Cost-Effectiveness and Decision Modeling in R

Exercises – Microsimulation models - Includes individual characteristics: age, age dependent mortality probabilities, individual treatment effect modifyer, state-residency for the sick (S1) state, increasing change of death in the first 6 year of sickness (tunnel)

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Please cite our publications when using this code:

- Jalal H, Pechlivanoglou P, Krijkamp E, Alarid-Escudero F, Enns E, Hunink MG. An Overview of R in Health Decision Sciences. Med Decis Making. 2017; 37(3): 735-746. https://journals.sagepub.com/doi/abs/10.1177/0272989X16686559

- Krijkamp EM, Alarid-Escudero F, Enns EA, Jalal HJ, Hunink MGM, Pechlivanoglou P. Microsimulation modeling for health decision sciences using R: A tutorial. Med Decis Making. 2018;38(3):400–22. https://journals.sagepub.com/doi/abs/10.1177/0272989X18754513

- Krijkamp EM, Alarid-Escudero F, Enns E, Pechlivanoglou P, Hunink MM, Jalal H. A Multidimensional Array Representation of State-Transition Model Dynamics. Med Decis Making. 2020 Online first. https://doi.org/10.1177/0272989X19893973

Exercise: A Microsimulation model – The Sick-Sicker model

In this exercise, we will model the hypothetical Sick-Sicker disease using a microsimulation model. The Sick-Sicker disease has been previously modeled as a Markov model using four health states (Figure 1): Healthy (H); two disease states, Sick (S1) and Sicker (S2); and Dead (D).

One of the advantages of using a microsimulation implementation is the ability to incorporate variation in the baseline characteristics for every individual. To illustrate this, we assume that individual mortality rates depend on baseline characteristics.

The model incorporates the following:

i) The mortality rates depend on age

ii) The improvement on quality of life by the treatment varies across individuals through a characteristic that acts as a treatment effect modifier. All model parameter values and R variable names are presented in Table 1.

iii) The probability to die when in sick (S1), `p_S1D`, is increaseing by cycle spend in the sick state. See Table 1 for the numbers.

After you have successfully implemented the natural history of the Sick-Sicker disease as a microsimulation, you can expand the model to include the possibility of treatment and evaluate whether it is cost-effective given a willingness to pay of $20,000. This hypothetical treatment improves the quality of life for those in the Sick (S1) state but not for those in the Sicker (S2) state. However, it is not possible to distinguish between individuals in the Sick state from those in the Sicker state, so under a treatment strategy, individuals in both sick states must be treated (and incur the costs of treatment), while only those in the sick state benefit from it. Treatment parameters are also summarized in the table below.

Tasks

There are quite some steps you need to take in order to create a microsimulation reflecting this case. Download the all the materials as a folder.

1. Open the "microsim_Sick-Sicker_time_template.Rmd" template to load the data for the time dependency and the individual characteristics. This templates makes use the files called `mortProb.csv` and `MyPopulation-AgeDistribtion.csv`. Start adjusting the `Probs()`, `Costs()` and `Eff()` functions to incorporate the new case.

2. Simulate a population of 100,000 individuals and plot the resulting distributions of remaining lifetime costs and QALYs.

3. Expand your microsimulation to include the possibility of the hypothetical treatment for the Sick-Sicker disease (and its impact on costs and quality of life). Create a new variable that can be used to turn treatment on and off in the model.

4. Simulate a population of 100,000 individuals under a treatment strategy where anyone who is sick (in the Sick or Sicker states) receives treatment. Plot the resulting distributions of remaining lifetime costs and QALYs.

