

Day 2, exercise 3: Estimating healthy life expectancy with the Sullivan method

2023-04-18

In this exercise, we will see how to use the Sullivan method to estimate healthy life expectancy. We will calculate life expectancy and healthy life expectancy for women aged 50-54 in Spain and Czechia between 2010 and 2015.

The dataset “SullivanData.RData” contains death rates (from the HMD) and the proportion of people with activity limitations (from the Statistics on Income and Living Conditions (SILC), as reported by the EuroHex website (<http://www.eurohex.eu/>)). These are the only data we need to use the Sullivan method.

Let's load the data, packages and functions.

```
load("SullivanData.RData")

library(tidyverse)
library(viridis)
```

Let's have a look at the dataset.

```
data
```

##	country	year	age	mx	qx	ax	lx	dx	Lx
## 1	Spain	2010	50-54	0.0020300	0.010098749	2.5	97885.99	988.5260	486958.6
## 2	Spain	2010	55-59	0.0029500	0.014642015	2.5	96897.47	1418.7742	480940.4
## 3	Spain	2010	60-64	0.0039500	0.019556876	2.5	95478.69	1867.2649	472725.3
## 4	Spain	2010	65-69	0.0061500	0.030284378	2.5	93611.43	2834.9638	460969.7
## 5	Spain	2010	70-74	0.0110500	0.053764749	2.5	90776.46	4880.5737	441680.9
## 6	Spain	2010	75-79	0.0216400	0.102646808	2.5	85895.89	8816.9388	407437.1
## 7	Spain	2010	80-84	0.0447600	0.201277093	2.5	77078.95	15514.2270	346609.2
## 8	Spain	2010	85+	0.1270055	1.000000000	0.5	61564.72	61564.7231	484740.6
## 9	Spain	2011	50-54	0.0020800	0.010346200	2.5	97899.66	1012.8895	486966.1
## 10	Spain	2011	55-59	0.0029300	0.014543469	2.5	96886.77	1409.0698	480911.2
## 11	Spain	2011	60-64	0.0040200	0.019900005	2.5	95477.70	1900.0068	472638.5
## 12	Spain	2011	65-69	0.0061600	0.030332874	2.5	93577.70	2838.4805	460792.3
## 13	Spain	2011	70-74	0.0107200	0.052201013	2.5	90739.22	4736.6790	441854.4
## 14	Spain	2011	75-79	0.0211600	0.100484376	2.5	86002.54	8641.9114	408407.9
## 15	Spain	2011	80-84	0.0444600	0.200062998	2.5	77360.63	15476.9988	348110.6
## 16	Spain	2011	85+	0.1263185	1.000000000	0.5	61883.63	61883.6275	489901.7
## 17	Spain	2012	50-54	0.0019800	0.009851236	2.5	97997.59	965.3974	487574.5
## 18	Spain	2012	55-59	0.0028300	0.014050592	2.5	97032.19	1363.3598	481752.6
## 19	Spain	2012	60-64	0.0040800	0.020194021	2.5	95668.83	1931.9384	473514.3
## 20	Spain	2012	65-69	0.0060800	0.029944838	2.5	93736.89	2806.9362	461667.1
## 21	Spain	2012	70-74	0.0105300	0.051299540	2.5	90929.96	4664.6650	442988.1
## 22	Spain	2012	75-79	0.0211000	0.100213726	2.5	86265.29	8644.9665	409714.1
## 23	Spain	2012	80-84	0.0450000	0.202247191	2.5	77620.33	15698.4931	348855.4
## 24	Spain	2012	85+	0.1318463	1.000000000	0.5	61921.83	61921.8340	469651.6
## 25	Spain	2013	50-54	0.0020400	0.010148244	2.5	98091.66	995.4581	487969.6
## 26	Spain	2013	55-59	0.0029100	0.014444913	2.5	97096.20	1402.5462	481974.6

