# A Simplified Model of the Cost-Effectiveness of Screening: An Open-Source Teaching and Research Tool Coded in *R*

James O'Mahony, PhD[1], Yi-Shu Lin, MSc, MBA[1]

[1]Centre for Health Policy and Management, Trinity College Dublin.

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

# Conflict of Interest Declaration

None to declare

# Background

- Screening cost-effectiveness analyses models typically address specific policy questions.
- Tend to be large and complex.
- Not suited to teaching the fundamentals of screening modelling or demonstrating methods issues.

# Objectives

- To demonstrate a simplified pedagogical model of the cost-effectiveness of screening and explain its potential as a teaching and research tool:
    1. Teach the intuition of changing parameter values on screening cost-effectiveness for those without technical training;
    2. Basic modelling framework to train graduate students;
    3. Prioritising transparency over speed and elegance.

# Model description

## Input – Excel

1. Excel interface
2. Defines parameter values and screening strategies
3. Save values into files with VBA

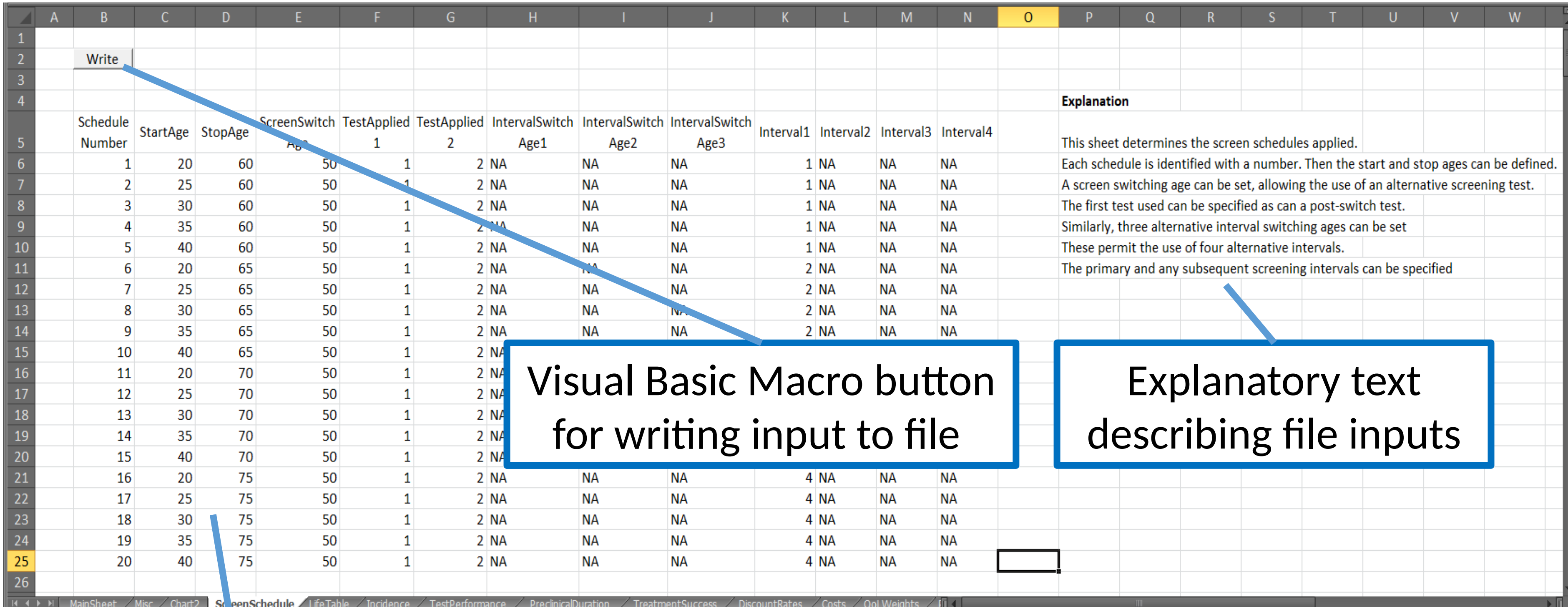
## Model – R

1. A de novo model: discrete event simulation
2. Structure is hard coded (currently)
3. Largely vectorised (with some loops)
4. Single file with markup: approximately 600 lines of code
5. Published in GitHub: https://github.com/yishu-lin/screeningmodel.git

## Output – Excel / R ShinyApp

R ShinyApp for exploration of results, options in visual interface

# Example of Excel inputs:
## specification of screening strategies



Write

| Schedule Number | StartAge | StopAge | ScreenSwitch Age | TestApplied 1 | TestApplied 2 | IntervalSwitch Age1 | IntervalSwitch Age2 | IntervalSwitch Age3 | Interval1 | Interval2 | Interval3 | Interval4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 60 | 50 | 1 | 2 | NA | NA | NA | 1 | NA | NA | NA |
| 2 | 25 | 60 | 50 | 1 | 2 | NA | NA | NA | 1 | NA | NA | NA |
| 3 | 30 | 60 | 50 | 1 | 2 | NA | NA | NA | 1 | NA | NA | NA |
| 4 | 35 | 60 | 50 | 1 | 2 | NA | NA | NA | 1 | NA | NA | NA |
| 5 | 40 | 60 | 50 | 1 | 2 | NA | NA | NA | 1 | NA | NA | NA |
| 6 | 20 | 65 | 50 | 1 | 2 | NA | NA | NA | 2 | NA | NA | NA |
| 7 | 25 | 65 | 50 | 1 | 2 | NA | NA | NA | 2 | NA | NA | NA |
| 8 | 30 | 65 | 50 | 1 | 2 | NA | NA | NA | 2 | NA | NA | NA |
| 9 | 35 | 65 | 50 | 1 | 2 | NA | NA | NA | 2 | NA | NA | NA |
| 10 | 40 | 65 | 50 | 1 | 2 | NA | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 11 | 20 | 70 | 50 | 1 | 2 | NA | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 12 | 25 | 70 | 50 | 1 | 2 | NA | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 13 | 30 | 70 | 50 | 1 | 2 | NA | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 14 | 35 | 70 | 50 | 1 | 2 | NA | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 15 | 40 | 70 | 50 | 1 | 2 | NA | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 16 | 20 | 75 | 50 | 1 | 2 | NA | NA | NA | 4 | NA | NA | NA |
| 17 | 25 | 75 | 50 | 1 | 2 | NA | NA | NA | 4 | NA | NA | NA |
| 18 | 30 | 75 | 50 | 1 | 2 | NA | NA | NA | 4 | NA | NA | NA |
| 19 | 35 | 75 | 50 | 1 | 2 | NA | NA | NA | 4 | NA | NA | NA |
| 20 | 40 | 75 | 50 | 1 | 2 | NA | NA | NA | 4 | NA | NA | NA |

**Explanation**

This sheet determines the screen schedules applied.
Each schedule is identified with a number. Then the start and stop ages can be defined.
A screen switching age can be set, allowing the use of an alternative screening test.
The first test used can be specified as can a post-switch test.
Similarly, three alternative interval switching ages can be set
These permit the use of four alternative intervals.
The primary and any subsequent screening intervals can be specified

MainSheet | Misc | Chart2 | ScreenSchedule | LifeTable | Incidence | TestPerformance | PreclinicalDuration | TreatmentSuccess | DiscountRates | Costs | QoLWeights

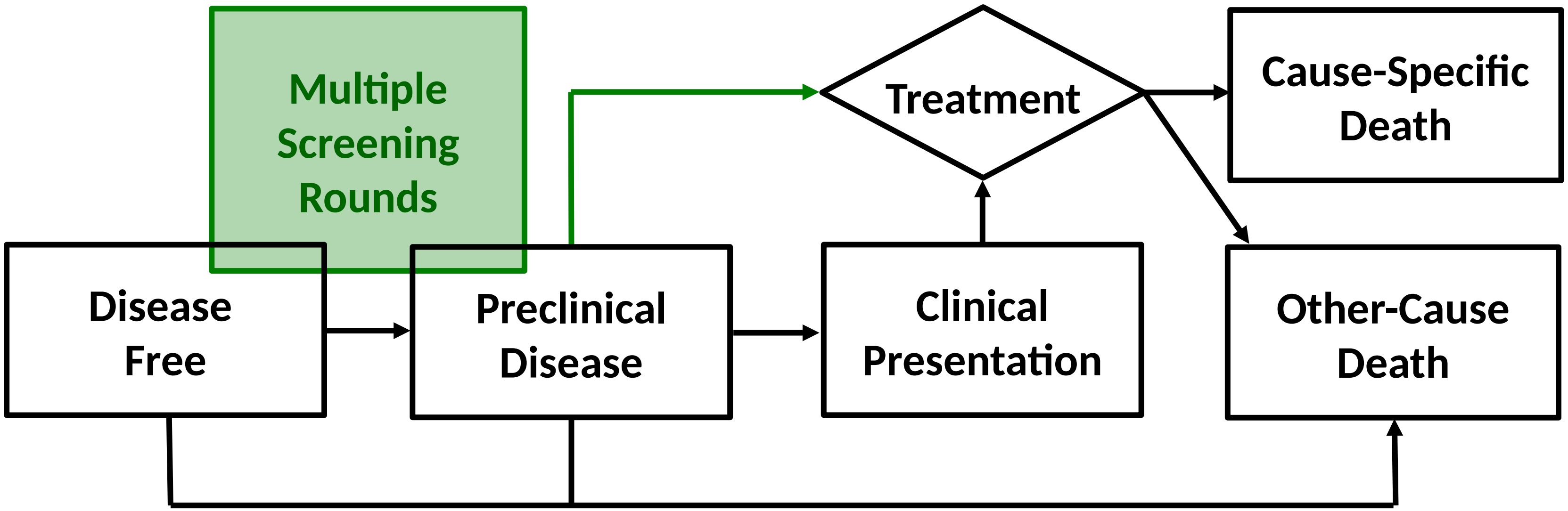
Visual Basic Macro button for writing input to file

Explanatory text describing file inputs

Specification of screening strategies

Tabs for defining other input parameters

# Model structure



# Simplifying assumptions

1. There can be only one lesion per lifetime.
2. The lesion has a single grade.
3. Screen test result is binary (healthy/sick).
4. Treatment outcome is binary (cured/uncured).
5. Cure is perfect.
6. Screening imposes no morbidity.
7. Triage testing is not explicitly modelled.

