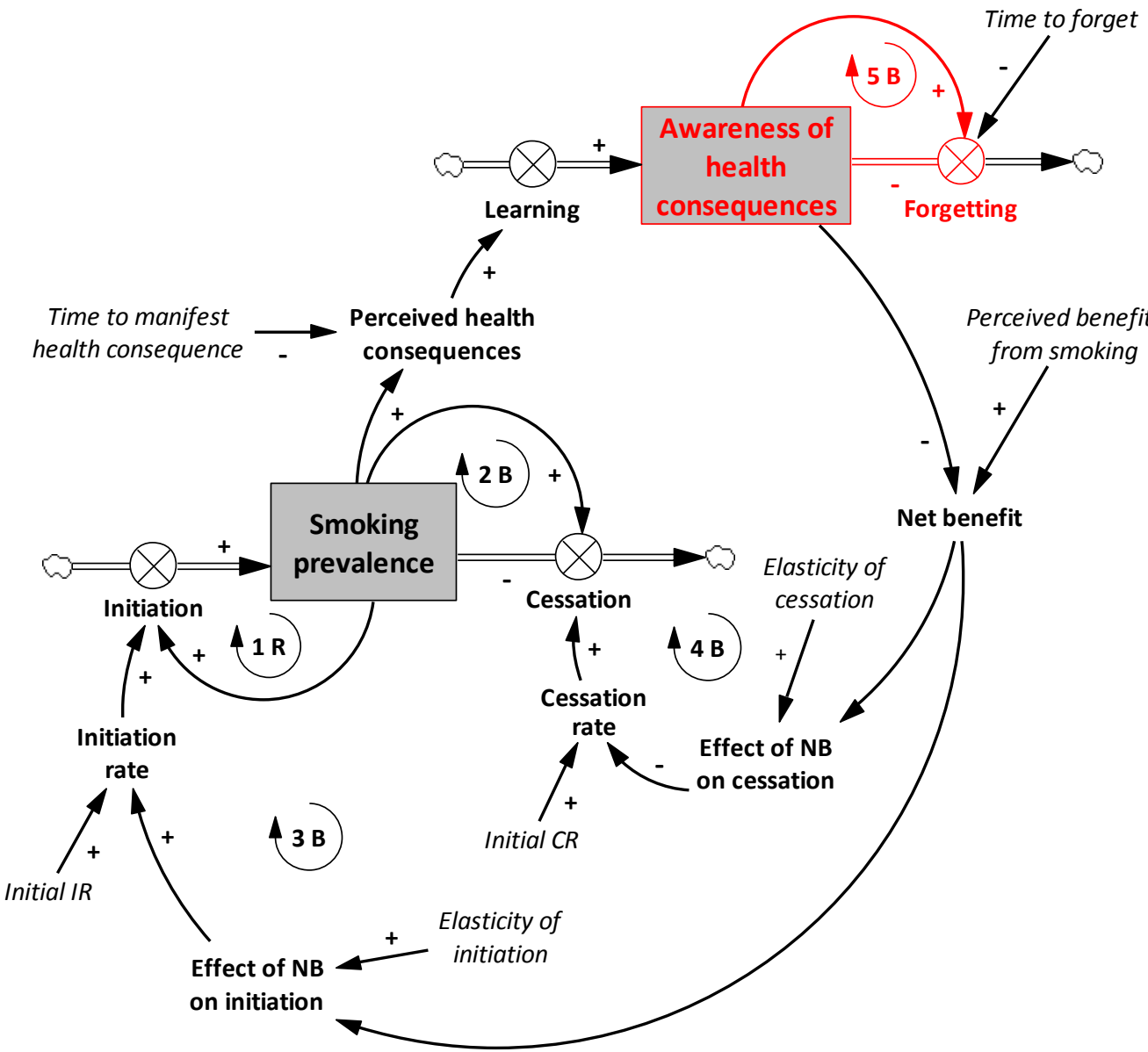
Result of ***one*** manual calibration



Result of an automated calibration



What if society does not forget?



