Report for the Markov model (cohort state-transition model)

Data and parameters

% latex table generated in R 3.6.3 by xtable 1.8-4 package % Tue Jan 19 16:53:45 2021

Table 1: Data from Global Health Data Exchange

	index	sex	incidence	death_CVD	death_nonCVD
1	40	male	0.003888	0.000819	0.002494
2	45	male	0.006729	0.001340	0.003399
3	50	male	0.010564	0.002302	0.004951
4	55	male	0.015291	0.003665	0.007282
5	60	male	0.022078	0.006404	0.011159
6	65	male	0.030980	0.011155	0.016946
7	70	male	0.043589	0.019978	0.026305
8	40	female	0.004545	0.000351	0.001137
9	45	female	0.007094	0.000643	0.001620
10	50	female	0.010133	0.001206	0.002475
11	55	female	0.013734	0.002014	0.003705
12	60	female	0.018272	0.003872	0.005850
13	65	female	0.023744	0.006996	0.009060
14	70	female	0.033907	0.013398	0.014907

% latex table generated in R 3.6.3 by xtable 1.8-4 package % Tue Jan 19 16:53:45 2021

Table 2: Distribution of the population

	index	sex	num
1	40	male	229
2	45	male	444
3	50	male	422
4	55	male	410
5	60	male	322
6	65	male	160
7	70	male	116
8	40	female	498
9	45	female	856
10	50	female	822
11	55	female	842
12	60	female	519
13	65	female	394
14	70	female	187

% latex table generated in R 3.6.3 by xtable 1.8-4 package % Tue Jan 19 16:53:45 2021

Table 3: Distribution of the population under different strategies

	index	sex	strategy	low	medium	high
1	40	male	strategy1	159	8	62
2	45	male	strategy1	173	64	207
3	50	male	strategy1	188	63	171
4	55	male	strategy1	200	89	121
5	60	male	strategy1	129	89	104
6	65	male	strategy1	71	42	47
7	70	male	strategy1	48	28	40
8	40	female	strategy1	444	6	48
9	45	female	strategy1	738	18	100
10	50	female	strategy1	677	20	125
11	55	female	strategy1	440	217	185
12	60	female	strategy1	216	164	139
13	65	female	strategy1	128	136	130
14	70	female	strategy1	65	55	67
15	40	male	strategy2	163	50	16
16	45	male	strategy2	212	168	64
17	50	male	strategy2	106	231	85
18	55	male	strategy2	35	210	165
19	60	male	strategy2	5	81	236
20	65	male	strategy2	1	15	144
21	70	male	strategy2	0	3	113
22	40	female	strategy2	478	17	3
23	45	female	strategy2	734	108	14
24	50	female	strategy2	537	238	47
25	55	female	strategy2	277	433	132
26	60	female	strategy2	44	282	193
27	65	female	strategy2	4	104	286
28	70	female	strategy2	0	23	164
29	40	male	strategy3	0	0	0
30	45	male	strategy3	0	0	0
31	50	male	strategy3	106	231	85
32	55	male	strategy3	35	210	165
33	60	male	strategy3	5	81	236
34	65	male	strategy3	1	15	144
35	70	male	strategy3	0	3	113
36	40	female	strategy3	0	0	0
37	45	female	strategy3	0	0	0
38	50	female	strategy3	537	238	47
39	55	female	strategy3	277	433	132
40	60	female	strategy3	44	282	193
41	65	female	strategy3	4	104	286
42	70	female	strategy3	0	23	164

Component 1: A transition probability matrix P_t

$$P_t = \begin{Bmatrix} p_{[1,1,t]} & p_{[1,2,t]} & p_{[1,3,t]} & p_{[1,4,t]} \\ p_{[2,1,t]} & p_{[2,2,t]} & p_{[2,3,t]} & p_{[2,4,t]} \\ p_{[3,1,t]} & p_{[3,2,t]} & p_{[3,3,t]} & p_{[3,4,t]} \\ p_{[4,1,t]} & p_{[4,2,t]} & p_{[4,3,t]} & p_{[4,4,t]} \end{Bmatrix}$$