# Model application

**Starting Age**
- 20, 25, 30, 35, 40

**Stop Age**
- 50, 55, 60, 65, 70

**Screening Interval**
- 1-10 year

- We use an illustrative example of a CEA of 251 screening strategies:
- We use arbitrary illustrative values for disease incidence, preclinical duration, test performance, treatment effects and the costs of screening and treatment.
- We estimate the costs and effects (LYG) of the 251 strategies
- We identify the efficient frontier, incremental cost-effectiveness ratios (ICERs) and the optimal strategy for a given threshold.

# Model application

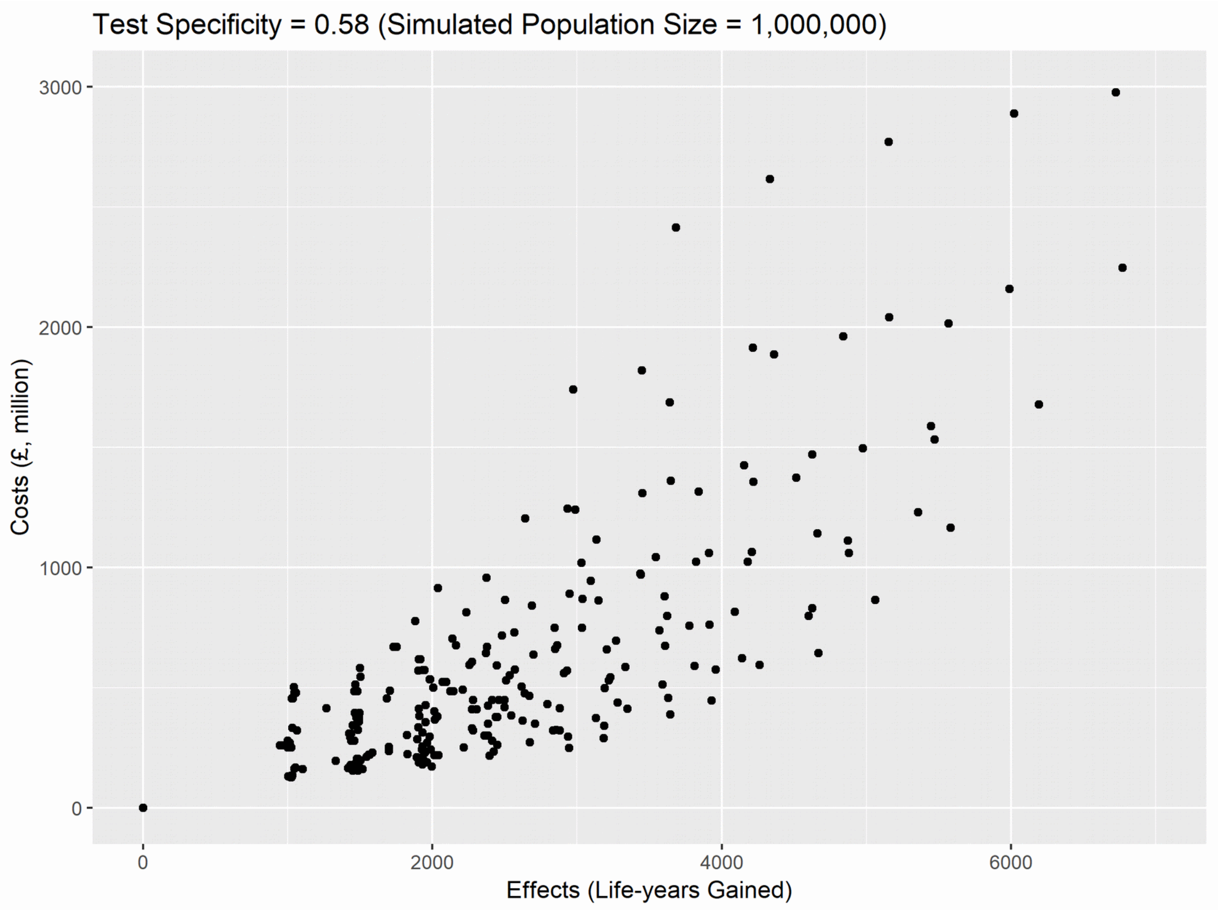
- We vary the input parameter values one at a time: one-way sensitivity analysis (OWSA).
- We simulate higher and lower values relative to the basecase.
- The OWSA demonstrates the effect of parameter variation on the efficient frontier.

# Results:

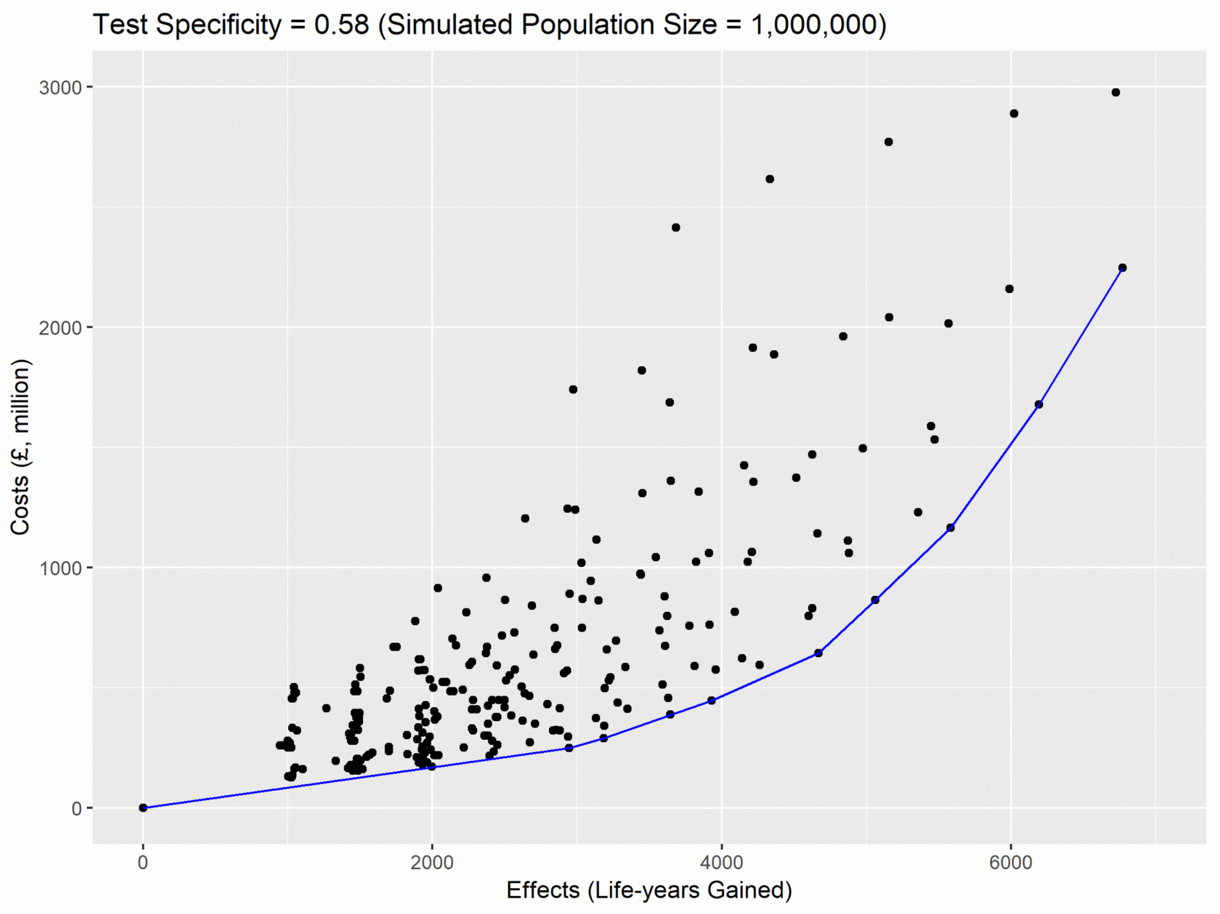
| Number of Simulations | Run Time |
|---|---|
| 1<br>(251 strategies) | 2.94 minutes |
| 241<br>(251 strategies)<br>(for OWSA) | 9.62 hours<br>(2.39 minutes per run) |