## 27	Spain	2013	60-64	0.0040500	0.020047024	2.5	95693.65	1918.3729	473672.3
## 28	Spain	2013	65-69	0.0060500	0.029799286	2.5	93775.28	2794.4363	461890.3
## 29	Spain	2013	70-74	0.0102600	0.050017062	2.5	90980.84	4550.5945	443527.7
## 30	Spain	2013	75-79	0.0198500	0.094557580	2.5	86430.25	8172.6351	411719.7
## 31	Spain	2013	80-84	0.0418600	0.189471778	2.5	78257.61	14827.6092	354219.0
## 32	Spain	2013	85+	0.1226544	1.000000000	0.5	63430.00	63430.0042	517144.1
## 33	Spain	2014	50-54	0.0019200	0.009554140	2.5	98124.06	937.4910	488276.6
## 34	Spain	2014	55-59	0.0029000	0.014395632	2.5	97186.57	1399.0621	482435.2
## 35	Spain	2014	60-64	0.0040600	0.020096025	2.5	95787.51	1924.9482	474125.2
## 36	Spain	2014	65-69	0.0059600	0.029362499	2.5	93862.56	2756.0393	462422.7
## 37	Spain	2014	70-74	0.0101300	0.049398971	2.5	91106.52	4500.5684	444281.2
## 38	Spain	2014	75-79	0.0195700	0.093285983	2.5	86605.95	8079.1214	412832.0
## 39	Spain	2014	80-84	0.0415000	0.187995470	2.5	78526.83	14762.6884	355727.4
## 40	Spain	2014	85+	0.1218716	1.000000000	0.5	63764.14	63764.1421	523207.6
## 41	Spain	2015	50-54	0.0019600	0.009752214	2.5	98214.34	957.8073	488677.2
## 42	Spain	2015	55-59	0.0030400	0.015085351	2.5	97256.53	1467.1490	482614.8
## 43	Spain	2015	60-64	0.0040900	0.020243015	2.5	95789.38	1939.0660	474099.3
## 44	Spain	2015	65-69	0.0060200	0.029653712	2.5	93850.32	2783.0103	462294.1
## 45	Spain	2015	70-74	0.0101200	0.049351409	2.5	91067.31	4494.3000	444100.8
## 46	Spain	2015	75-79	0.0199300	0.094920582	2.5	86573.01	8217.5604	412321.1
## 47	Spain	2015	80-84	0.0430700	0.194416232	2.5	78355.45	15233.5710	353693.3
## 48	Spain	2015	85+	0.1316326	1.000000000	0.5	63121.88	63121.8772	479530.6
## 49	Czechia	2010	50-54	0.0030400	0.015085351	2.5	97311.01	1467.9708	482885.1
## 50	Czechia	2010	55-59	0.0047800	0.023617768	2.5	95843.04	2263.5987	473556.2
## 51	Czechia	2010	60-64	0.0076900	0.037724742	2.5	93579.44	3530.2604	459071.6
## 52	Czechia	2010	65-69	0.0127700	0.061874652	2.5	90049.18	5571.7619	436316.5
## 53	Czechia	2010	70-74	0.0211000	0.100213726	2.5	84477.42	8465.7973	401222.6
## 54	Czechia	2010	75-79	0.0380800	0.173849525	2.5	76011.63	13214.5849	347021.7
## 55	Czechia	2010	80-84	0.0744900	0.313979220	2.5	62797.04	19716.9657	264692.8
## 56	Czechia	2010	85+	0.1658415	1.000000000	0.5	43080.07	43080.0745	259766.6
## 57	Czechia	2011	50-54	0.0028300	0.014050592	2.5	97373.28	1368.1523	483446.0
## 58	Czechia	2011	55-59	0.0048300	0.023861868	2.5	96005.13	2290.8618	474298.5
## 59	Czechia	2011	60-64	0.0076100	0.037339614	2.5	93714.27	3499.2547	459823.2
## 60	Czechia	2011	65-69	0.0125800	0.060982113	2.5	90215.02	5501.5022	437321.3
## 61	Czechia	2011	70-74	0.0205100	0.097548215	2.5	84713.51	8263.6520	402908.4
## 62	Czechia	2011	75-79	0.0368600	0.168749714	2.5	76449.86	12900.8922	349997.1
## 63	Czechia	2011	80-84	0.0734100	0.310132866	2.5	63548.97	19708.6239	268473.3
## 64	Czechia	2011	85+	0.1612960	1.000000000	0.5	43840.35	43840.3451	271800.6
## 65	Czechia	2012	50-54	0.0027600	0.013705433	2.5	97432.72	1335.3576	483825.2
## 66	Czechia	2012	55-59	0.0047800	0.023617768	2.5	96097.36	2269.6052	474812.8
## 67	Czechia	2012	60-64	0.0076400	0.037484055	2.5	93827.76	3517.0447	460346.2
## 68	Czechia	2012	65-69	0.0121600	0.059006211	2.5	90310.71	5328.8929	