Thus,

$P4 = 1 - P1 - P2 - P3$

$P1 = p\_live\_cvd * (1 - p\_acvd\_cvdth)$

$P2 = p\_live\_cvdth + p\_live\_cvd * p\_acvd\_cvdth$

$P3 = p\_live\_oth\_death$

$P6 = 1 - (p\_ccvd\_cvdth + p\_ccvd\_acvd * p\_acvd\_cvdth) - p\_live\_oth\_death$

$P5 = p\_ccvd\_cvdth + p\_ccvd\_acvd * p\_acvd\_cvdth$

Strategy 0 (a male 40-45)

In what follows, an example for the groups of male patients, aging from 40 to 45 is illustrated.

```
## , , 1
##
##           S1          S2           S3          S4
## S1 0.9938017 0.003707301 1.417524e-07 0.002490893
## S2 0.0000000 0.994720043 2.789064e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 2
##
##           S1          S2           S3          S4
## S1 0.9938017 0.003707301 1.417524e-07 0.002490893
## S2 0.0000000 0.994720043 2.789064e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 3
##
##           S1          S2           S3          S4
## S1 0.9938017 0.003707301 1.417524e-07 0.002490893
## S2 0.0000000 0.994720043 2.789064e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 4
##
##           S1          S2           S3          S4
## S1 0.9938017 0.003707301 1.417524e-07 0.002490893
## S2 0.0000000 0.994720043 2.789064e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
```

```
##
## , , 5
##
##           S1          S2           S3          S4
## S1 0.9938017 0.003707301 1.417524e-07 0.002490893
## S2 0.0000000 0.994720043 2.789064e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 6
##
##           S1          S2           S3         S4
## S1 0.9901992 0.006407162 4.007247e-07 0.00339323
## S2 0.0000000 0.992025236 4.581534e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
## , , 7
##
##           S1          S2           S3         S4
## S1 0.9901992 0.006407162 4.007247e-07 0.00339323
## S2 0.0000000 0.992025236 4.581534e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
## , , 8
##
##           S1          S2           S3         S4
## S1 0.9901992 0.006407162 4.007247e-07 0.00339323
## S2 0.0000000 0.992025236 4.581534e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
## , , 9
##
##           S1          S2           S3         S4
## S1 0.9901992 0.006407162 4.007247e-07 0.00339323
## S2 0.0000000 0.992025236 4.581534e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
## , , 10
##
##           S1          S2           S3         S4
## S1 0.9901992 0.006407162 4.007247e-07 0.00339323
## S2 0.0000000 0.992025236 4.581534e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
```

Component 2: The cohort trace matrix M

```
##           S1          S2           S3          S4
## 0  1.0000000 0.000000000 0.000000e+00 0.000000000
```

```
## 1  0.9938017 0.003707301 1.417524e-07 0.002490893
## 2  0.9876417 0.007372048 1.062253e-05 0.004975580
## 3  0.9815200 0.010994609 3.132364e-05 0.007454053
## 4  0.9754362 0.014575348 6.212744e-05 0.009926300
## 5  0.9693901 0.018114626 1.029173e-04 0.012392312
## 6  0.9598894 0.024181206 1.862985e-04 0.015743143
## 7  0.9504817 0.030138534 2.974702e-04 0.019082321
## 8  0.9411662 0.035988076 4.359318e-04 0.022409791
## 9  0.9319420 0.041731284 6.011895e-04 0.025725500
## 10 0.9228083 0.047369591 7.927563e-04 0.029029397
```

This matrix is the trace matrix of the specific population (male, 40-45) during these 10 cycles. The whole cohort starts in $S1$ state and transitions to the rest of the states over time.

```
## [1] 0.04118741
```

```
##             [,1]
##  [1,] 0.04118741
##  [2,] 0.07118236
##  [3,] 0.11153694
##  [4,] 0.16106529
##  [5,] 0.23176968
##  [6,] 0.32378282
##  [7,] 0.45271856
##  [8,] 0.04813152
##  [9,] 0.07502982
## [10,] 0.10700937
## [11,] 0.14477728
## [12,] 0.19217932
## [13,] 0.24905220
## [14,] 0.35385848
```

```
##          male     female
## 40 0.04118741 0.04813152
## 45 0.07118236 0.07502982
```

```
## [1] 895.191
```

Under strategy0 (no screening), 895.1910471 is the number of patients transitioned from S1 to S2.