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

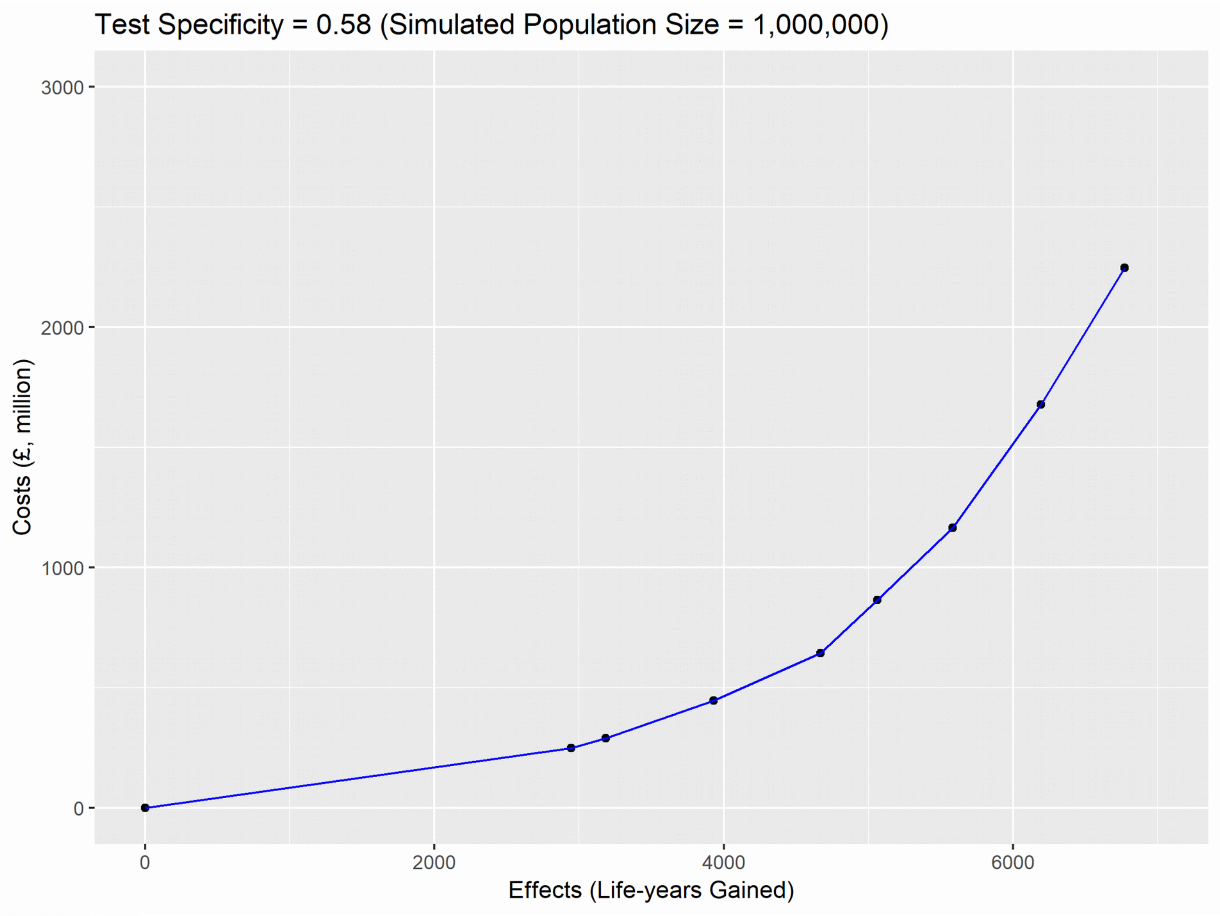
# Find Optimal Strategy (1/10)