5. Calculate the incremental cost-effectiveness ratio (ICER) of treatment compared to no treatment.

Table 1: Input parameters for the time dependent Sick-Sicker Microsimulation

Parameter	R name	Value
Time horizon	`n_t`	30 years
Cycle length		1 year
Names of simulated individuals	`n_i`	1000
Names of health states	`v_n`	H, S1, S2, D
Annual discount rate (costs/QALYs)	`d_e` `d_c`	3%
Population characteristics		
- Agedistribution	–	Range:25-55 distributed as in `MyPopulation-AgeDistribution.csv`
Annual transition probabilities		
- Disease onset (H to S1)	`p_HS1`	0.15
- Recovery (S1 to H)	`p_S1H`	0.5
- Disease progression (S1 to S2)	`p_S1S2`	0.105
Annual mortality		
- All-cause mortality (H to D)	`p_HD`	Human Mortality Database: age dependent from 2015
- Probability of death is S1 (S1 to D)	`p_S1D`	
	First year	0.0149
	Second year	0.018
	Third year	0.021
	Fourth year	0.026
	Fifth year	0.031
	Sixth and more years	0.037
- Probability of death in S2 (S2 to D)	`p_S2D`	0.048
Annual costs		
- Healthy individuals	`c_H`	$2,000
- Sick individuals in S1	`c_S1`	$4,000
- Sick individuals in S2	`c_S2`	$15,000
- Dead individuals	`c_D`	$0
- Additional costs of sick individuals treated in S1 or S2	`c_trt`	$12,000
Utility weights		
- Healthy individuals	`u_H`	1.00
- Sick individuals in S1	`u_S1`	0.75
- Sick individuals in S2	`u_S2`	0.50
- Dead individuals	`u_D`	0.00
Intervention effect		
- Utility for treated individuals in S1	`u_trt`	0.95
Time varying extension of Sick-Sicker model		
- Treatment effect modifier at baseline	`v_x`	Uniform(0.95, 1.05)

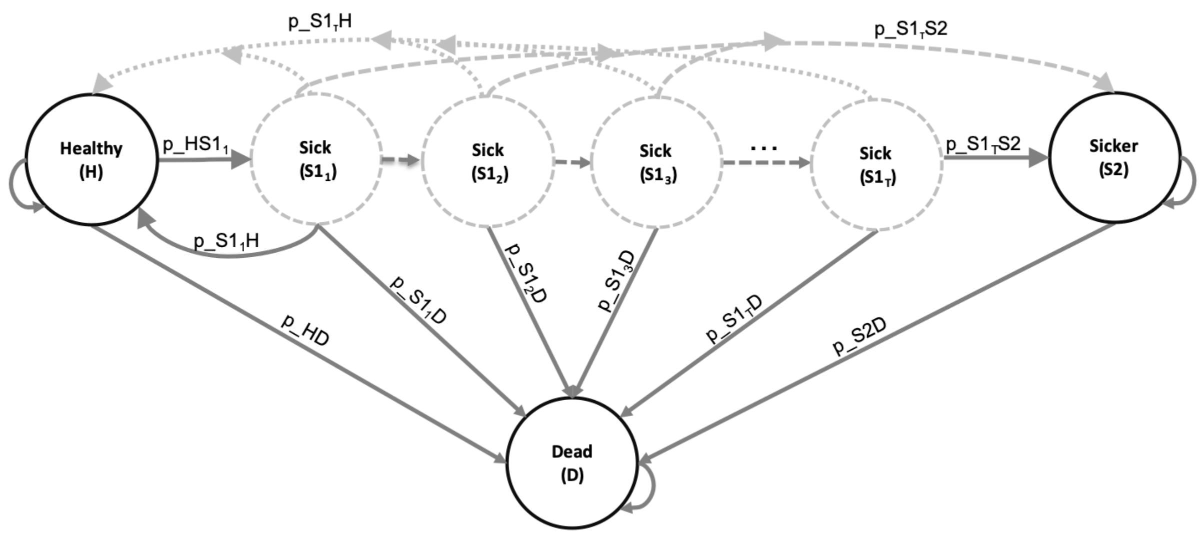

Figure 1: Schematic representation of the Sick-Sicker model with tunnels for the sick state