Feedback loops:

1 – Reinforcing
"Initiation loop"

2 – Balancing
"Cessation loop"

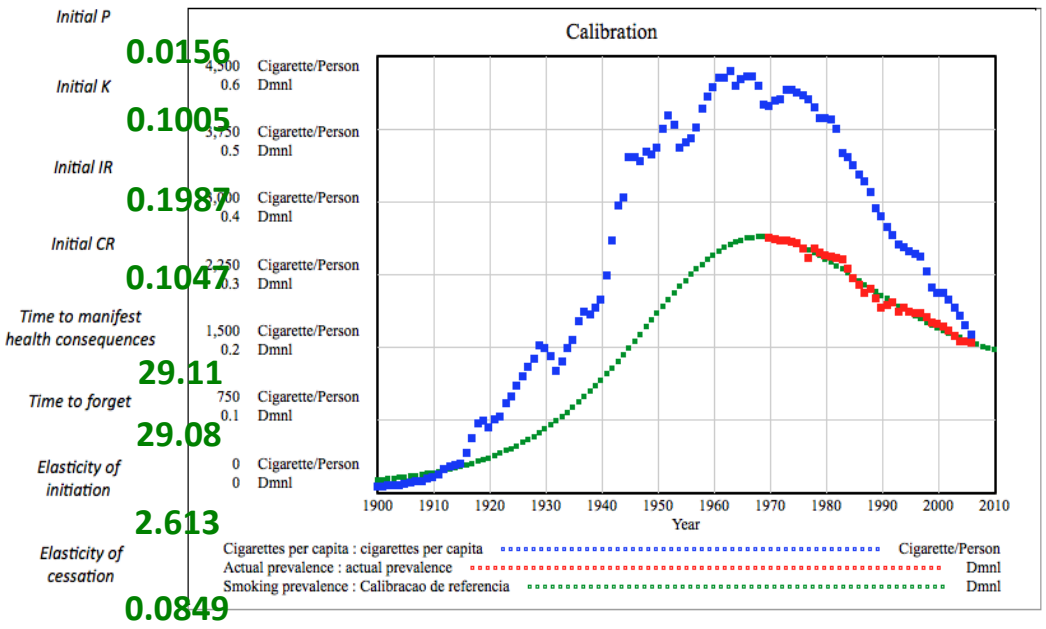
3 – Balancing
"Awareness curbs initiation"

4 – Balancing
"Awareness boosts cessation"

5 – Balancing
"Losing awareness"

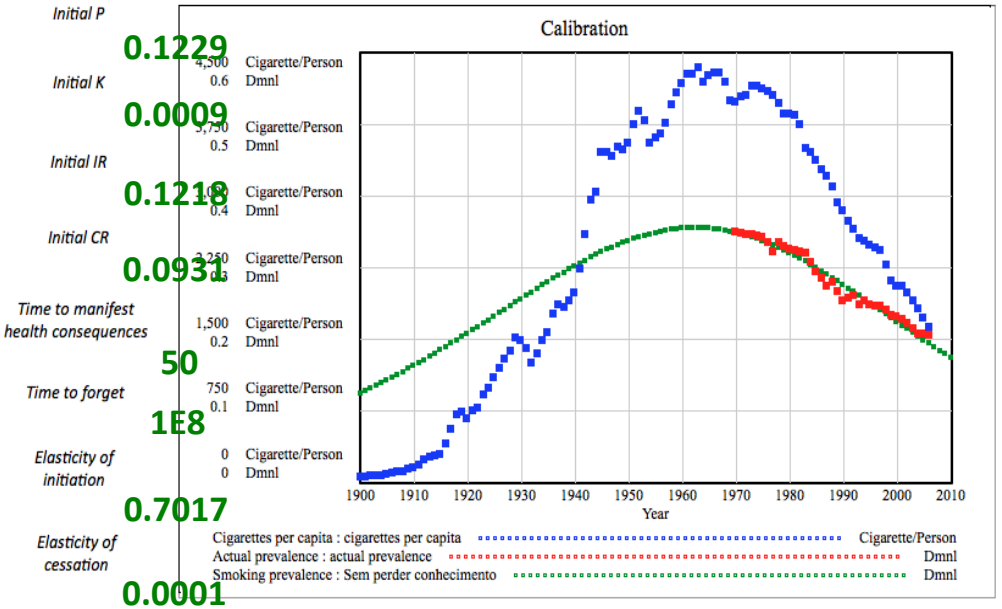
Re-do calibration without loop 5

- Make time to forget equal to 1e8
- See if you can find a good fit using the ranges that your group estimated for the parameters
- If not, try using parameters outside of the range values
  - Label this 2nd calibration with your group name and copy onto thumb drive for comparison with other groups
  - Discuss:
    1. Do you agree with the simulated prevalence prior to 1970?
    2. What is the future tendency for the variable prevalence?
    3. Which theory (hypothesis/story) would you tell? Why?
       - Can you be certain of it? Did calibration validate the theory?