438231.3
## 69	Czechia	2012	70-74	0.0204100	0.097095692	2.5	84981.82	8251.3685	404280.7
## 70	Czechia	2012	75-79	0.0364200	0.166903442	2.5	76730.45	12806.5762	351635.8
## 71	Czechia	2012	80-84	0.0717200	0.304078691	2.5	63923.87	19437.8879	271024.6
## 72	Czechia	2012	85+	0.1648403	1.000000000	0.5	44485.99	44485.9859	269873.2
## 73	Czechia	2013	50-54	0.0029100	0.014444913	2.5	97603.33	1409.8716	484492.0
## 74	Czechia	2013	55-59	0.0045200	0.022347474	2.5	96193.46	2149.6807	475593.1
## 75	Czechia	2013	60-64	0.0076000	0.037291462	2.5	94043.78	3507.0299	461451.3
## 76	Czechia	2013	65-69	0.0125700	0.060935114	2.5	90536.75	5516.8669	438891.6
## 77	Czechia	2013	70-74	0.0200000	0.095238095	2.5	85019.88	8097.1313	404856.6
## 78	Czechia	2013	75-79	0.0353100	0.162229216	2.5	76922.75	12479.1170	353415.9
## 79	Czechia	2013	80-84	0.0704500	0.299500478	2.5	64443.63	19300.8981	273965.9
## 80	Czechia	2013	85+	0.1645969	1.000000000	0.5	45142.73	45142.7323	274262.3

```

## 81 Czechia 2014 50-54 0.0025900 0.012866688 2.5 97630.67 1256.1834 485012.9
## 82 Czechia 2014 55-59 0.0042800 0.021173444 2.5 96374.48 2040.5798 476771.0
## 83 Czechia 2014 60-64 0.0070200 0.034494619 2.5 94333.90 3254.0121 463534.5
## 84 Czechia 2014 65-69 0.0115000 0.055893074 2.5 91079.89 5090.7352 442672.6
## 85 Czechia 2014 70-74 0.0187400 0.089506615 2.5 85989.16 7696.5984 410704.3
## 86 Czechia 2014 75-79 0.0336500 0.155194281 2.5 78292.56 12150.5574 361086.4
## 87 Czechia 2014 80-84 0.0647700 0.278718506 2.5 66142.00 18434.9998 284622.5
## 88 Czechia 2014 85+ 0.1574953 1.000000000 0.5 47707.00 47707.0017 302910.7
## 89 Czechia 2015 50-54 0.0026200 0.013014753 2.5 97649.20 1270.8802 485068.8
## 90 Czechia 2015 55-59 0.0042000 0.020781791 2.5 96378.32 2002.9141 476884.3
## 91 Czechia 2015 60-64 0.0070300 0.034542908 2.5 94375.40 3260.0010 463727.0
## 92 Czechia 2015 65-69 0.0117600 0.057120653 2.5 91115.40 5204.5713 442565.6
## 93 Czechia 2015 70-74 0.0194300 0.092649548 2.5 85910.83 7959.5998 409655.2
## 94 Czechia 2015 75-79 0.0344300 0.158506549 2.5 77951.23 12355.7808 358866.7
## 95 Czechia 2015 80-84 0.0690400 0.294388538 2.5 65595.45 19310.5491 279700.9
## 96 Czechia 2015 85+ 0.1674258 1.000000000 0.5 46284.90 46284.9025 276450.3
##
##          ex prevalence
## 1  36.594223      0.233
## 2  31.942044      0.299
## 3  27.379541      0.358
## 4  22.875813      0.461
## 5  18.512153      0.514
## 6  14.421957      0.609
## 7  10.785691      0.688
## 8   7.873674      0.757
## 9  36.665935      0.187
## 10 32.023118      0.258
## 11 27.458824      0.325
## 12 22.965589      0.415
## 13 18.605788      0.476
## 14 14.492831      0.631
## 15 10.832543      0.712
## 16  7.916500      0.777
## 17 36.487812      0.213
## 18 31.825965      0.261
## 19 27.243885      0.302
## 20 22.753862      0.413
## 21 18.379082      0.473
## 22 14.237720      0.620
## 23 10.545009      0.729
## 24  7.584588      0.812
## 25 37.027791      0.247
## 26 32.381780      0.309
## 27 27.819746      0.372
## 28 23.337715      0.410
## 29 18.977737      0.506
## 30 14.845298      0.634
## 31 11.134547      0.734
## 32  8.152988      0.806
## 33 37.129607      0.251
## 34 32.463655      0.280
## 35 27.901301      0.335
## 36 23.422235      0.400
## 37 19.055148      0.475