Table 4: Incidence rate

Item		CVD incidence(HR)	CVD cause-specific mortality (HR)
Strategy 1	Low risk	0.63	1
	Medium risk	1.56	1
	High risk	1.6	1.7
Strategy 2	Low risk	0.43	1
	Medium risk	0.97	1
	High risk	2.06	1.7
Strategy 3	Low risk	0.45	1
	Medium risk	1.09	1
	High risk	2.11	1.7
Intervention	Weight control	0.93	0.93
	Smoke cession	0.85	0.72
	Salt reduction	0.81	0.66
Medication	Statin and antihypertensive	0.7	0.82

Strategy 2 (a male 40-45)

Thus, we take the example of individuals in the low level

$\underline{P4} = 1 - P1 - P2 - P3$

$\underline{P1} = p\_live\_cvd\_l * (1 - p\_acvd\_cvdth)$

$\underline{P2} = p\_live\_cvdth\_l + p\_live\_cvd\_l * p\_acvd\_cvdth$

$P3 = p\_live\_oth\_death$

$P6 = 1 - (p\_ccvd\_cvdth + p\_ccvd\_acvd * p\_acvd\_cvdth) - p\_live\_oth\_death$

$P5 = p\_ccvd\_cvdth + p\_ccvd\_acvd * p\_acvd\_cvdth$

We say that the screening strategy will have an influence on the first line of the transition matrix.

```
## , , 1
##
##           S1          S2           S3          S4
## S1 0.9959114 0.001597673 6.108865e-08 0.002490893
## S2 0.0000000 0.994722422 2.786685e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 2
##
##           S1          S2           S3          S4
## S1 0.9959114 0.001597673 6.108865e-08 0.002490893
## S2 0.0000000 0.994722422 2.786685e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 3
##
```

```
##           S1          S2           S3          S4
## S1 0.9959114 0.001597673 6.108865e-08 0.002490893
## S2 0.0000000 0.994722422 2.786685e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 4
##
##           S1          S2           S3          S4
## S1 0.9959114 0.001597673 6.108865e-08 0.002490893
## S2 0.0000000 0.994722422 2.786685e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 5
##
##           S1          S2           S3          S4
## S1 0.9959114 0.001597673 6.108865e-08 0.002490893
## S2 0.0000000 0.994722422 2.786685e-03 0.002490893
## S3 0.0000000 0.000000000 1.000000e+00 0.000000000
## S4 0.0000000 0.000000000 0.000000e+00 1.000000000
##
## , , 6
##
##           S1          S2           S3         S4
## S1 0.9938409 0.002765652 1.729728e-07 0.00339323
## S2 0.0000000 0.992031641 4.575129e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
## , , 7
##
##           S1          S2           S3         S4
## S1 0.9938409 0.002765652 1.729728e-07 0.00339323
## S2 0.0000000 0.992031641 4.575129e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
## , , 8
##
##           S1          S2           S3         S4
## S1 0.9938409 0.002765652 1.729728e-07 0.00339323
## S2 0.0000000 0.992031641 4.575129e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
## , , 9
##
##           S1          S2           S3         S4
## S1 0.9938409 0.002765652 1.729728e-07 0.00339323
## S2 0.0000000 0.992031641 4.575129e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
##
```

```
## , , 10
##
##           S1          S2           S3         S4
## S1 0.9938409 0.002765652 1.729728e-07 0.00339323
## S2 0.0000000 0.992031641 4.575129e-03 0.00339323
## S3 0.0000000 0.000000000 1.000000e+00 0.00000000
## S4 0.0000000 0.000000000 0.000000e+00 1.00000000
```

```
##           S1          S2           S3          S4
## 0  1.0000000 0.000000000 0.000000e+00 0.000000000
## 1  0.9959114 0.001597673 6.108865e-08 0.002490893
## 2  0.9918395 0.003180382 4.574139e-06 0.004975580
## 3  0.9877842 0.004748233 1.349745e-05 0.007454068
## 4  0.9837455 0.006301330 2.678962e-05 0.009926360
## 5  0.9797234 0.007839778 4.440954e-05 0.012392460
## 6  0.9736892 0.010486882 8.044700e-05 0.015743489
## 7  0.9676922 0.013096204 1.285943e-04 0.019083024
## 8  0.9617321 0.015668148 1.886785e-04 0.022411065
## 9  0.9558087 0.018203115 2.605286e-04 0.025727609
## 10 0.9499219 0.020701500 3.439755e-04 0.029032655
```