Results with and without "losing awareness" loop

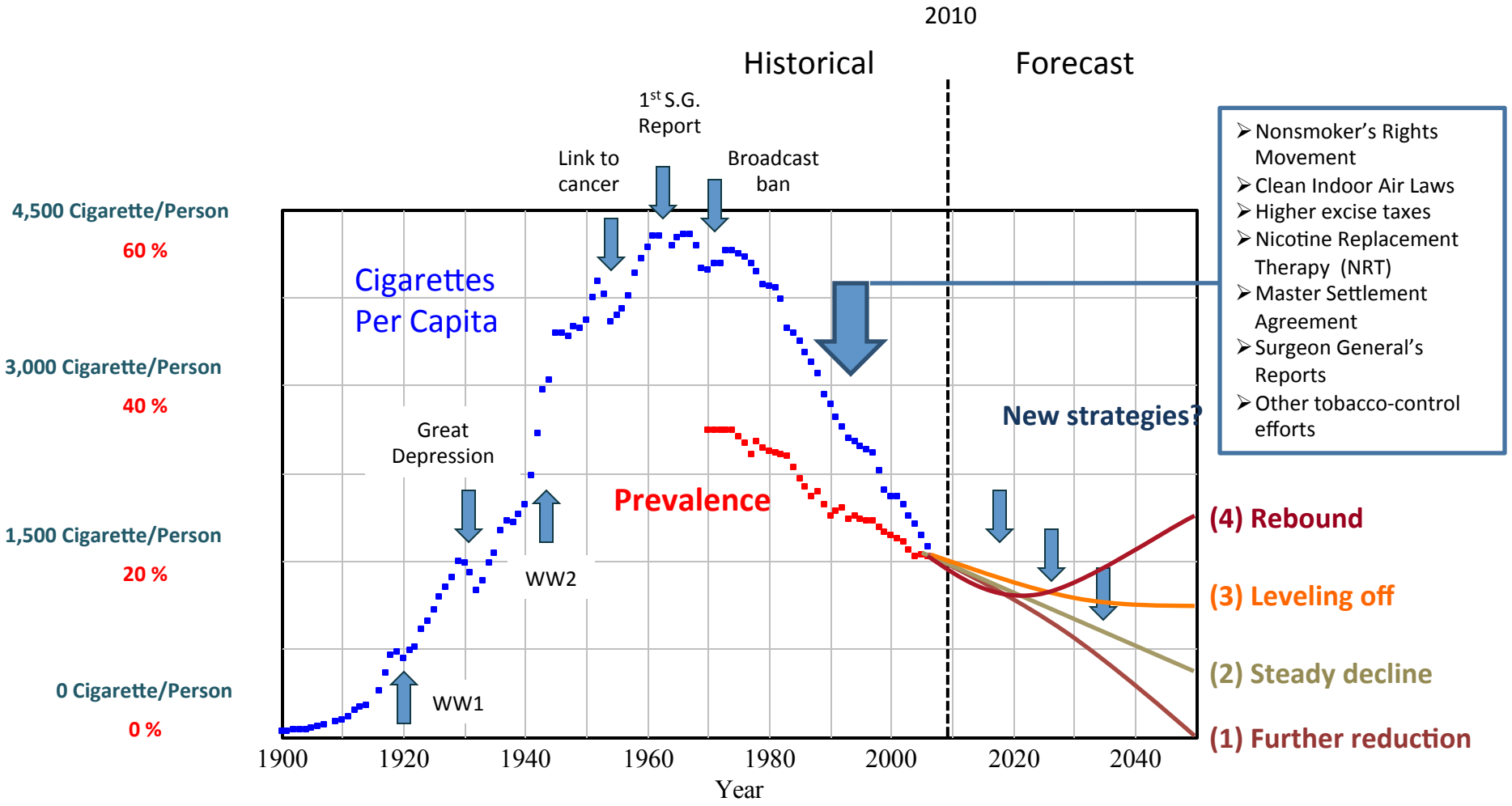
- Calibration is useful for model testing and confidence building (*vs.* validation)
- Which "story" to tell often involves judgment and choice!



Lesson 3

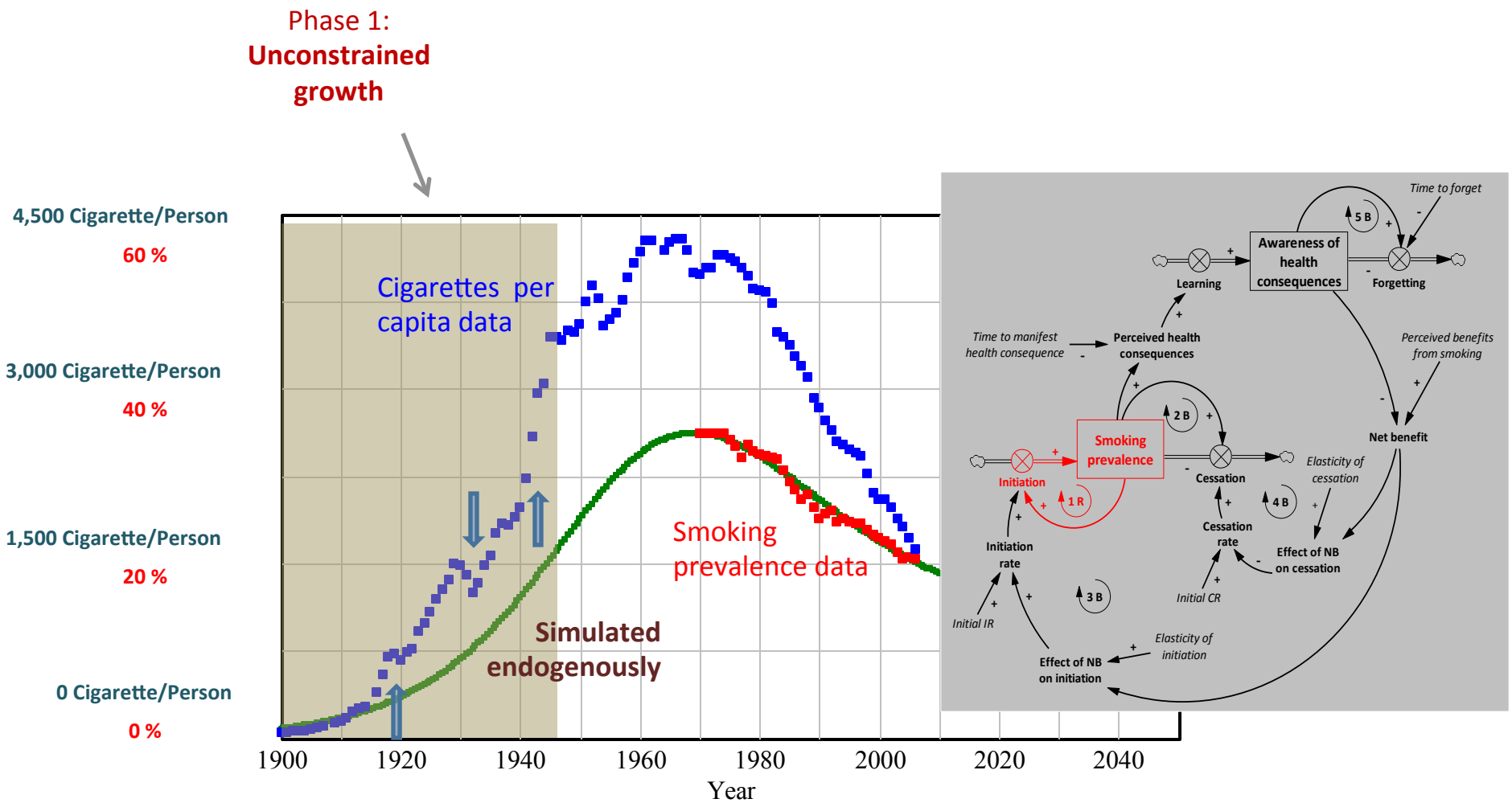
Story telling

Reference behavior and future scenarios (USA)



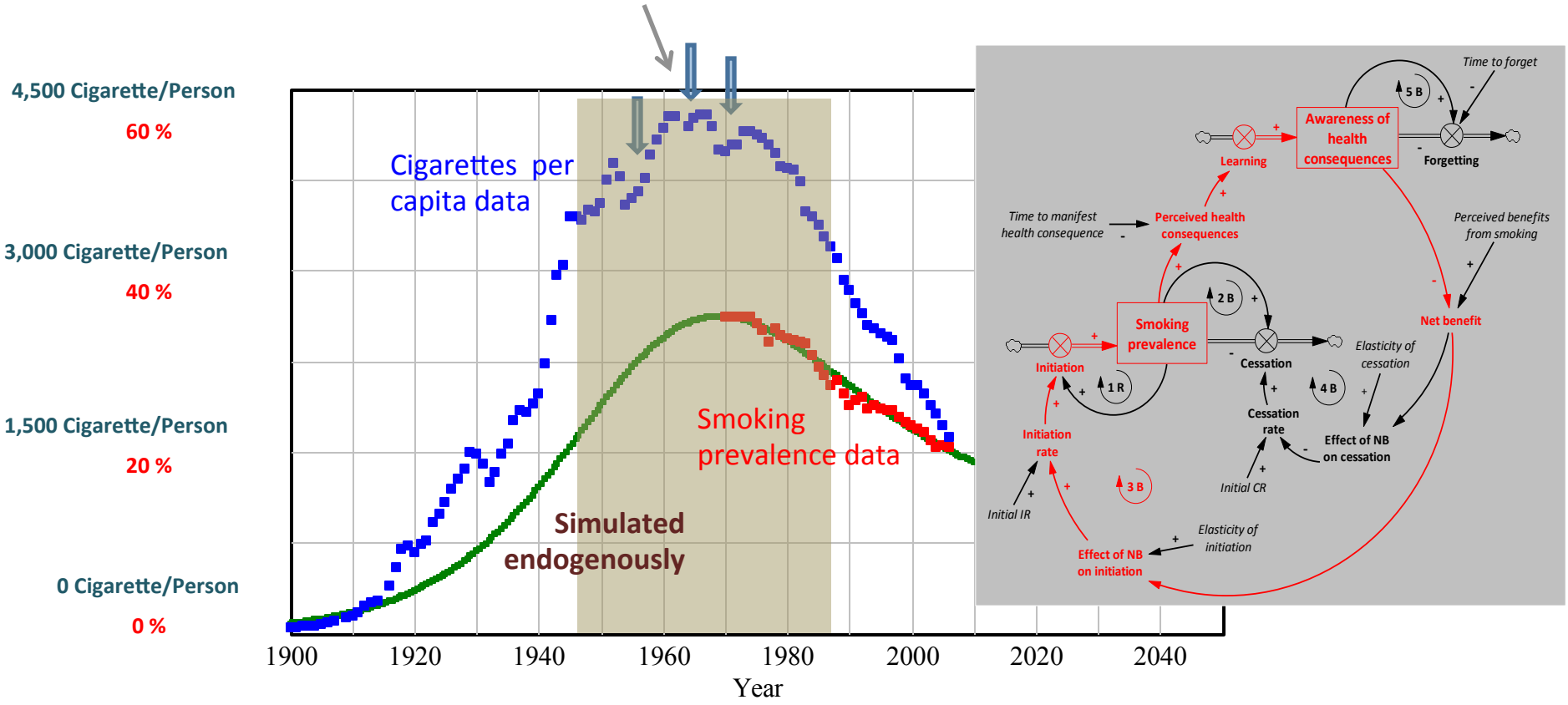
Data sources:
Cigarettes per capita - http://www.cdc.gov/tobacco/data_statistics/tables/economics/consumption/
Prevalence - David Mendez & Kenneth Warner, SGR Meeting (July 2010)

Analysis of the base run: Phase 1

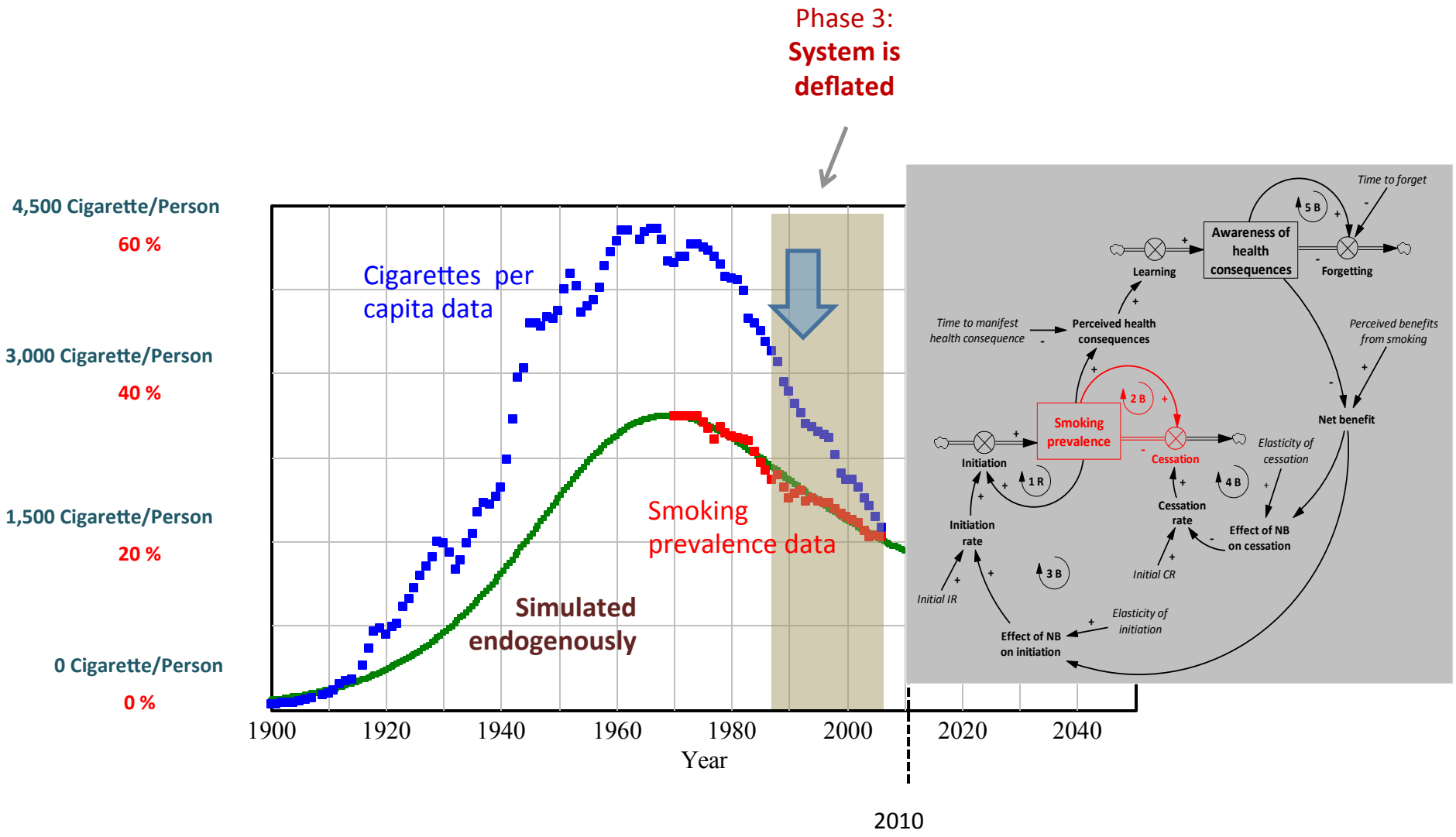


Analysis of the base run: Phase 2

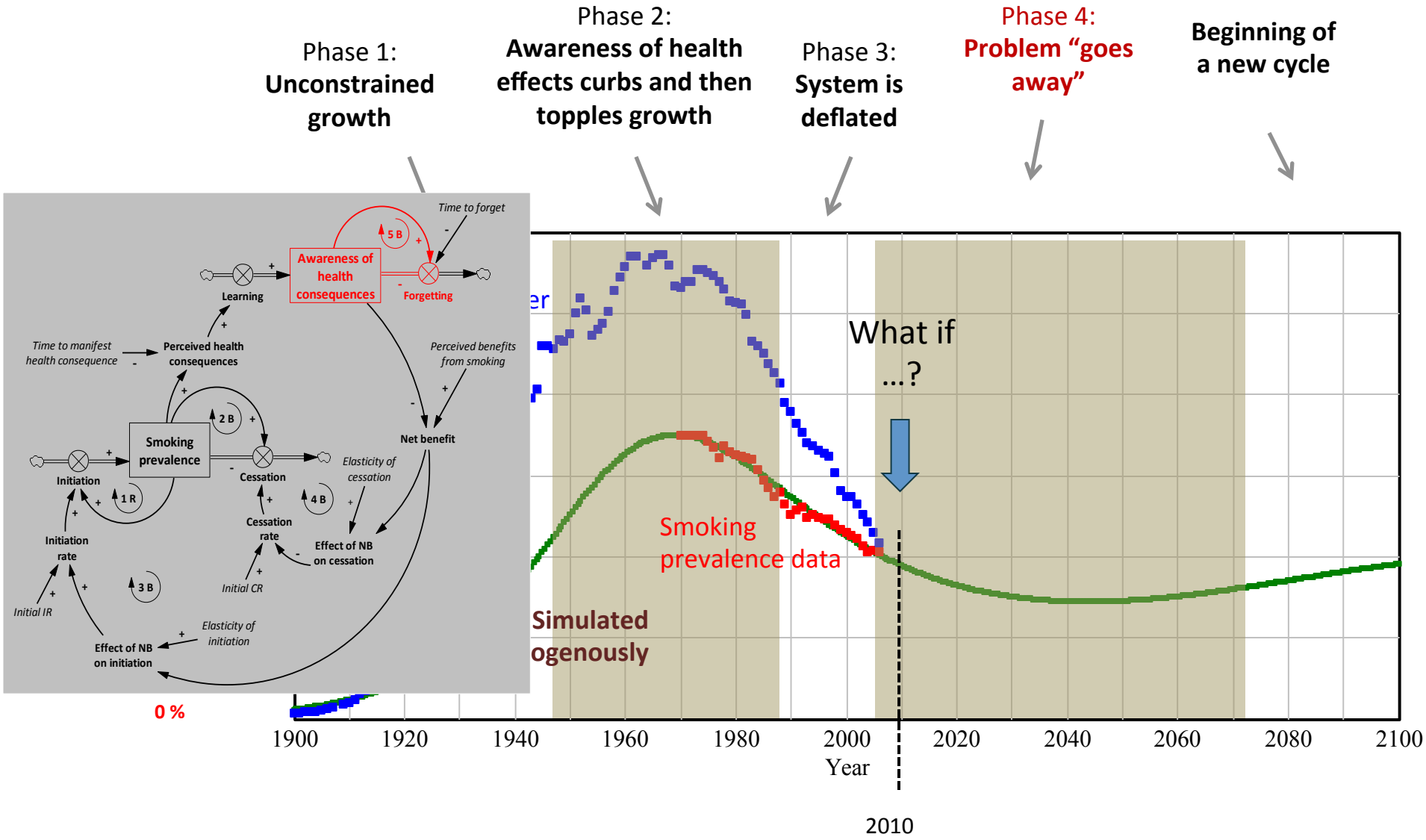
Phase 2:
Awareness of health effects curbs and then topples growth



Analysis of the base run: Phase 3



Societal lifecycle of smoking



Four “what if” scenarios

- What happens if we “reduce initiation?”

  Initiation fraction reduced by 20%

- What happens if we “increase cessation?”

  Cessation fraction increased by 40%

- What if we “lose focus?”