```

## 38	14.915453	0.584
## 39	11.192800	0.691
## 40	8.205358	0.826
## 41	36.627351	0.219
## 42	31.963446	0.291
## 43	27.414720	0.366
## 44	22.929490	0.417
## 45	18.553813	0.457
## 46	14.387222	0.649
## 47	10.633899	0.711
## 48	7.596900	0.847
## 49	32.108730	0.267
## 50	27.562229	0.289
## 51	23.168461	0.295
## 52	18.978741	0.336
## 53	15.065607	0.453
## 54	11.465102	0.592
## 55	8.351657	0.641
## 56	6.029854	0.817
## 57	32.329900	0.241
## 58	27.755000	0.331
## 59	23.372363	0.308
## 60	19.181959	0.358
## 61	15.265326	0.449
## 62	11.645162	0.586
## 63	8.501695	0.682
## 64	6.199783	0.809
## 65	32.371362	0.228
## 66	27.786451	0.327
## 67	23.398107	0.308
## 68	19.211959	0.348
## 69	15.259903	0.458
## 70	11.632066	0.591
## 71	8.461594	0.698
## 72	6.066477	0.735
## 73	32.446933	0.247
## 74	27.885854	0.321
## 75	23.466132	0.314
## 76	19.278275	0.389
## 77	15.367003	0.446
## 78	11.721425	0.508
## 79	8.507097	0.697
## 80	6.075448	0.815
## 81	33.056363	0.251
## 82	28.454647	0.307
## 83	24.016084	0.285
## 84	19.784789	0.361
## 85	15.808084	0.426
## 86	12.116344	0.532
## 87	8.882906	0.693
## 88	6.349396	0.773
## 89	32.697849	0.235
## 90	28.096049	0.294
## 91	23.639270	0.294

```
## 92 19.395608      0.365
## 93 15.419162      0.474
## 94 11.738338      0.589
## 95  8.478502      0.719
## 96  5.972797      0.787
```

In order to obtain the healthy life expectancy, we need to calculate the number of years lived in good health, in our case, without activity limitations.

```
data <- data %>%
  mutate(Lx_healthy = Lx*(1-prevalence))
```