# Find Optimal Strategy (2/10)

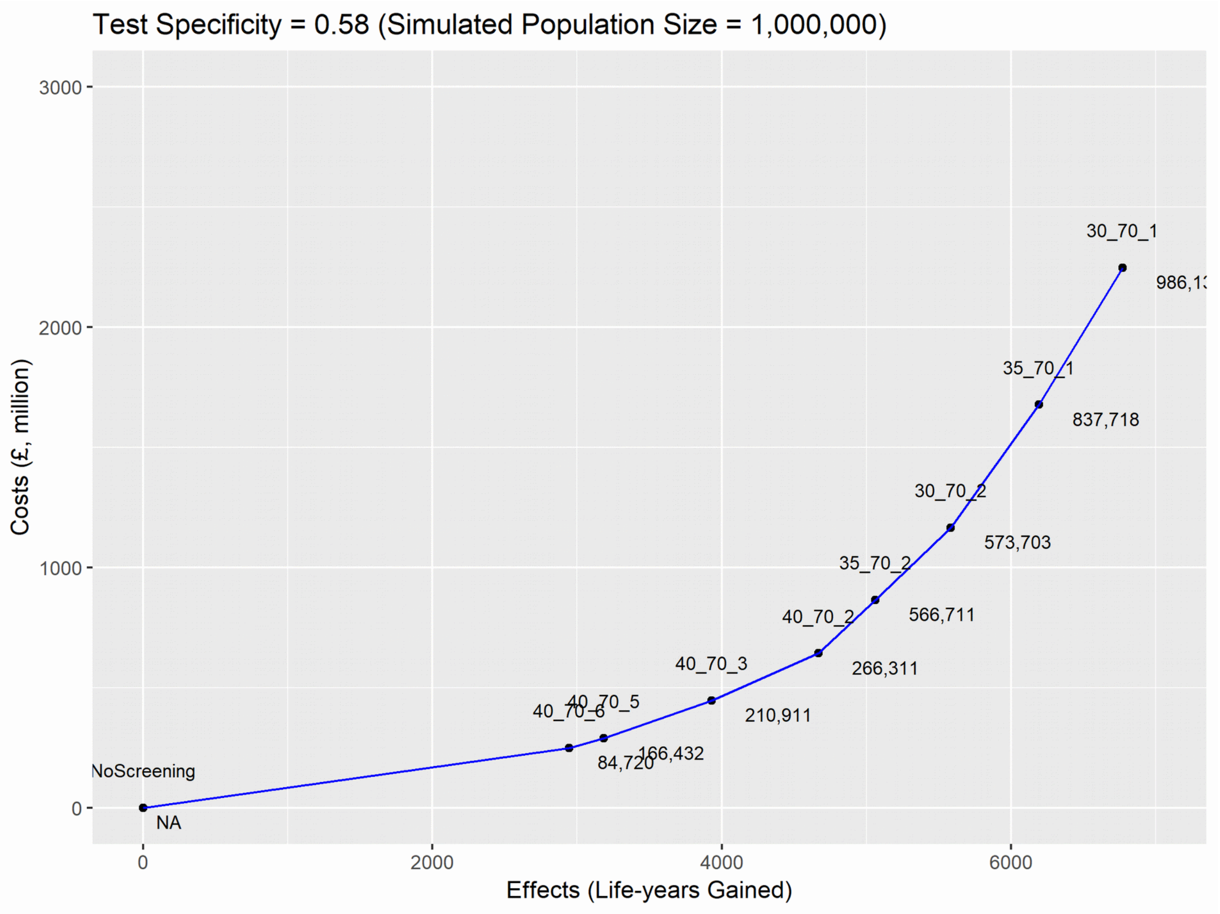


# Find Optimal Strategy (3/10)

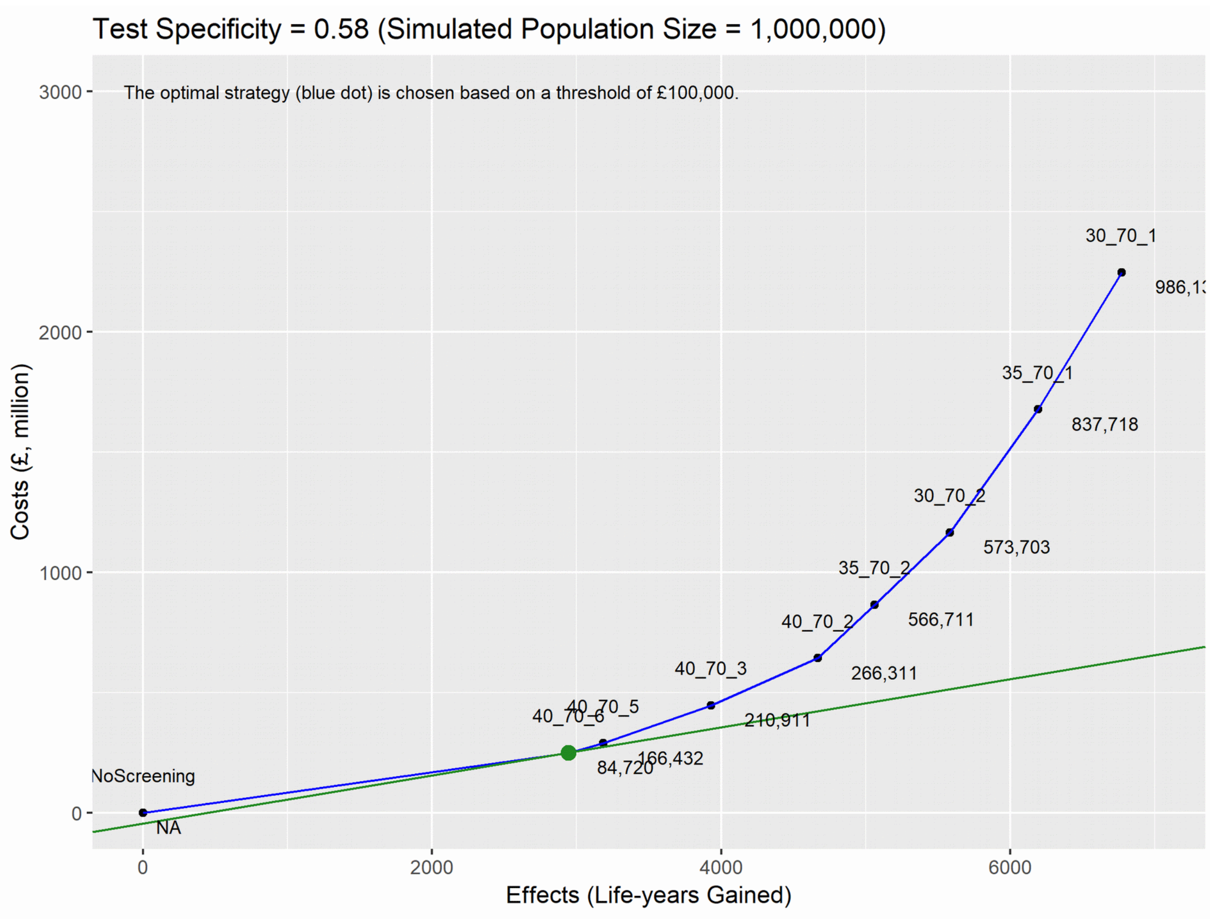



Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

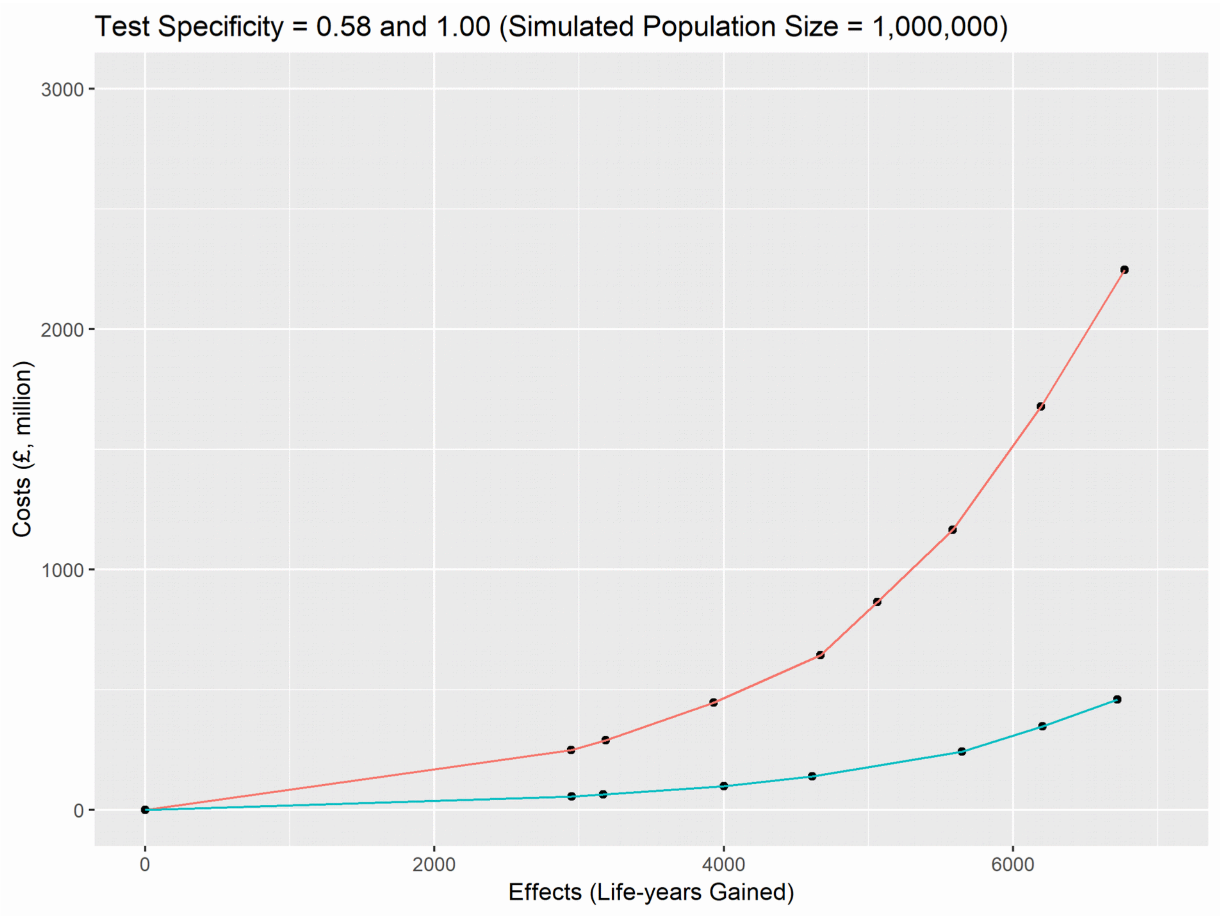
# Find Optimal Strategy (4/10)



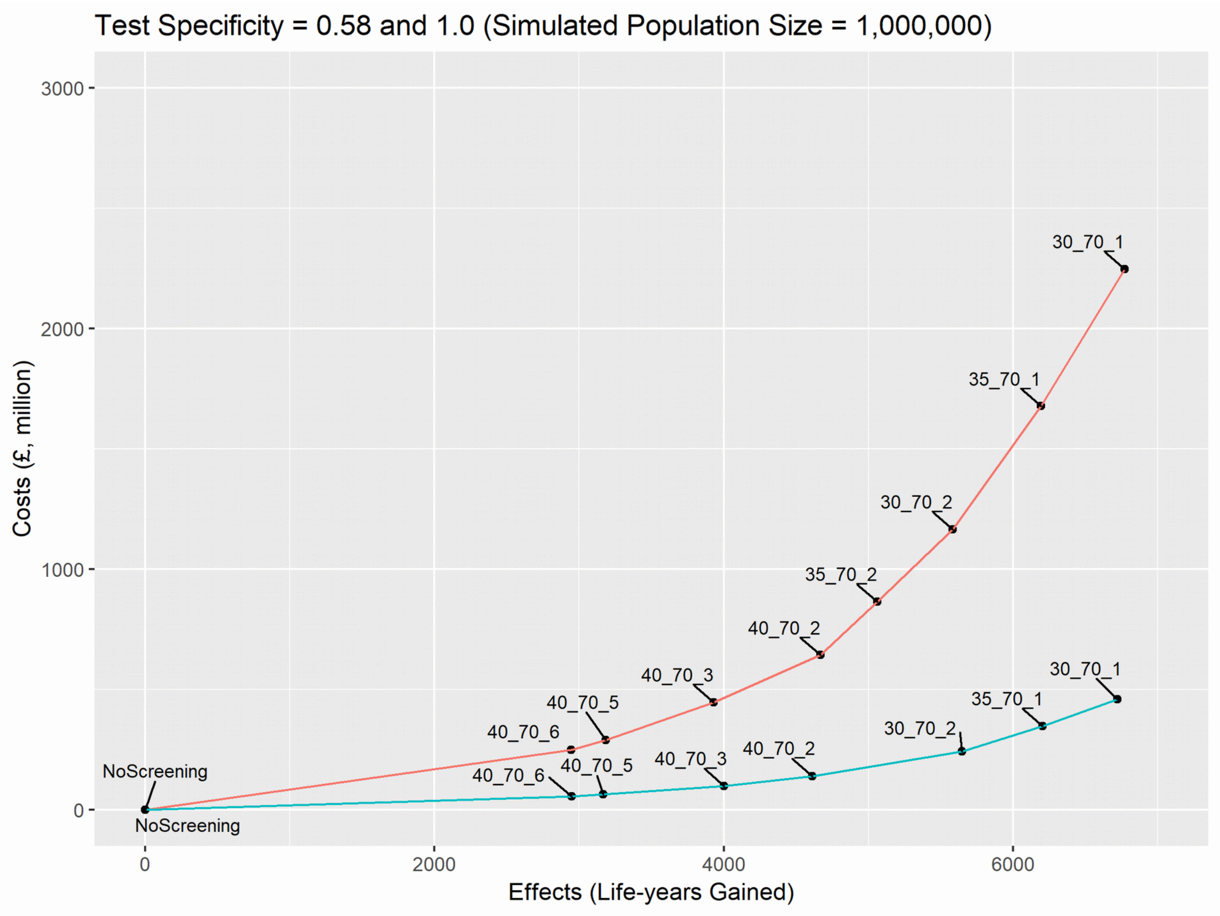
# Find Optimal Strategy (5/10)