This matrix is the trace matrix of the specific population (male, 40-45) during these 10 cycles under Strategy2. The whole cohort starts in $S1$ state and transitions to the rest of the states over time.

```
## [1] 0.01797355
```

```
##           S1          S2           S3          S4
## 0  1.0000000 0.000000000 0.000000e+00 0.000000000
## 1  0.9952031 0.002305980 5.647326e-08 0.002490893
## 2  0.9904292 0.004588728 6.538714e-06 0.004975580
## 3  0.9856781 0.006848420 1.938199e-05 0.007454063
## 4  0.9809499 0.009085230 3.852204e-05 0.009926340
## 5  0.9762444 0.011299333 6.389511e-05 0.012392411
## 6  0.9690368 0.015104120 1.157471e-04 0.015743374
## 7  0.9618824 0.018849834 1.850053e-04 0.019082790
## 8  0.9547808 0.022537157 2.713994e-04 0.022410640
## 9  0.9477317 0.026166767 3.746624e-04 0.025726905
## 10 0.9407346 0.029739331 4.945303e-04 0.029031566
```

```
## [1] 0.02583284
```

```
##           S1          S2           S3          S4
## 0  1.0000000 0.000000000 0.000000e+00 0.000000000
## 1  0.9947387 0.002770293 6.527652e-08 0.002490893
## 2  0.9895052 0.005511390 7.850143e-06 0.004975580
## 3  0.9842991 0.008223522 2.327324e-05 0.007454060
## 4  0.9791205 0.010906919 4.625386e-05 0.009926327
## 5  0.9739691 0.013561807 7.671192e-05 0.012392379
## 6  0.9659975 0.018120231 1.389388e-04 0.015743299
## 7  0.9580912 0.022604138 2.220196e-04 0.019082636
## 8  0.9502496 0.027014435 3.256134e-04 0.022410361
## 9  0.9424722 0.031352018 4.493835e-04 0.025726443
## 10 0.9347584 0.035617775 5.929971e-04 0.029030852
```

```
## [1] 0.03094887
```

We perform the same procedure for all risk levels under Strategy2: low, medium and high, and then obtain the following tables for the probability of transitioning from S1 to S2.

Table 5: prevented CVD (a male patient aged 40-45)

Stratification	CVD events
Low risk	0.0179736
Medium risk	0.0258328
High risk	0.0309489

When compared with what we calculated before, the probability of transitioning from S1 to S2 under Strategy 0 is 0.0411874, we may conclude that screening could help to prevent the CVD events under all three risk groups in the specific age and gender group.

Prevented CVD events under Strategy2

% latex table generated in R 3.6.3 by xtable 1.8-4 package % Tue Jan 19 16:53:46 2021

Table 6: prevented CVD events under the screening of Strategy 2

	index	sex	low	medium	high
1	40	male	0.0179735512363516	0.0258328354387439	0.0309488714501345
2	45	male	0.0307515242936025	0.0440518741298093	0.0526619911085829
3	50	male	0.0474778301200751	0.067719248865891	0.0807280561975468
4	55	male	0.0671078248329132	0.0951976201098379	0.113085118506986
5	60	male	0.093515620979756	0.131673447708389	0.155665808795515
6	65	male	0.124707736937782	0.173914670788674	0.204348500460409
7	70	male	0.166840944861418	0.230355674639071	0.268940757286528
8	40	female	0.0211407698824078	0.0303650714346771	0.0363631033411362
9	45	female	0.032727534109899	0.0468719572518638	0.056024988908411
10	50	female	0.0462344235513458	0.0659910276094477	0.0787028158495353
11	55	female	0.061739737652925	0.0877652840582465	0.104396449044258
12	60	female	0.0804086864575488	0.11373637041358	0.134854598484808
13	65	female	0.101189390888168	0.142185981925138	0.167872874658059
14	70	female	0.129702164398391	0.179409380051384	0.209711675696426

```
## [1] 518.7331
```