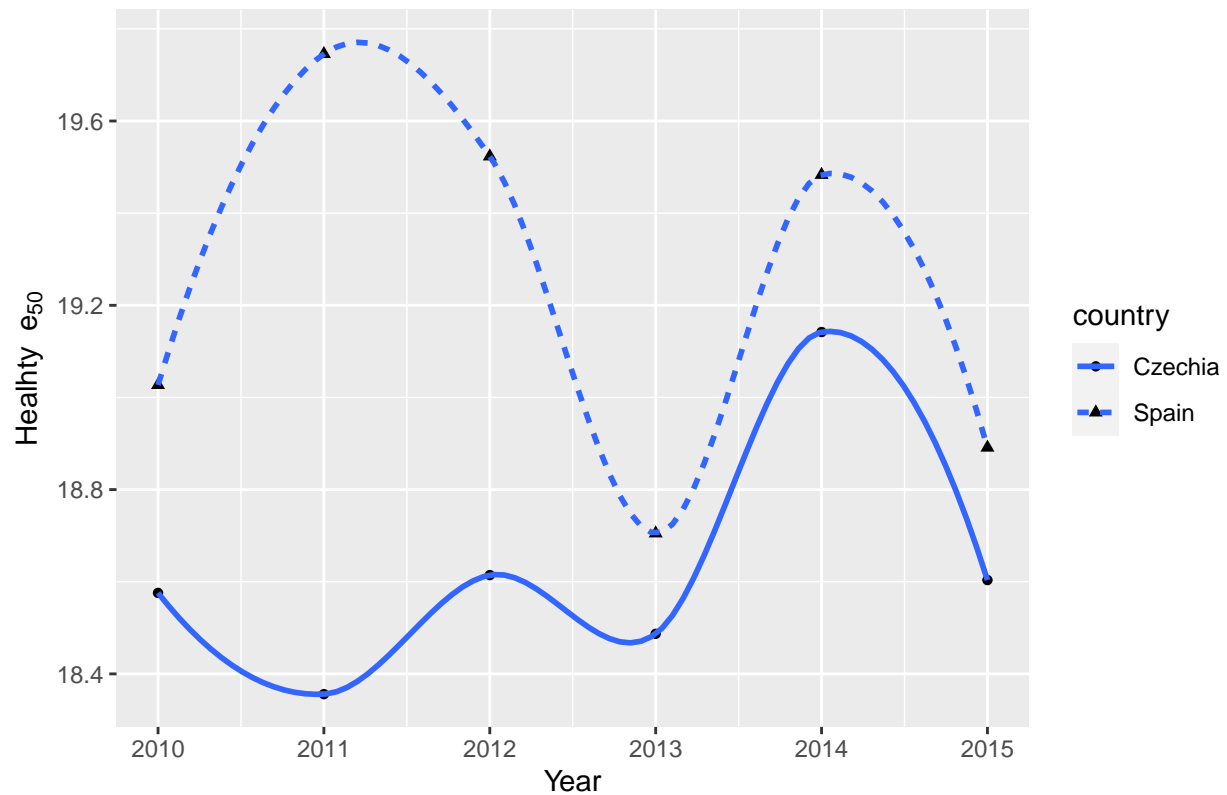
From here, we apply lifetable formulas to obtain the healthy life expectancy.

```
data <- data %>%
  group_by(year, country) %>%
  mutate(Tx_healthy = rev(cumsum(rev(Lx_healthy))),
         ex_healthy = Tx_healthy/lx) %>%
  ungroup()
```

That's it! We now have our healthy life expectancy and we could calculate the whole healthy lifetable if we wanted. Now let's look at the results by plotting healthy life expectancy at age 50.

```
data %>%
  filter(age=="50-54") %>%
  ggplot() +
    ggtitle("Healthy life expectancy at 50") +
    geom_point(aes(x=year, y=ex_healthy, shape=country)) +
    geom_smooth(aes(x=year, y=ex_healthy, linetype=country), se=F) +
    scale_y_continuous(bquote("Healthy "~"e"["50"])) +
    scale_x_continuous("Year")
```

Healthy life expectancy at 50



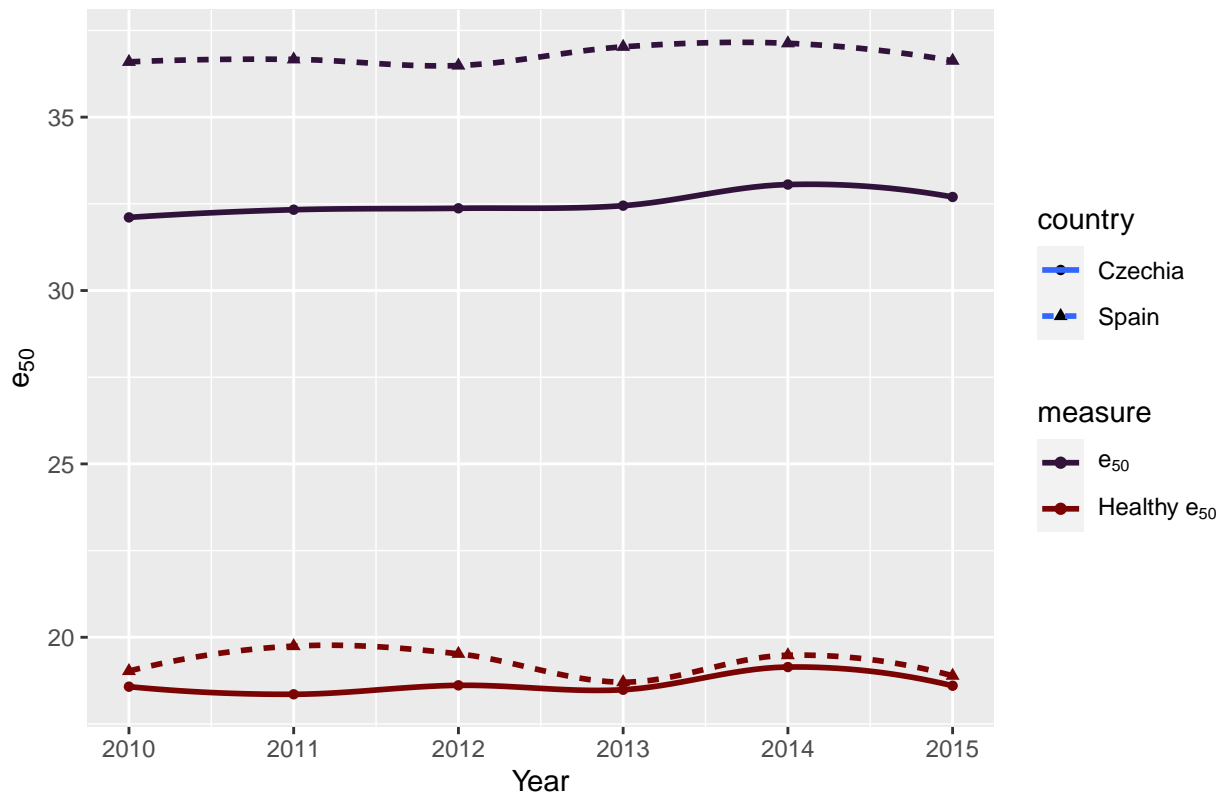
How does healthy life expectancy compare with life expectancy?

First, we need to turn the data in long format, because ggplot does not accept wide datasets.

```
data_ex <- data %>%
  pivot_longer(cols=c("ex", "ex_healthy"), names_to="type", values_to="ex")

# Now we can plot it
data_ex %>%
  filter(age=="50-54") %>%
  ggplot(aes(x=year, y=ex, colour=type)) +
  ggtitle("Life expectancy and healthy life expectancy at 50") +
  geom_point(aes(shape=country)) +
  geom_smooth(aes(linetype=country), se=F) +
  scale_colour_viridis_d(option="H", name="measure",
    labels=c(bquote("e"["50"]),
              bquote("Healthy e"["50"]))) +
  scale_y_continuous(bquote("e"["50"])) +
  scale_x_continuous("Year")
```

Life expectancy and healthy life expectancy at 50



Another way to look at healthy life expectancy is to calculate which percentage of total life expectancy is represented by healthy life expectancy (roughly, how much of the life expectancy is spent in good health)

```
data %>%
  # We need to express healthy life expectancy as a proportion of total life expectancy
  mutate(prop = ex_healthy/ex) %>%
  filter(age=="50-54") %>%
  ggplot(aes(x=year, y=prop*100, linetype=country)) +
  ggtitle("Healthy life expectancy vs total life expectancy at 50") +
  geom_point(aes(shape=country)) +
  geom_smooth(aes(linetype=country), se=F) +
  scale_y_continuous("%") +
  scale_x_continuous("Year")
```