# Find Optimal Strategy (6/10)

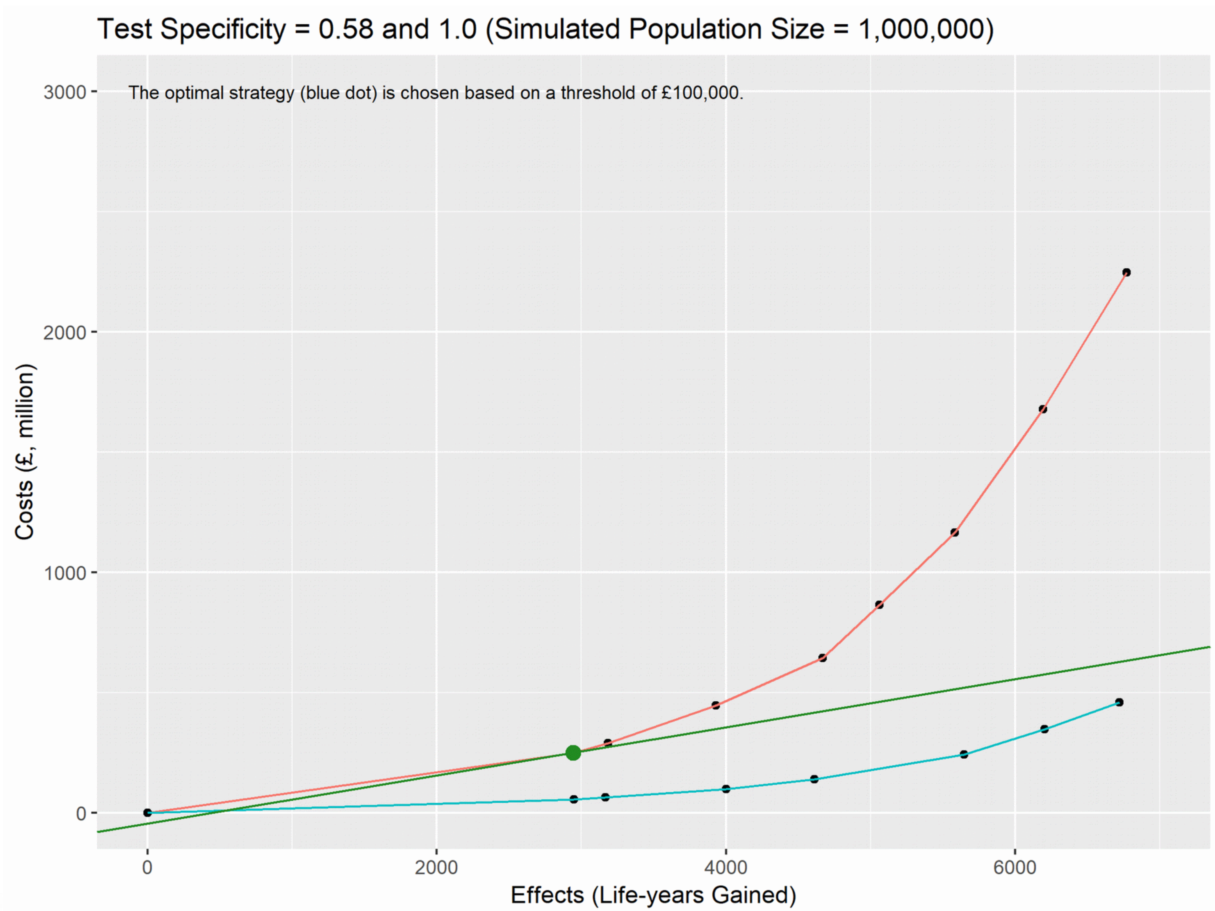


# Find Optimal Strategy (7/10)



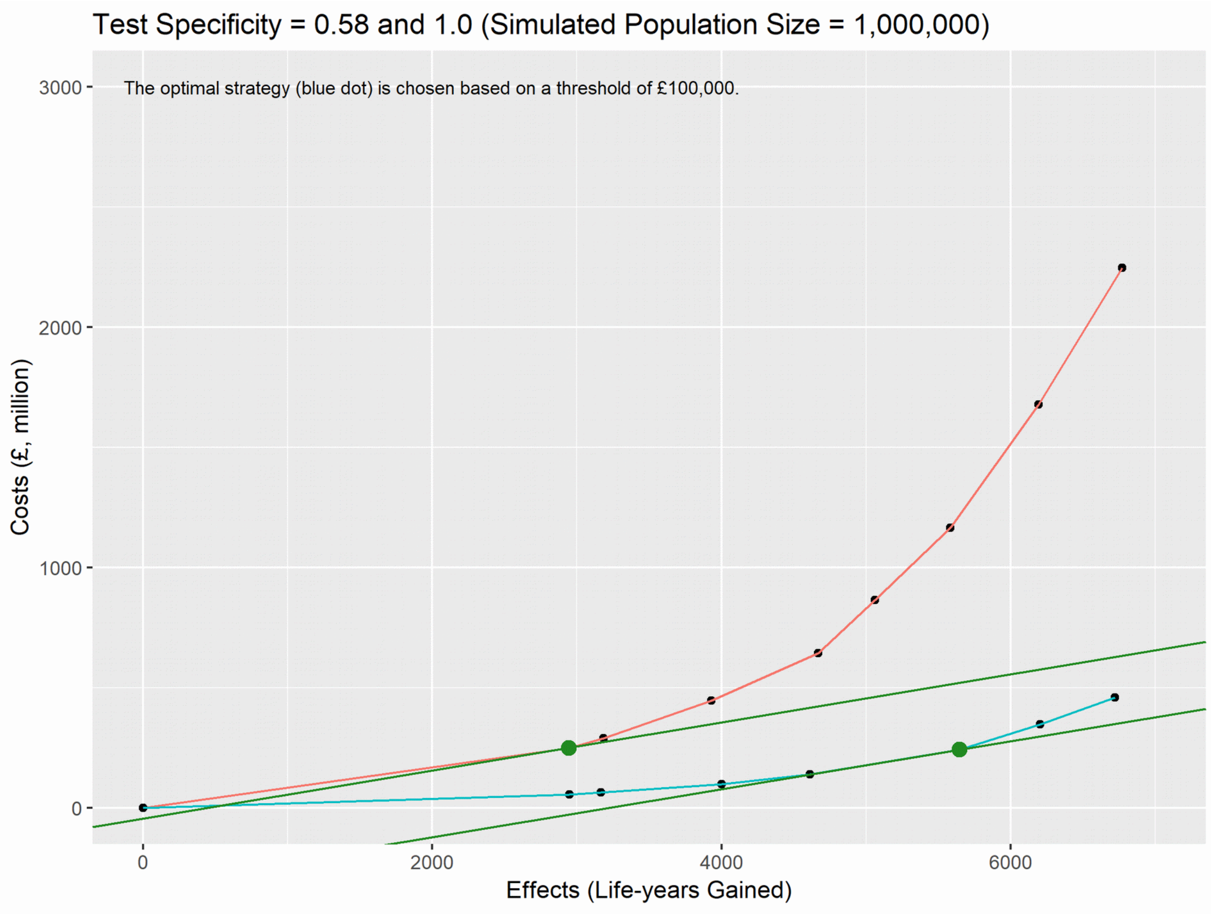

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

# Find Optimal Strategy (8/10)

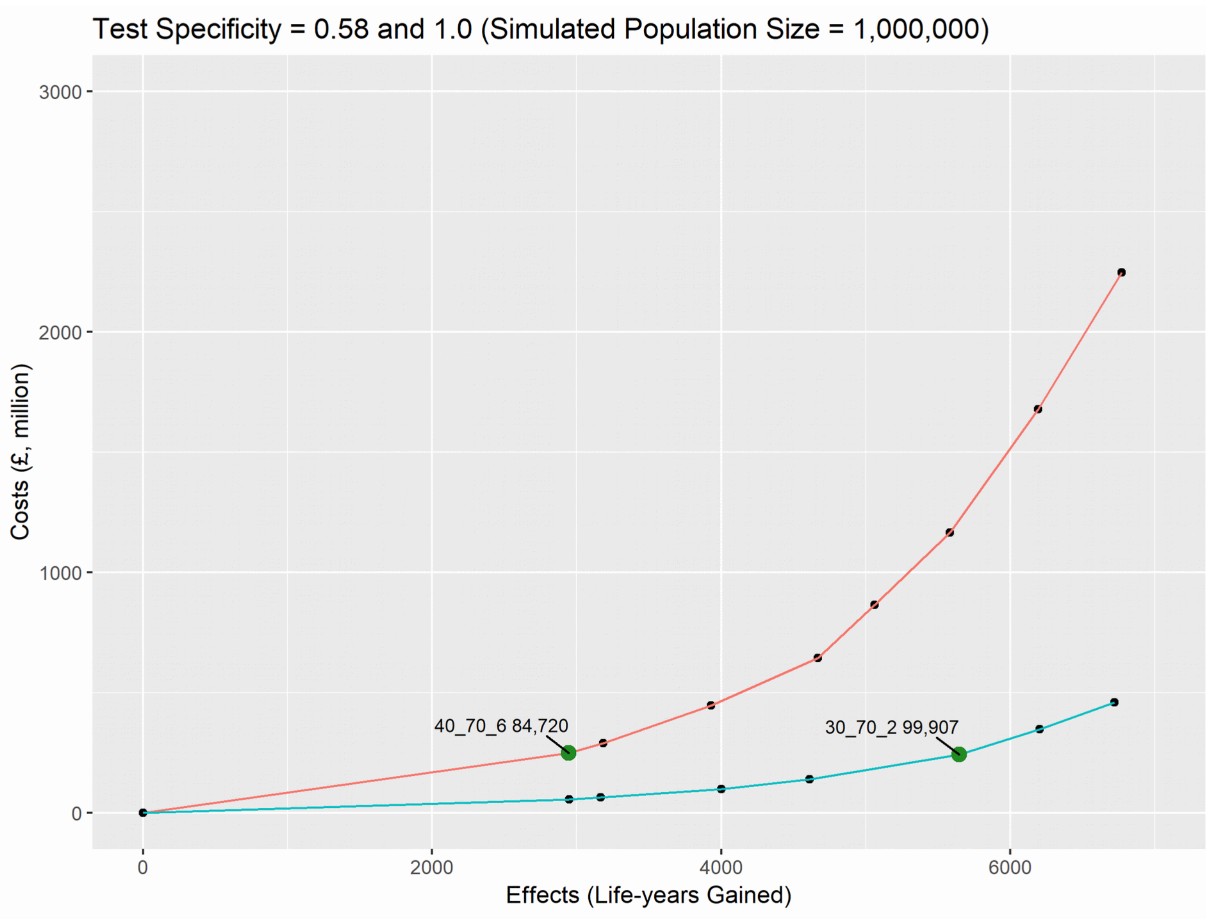



Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

# Find Optimal Strategy (9/10)

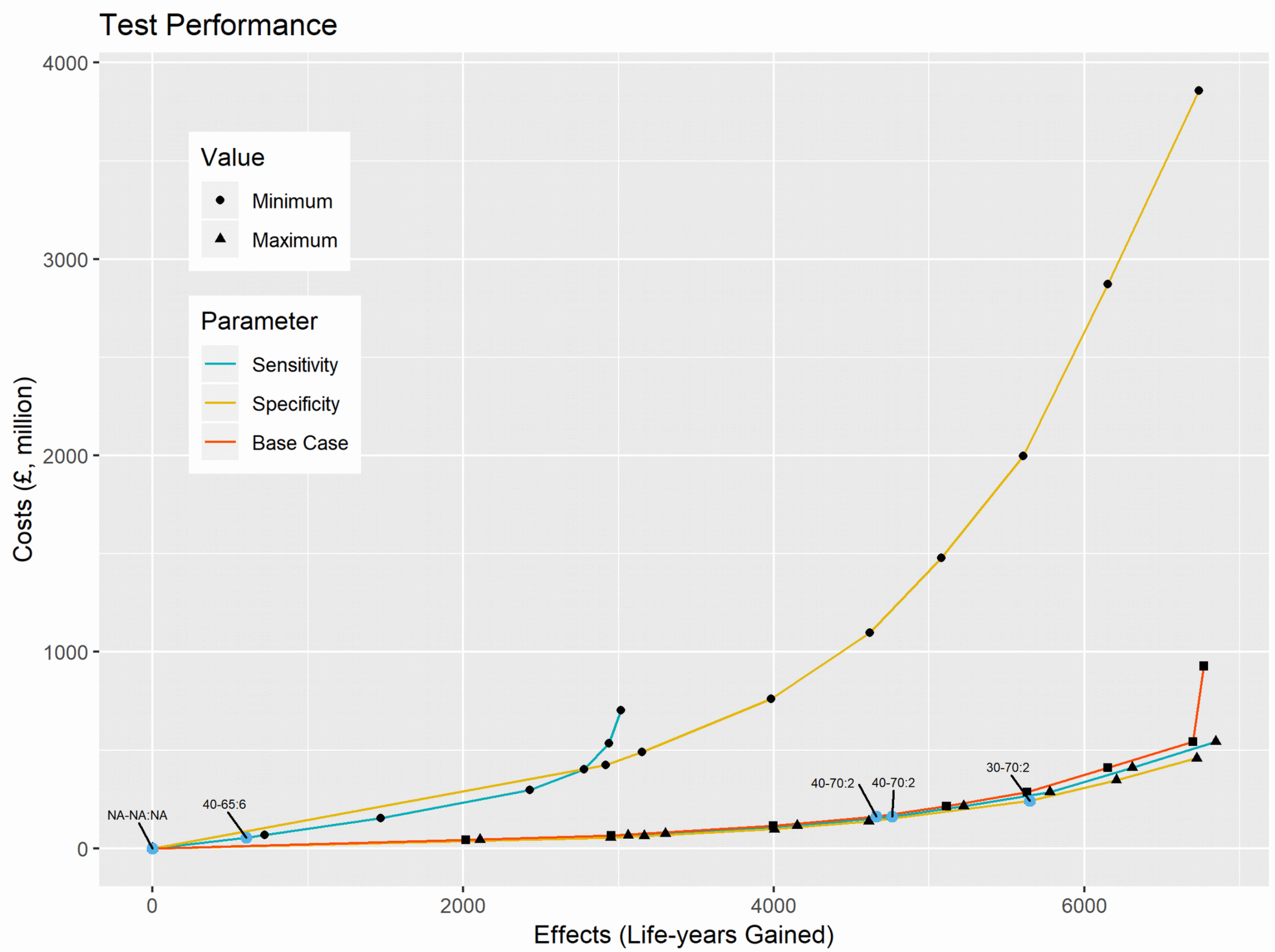


# Find Optimal Strategy (10/10)



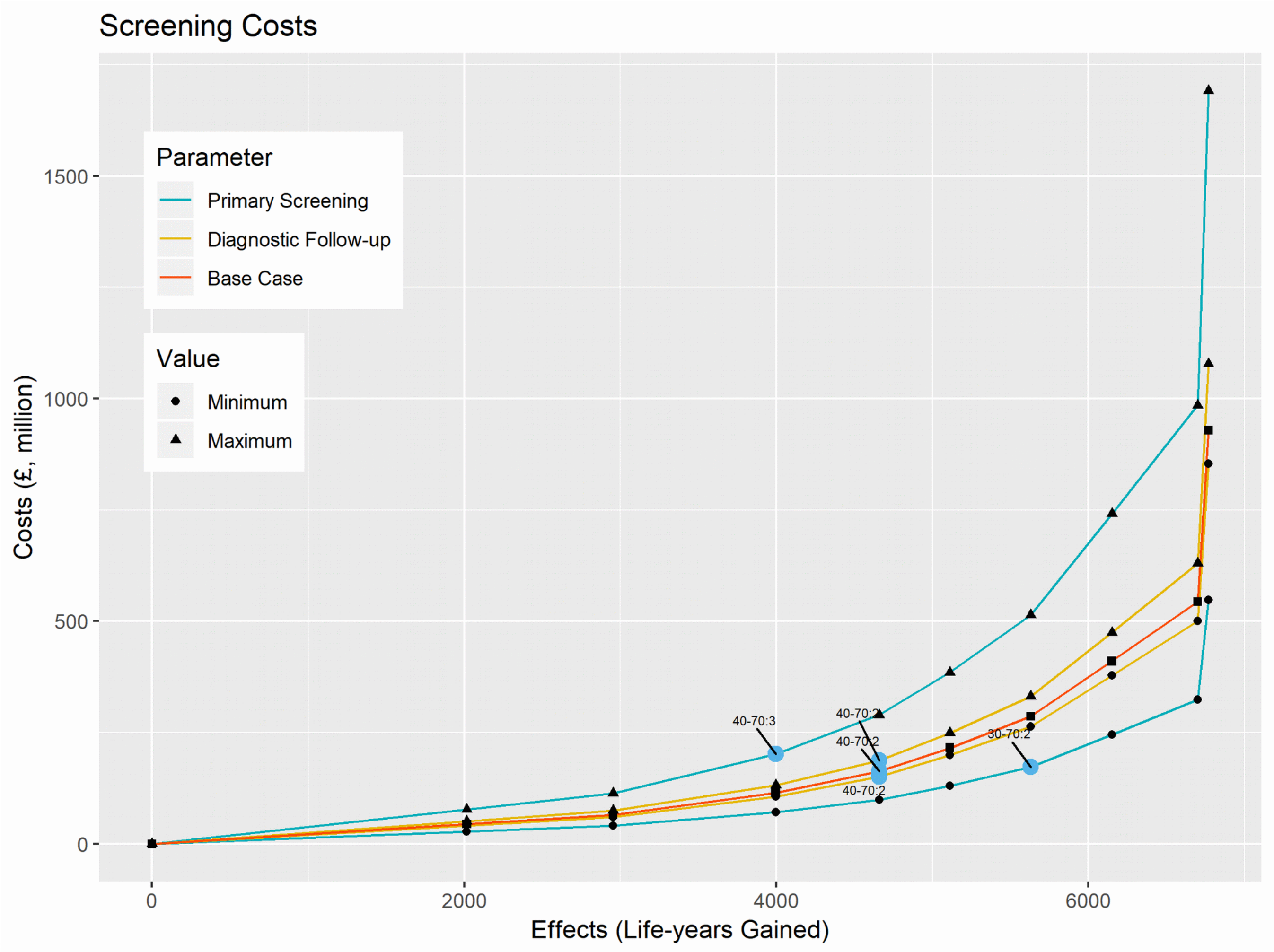

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