  Time to forget changed from 35 to 20 years

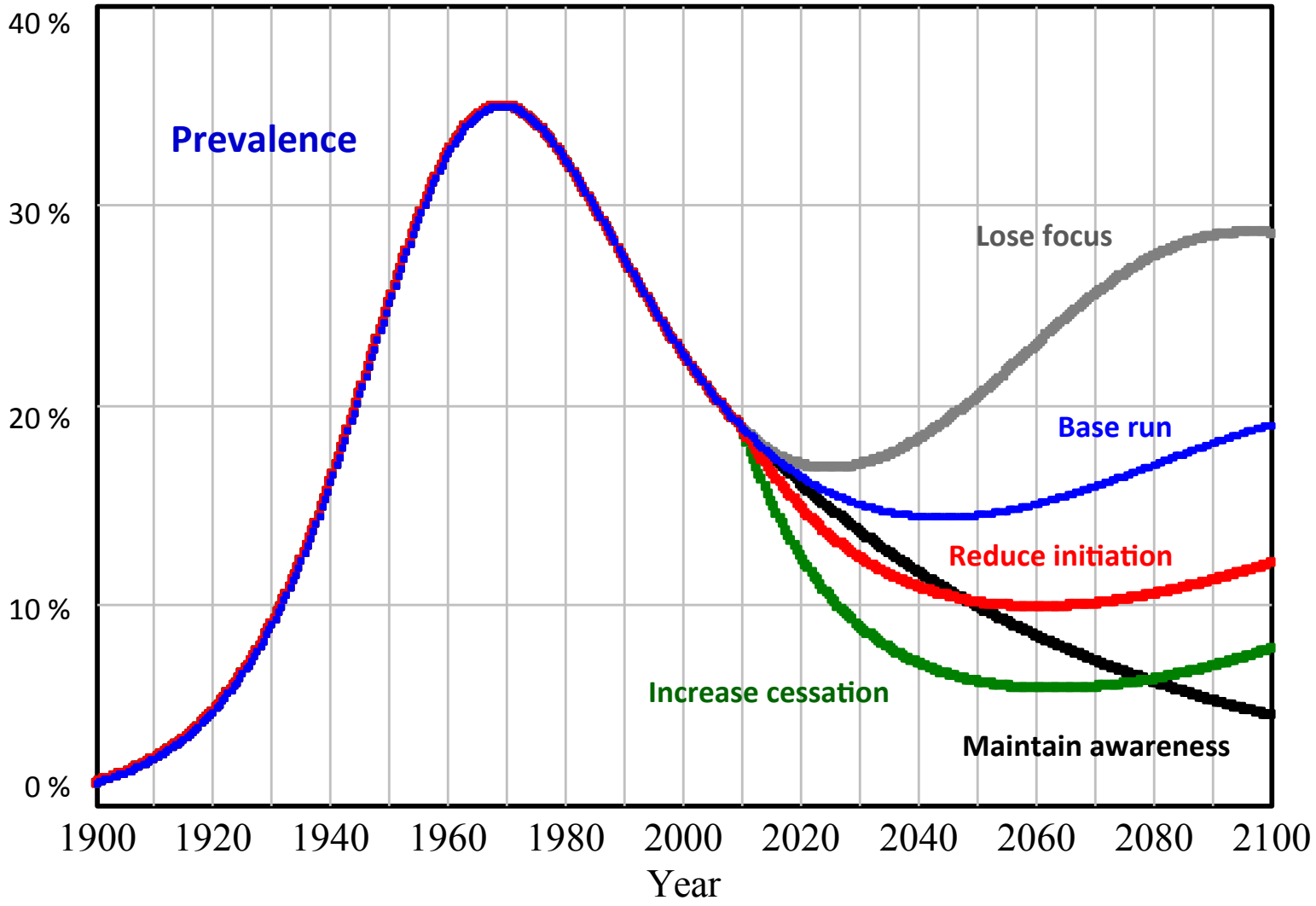
- What if we “maintain awareness?”

  Awareness fixed at 2010 level

(Predicated on all of these changes being implemented in 2010)

Four “what if” scenarios

(changes implemented in 2010)



Lesson 4

Policy implications

Policy implications

- Warning labels and other forms of institutionalization
- Use surveys to monitor awareness
- Account for possible impact of “reduced-risk” approvals on awareness
- Assess health consequences of new products and inform the public (known risks and uncertainty)
- Set a target for the level of prevalence
- Measure rates of change (initiation and cessation) as opposed to accumulation (prevalence)