# Efficient frontier (1/5)

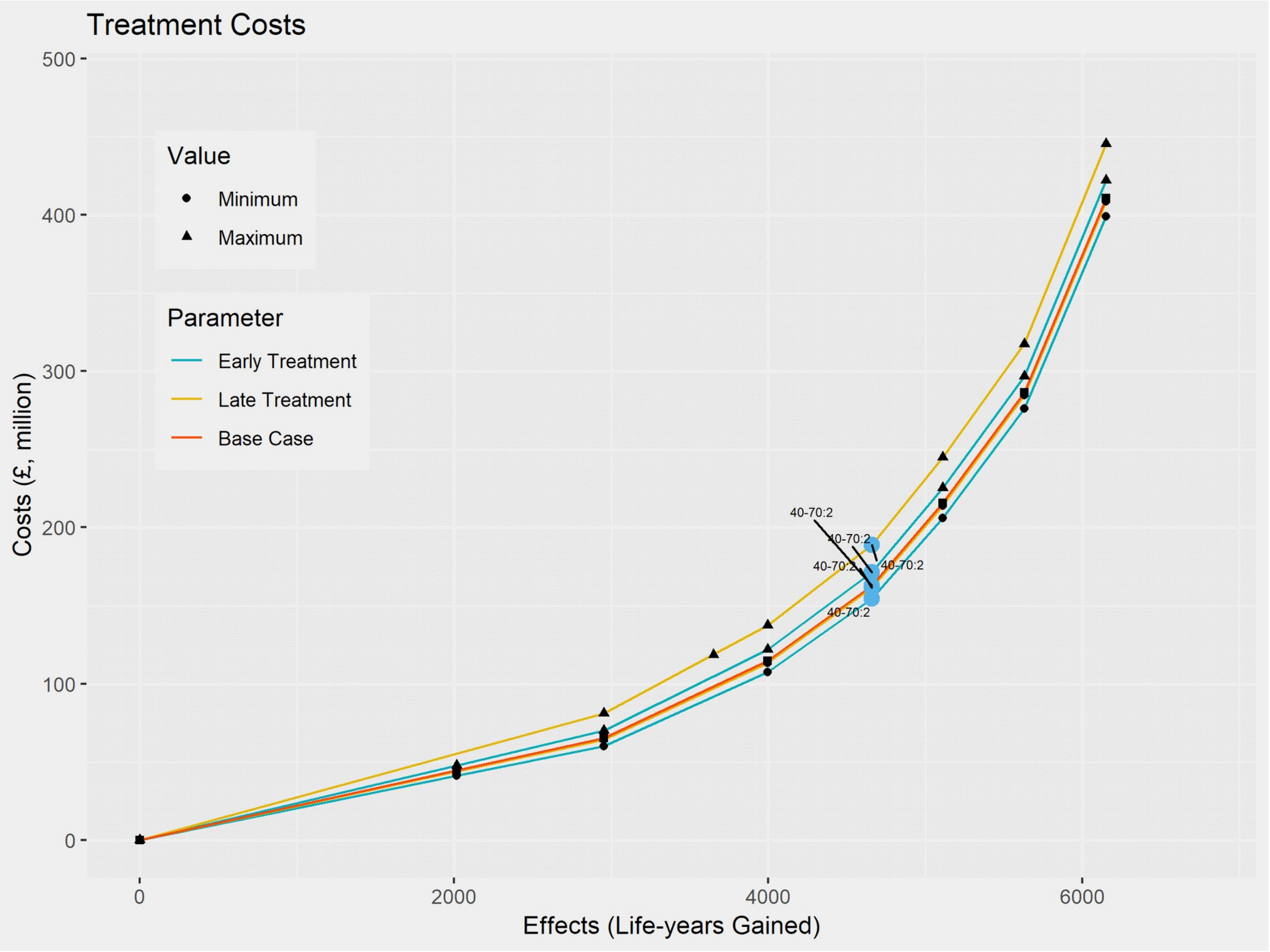



Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

# Efficient frontier (2/5)

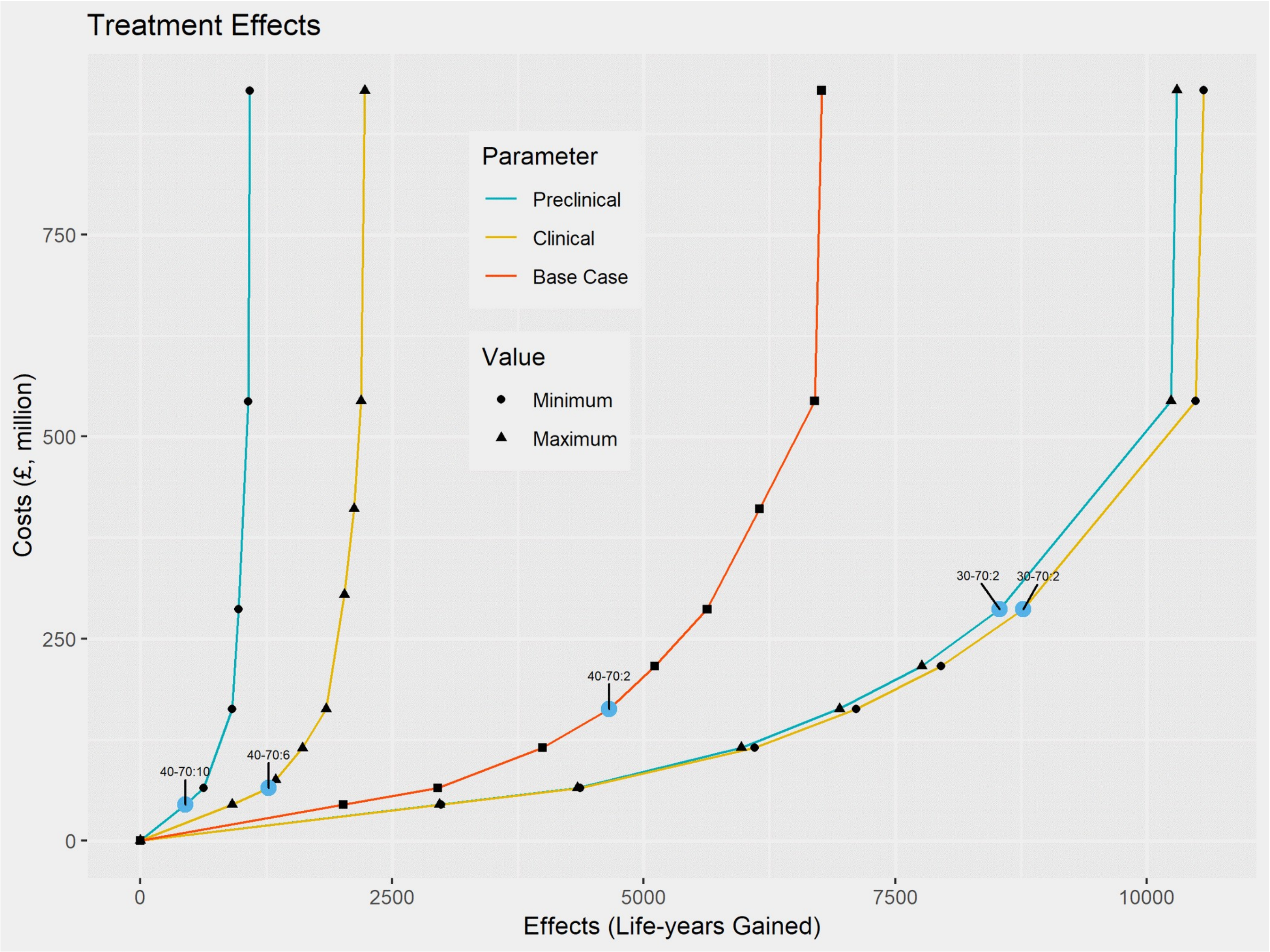


# Efficient frontier (3/5)

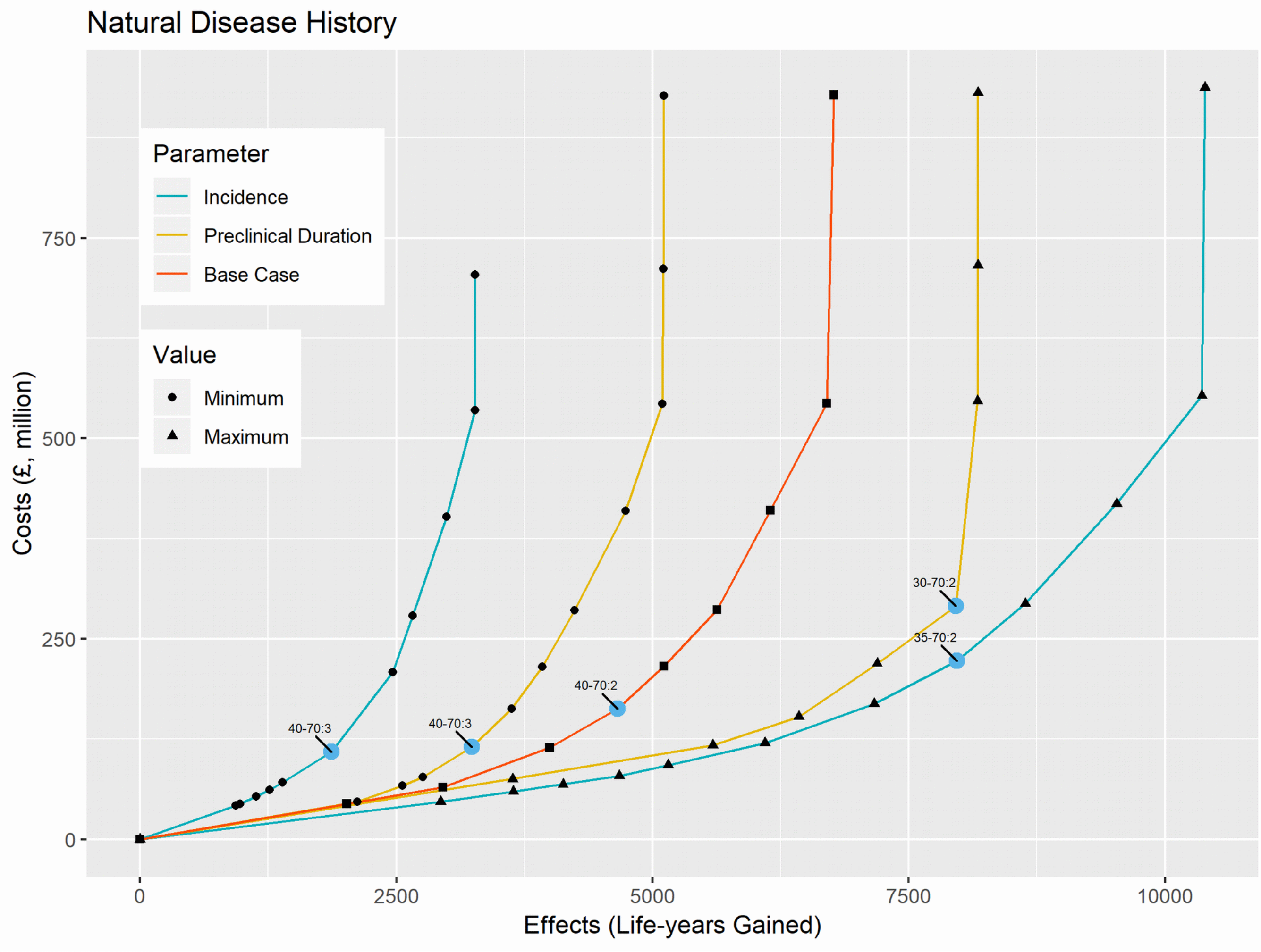



Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

# Efficient frontier (4/5)



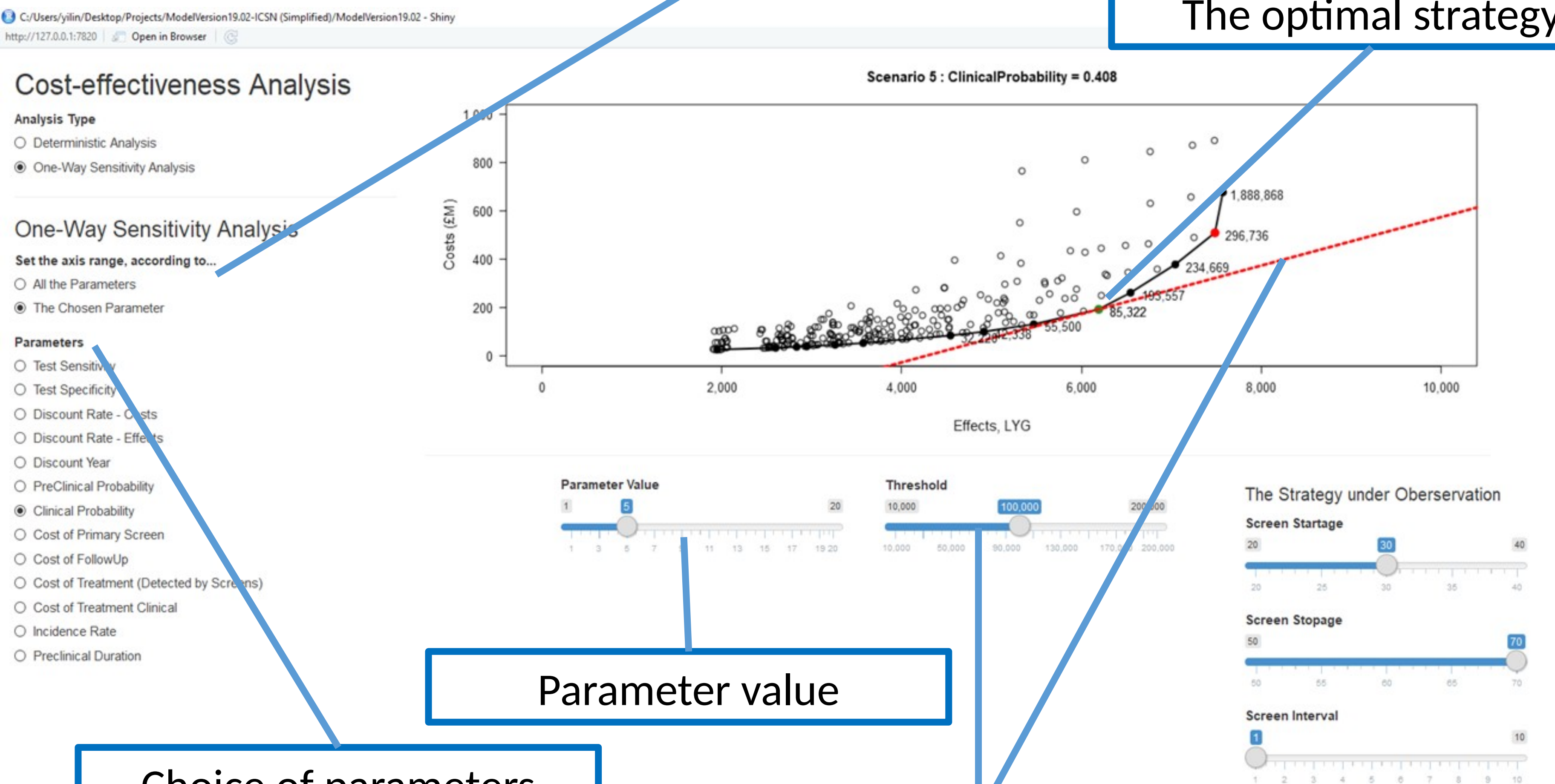
# Efficient frontier (5/5)



# R ShinyApp

- Permits exploration of previously simulated output
- Facilitates comparative statics
- Does not require model understanding or knowledge of R code

# R ShinyApp




Axis setting

The optimal strategy

Parameter value

Choice of parameters

Threshold

# Limitations

- Complexity accumulates quickly when adding features.
- Confidence in qualitative findings can only be know relative to “complete” model outputs.

# Extensions

- More representative model assumptions (with trade-off of additional complexity):
  - multiple disease stages, transition probabilities and test outcomes.
- More generalised code to avoid hard-coded structures.
- Probabilistic sensitivity analysis (PSA) and calibration.

# Join us!

- If you are <u>not</u> familiar with CEA in R
  - 1. Learn with our shared model code
  - 2. Give us your learning feedback

- If you are familiar with CEA in R
  - 1. Please apply our model
  - 2. Suggest improvements or extensions

# Any questions and suggestions?

**James O'Mahony, PhD**
jfomahon@tcd.ie

**Yi-Shu Lin, MSc, MBA**
yilin@tcd.ie

Centre for Health Policy & Management
Trinity College Dublin
Ireland

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin