Exploring the HALE Estimates of the Global Burden of Disease Study by a Simple, Gompertz, Weibull and an advanced IM model

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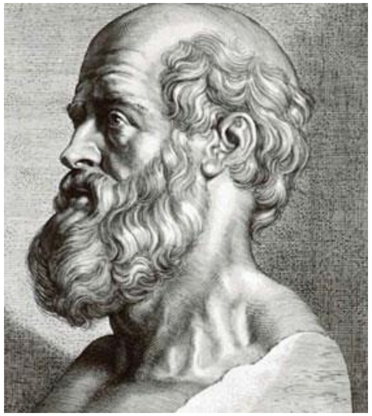
What is Health and Health Status

- **According to the World Health Organization (WHO)**
- "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

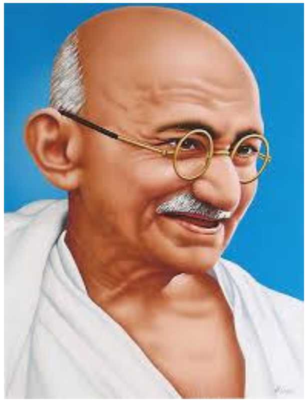
- **Physical health**
- **Mental health**
- **More….**



"We must turn to nature itself, to the observations of the body in health and in disease to learn the truth."
(*Hippocrates*)

Determinants of health

- Socioeconomic status
- Education
- Physical environment
- Job prospects and employment conditions
- Support from people around you
- Culture
- Genetic inheritance
- What we do and how we manage
- Access and use of health services
- Gender



"It is health that is real wealth and not pieces of gold and silver.“

(*Mahatma Gandhi*)

World Health Organization (WHO) and Health and Disease Measures

- **The STEPS Instrument and Support Materials**
- **THE STEPS INSTRUMENT**
- The tool used to collect data and measure noncommunicable disease (NCD) risk factors within the WHO STEPwise approach to surveillance is called the STEPS Instrument. The STEPS Instrument covers three different levels or 'steps' of risk factor assessment:
- **Step 1 (questionnaire),**
- **Step 2 (physical measurements) and**
- **Step 3 (biochemical measurements).**

Global Physical Activity Surveillance WHO Questionnaires

- Physical Activity
- Questions
- Activity at work
- Travel to and from places
- Recreational activities
- Sedentary behaviour
- Other…

The Global Burden of Disease Study

- The GBD 2000 project has adopted a similar approach to health state valuation, using a
- standard health state description based on eight core domains of health (mobility, self care,
- pain and discomfort, cognition, interpersonal activities, vision, sleep and energy, affect).
- As part of the World Health Survey being conducted by WHO (WHO, 2003), revised
- disability weights will be developed during 2003 that are based on health state valuations
- from large representative population samples in over 70 countries.

Our View of the Problem

Find a simple method measuring our health state

- **Christos H Skiadas,** Verifying the HALE measures of the Global Burden of Disease Study: Quantitative Methods Proposed,
- arXiv:1510.07346 [pdf], October 2015

- People have an estimate of their health state
- How this is done?
- By observing the overall social health status and especially the **Determinants** of health presented earlier
- **These hundreds, thousands or millions influences form the overall public opinion**. The most important part refers to the most critical issue that of live and die and the information coming from the environment.
- **People give their responses.**
- **Can we find a simple way to reproduce it?**

The Mortality Diagram

is constructed by using the force of mortality μx

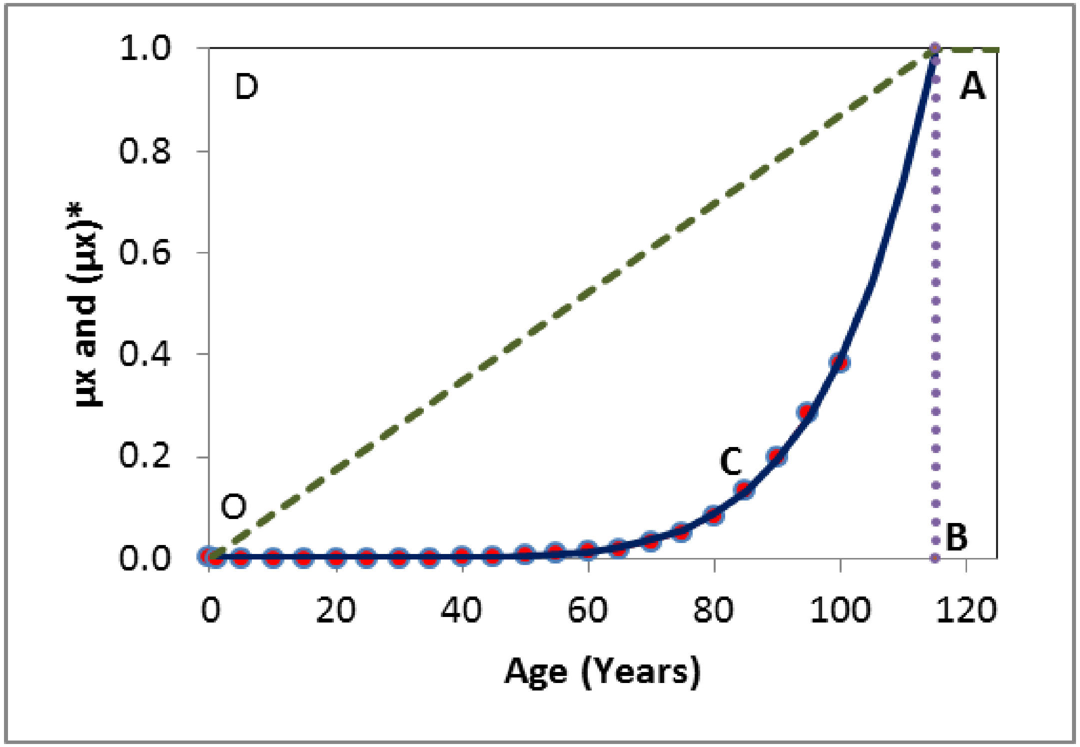
- **Christos H Skiadas,** Verifying the HALE measures of the Global Burden of Disease Study: Quantitative Methods Proposed, ArXiv.org, 2015

1. The Mortality Area (OCABO)
2. The Health Area (ODACO)
3. The Total Area (ODABO)
4. Equation $\mu_x = \left(\frac{x}{T}\right)^b$
5. $E_{mortality} = \frac{T}{(b+1)}$

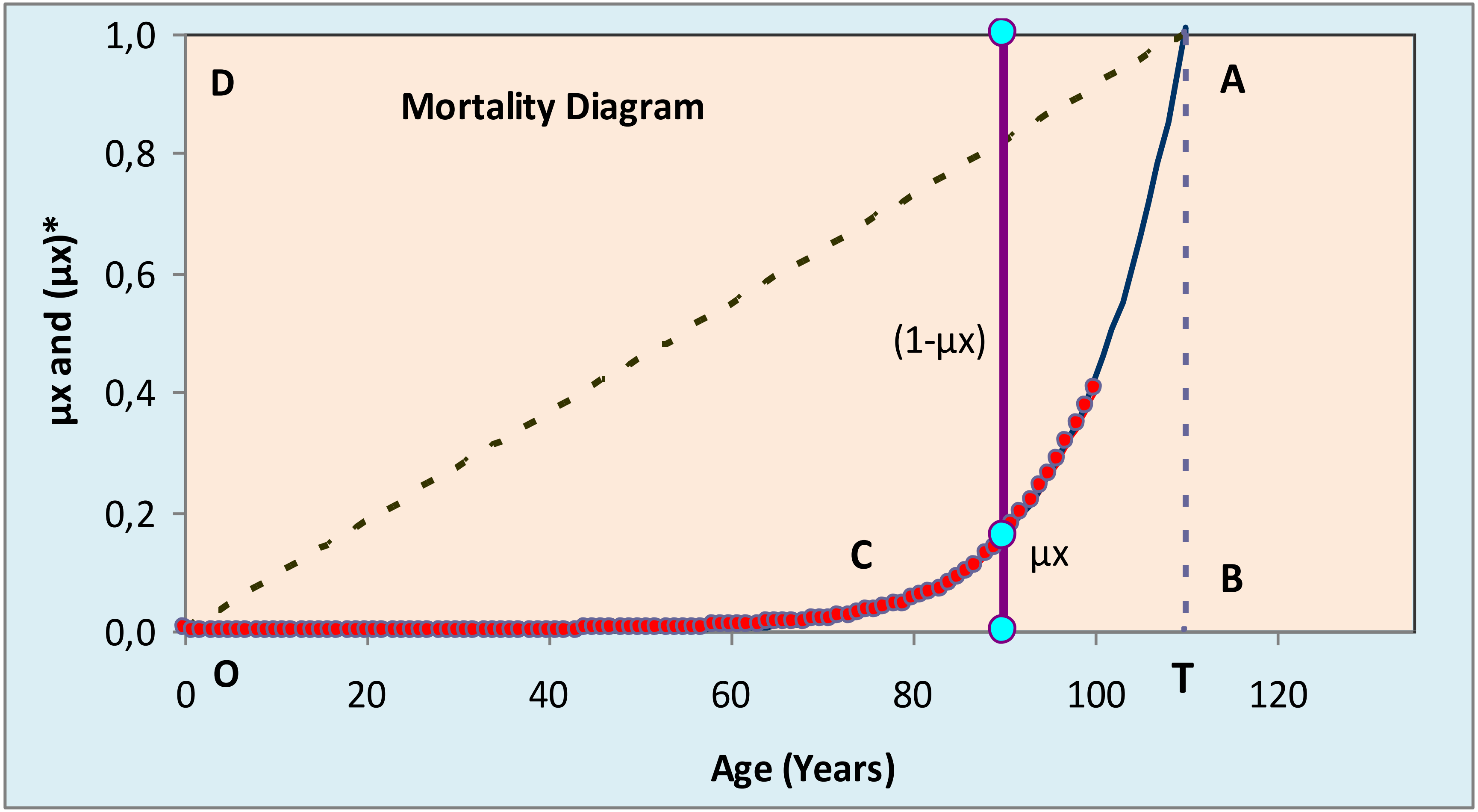
$$E_{health} = \frac{bT}{b+1}$$

$$\frac{E_{health}}{E_{mortality}} = b$$

$$\frac{E_{total}}{E_{mortality}} = b + 1$$



The Mortality Diagram



The Main Finding

We have used a Geometric approach to develop the parameter *b*

We can arrive to the Loss of Healthy Life Years of a Population by estimating the Parameter *b* presented earlier.

The only needed is information for the mortality of the population μx.

Fortunately this information is provided in all the Life Tables from the days of John Graunt (1661) and Edmont Halley (1693).

$$LHLY = \lambda \frac{E_{health}}{E_{mortality}} = b\lambda$$

The Main Finding

The parameter $\boldsymbol{b}$ **expresses the Loss of Healthy Life Years (LHLY)**

- **We check the LHLY estimated by our method with that of the WHO**
- **For comparisons between countries it is sufficient to select** $\boldsymbol{\lambda}$**=1**.
- To our great surprise selecting $\boldsymbol{\lambda}$**=1** provided results very close to those provided by WHO as it is presented in the following Tables and in other applications. It is clear that we have found an interesting estimator for the loss of healthy life years.

$$\frac{E_{health}}{E_{mortality}} = b$$

Estimation without a model from *mx*

As the needed data sets in the form of mx or qx data are provided from the life tables

we have developed a method of direct estimation of the loss of healthy life year estimators directly from the life table

by expanding the life table to the right.

The only needed is to estimate the following fraction from the life table data

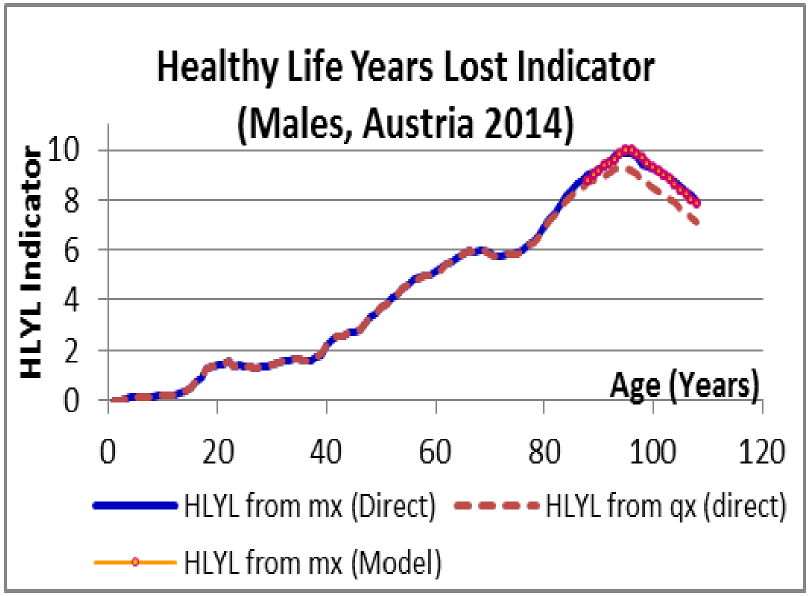
$$b = \frac{E_{total}}{E_{mortality}} = \frac{x m_x}{\sum_0^x m_x}$$

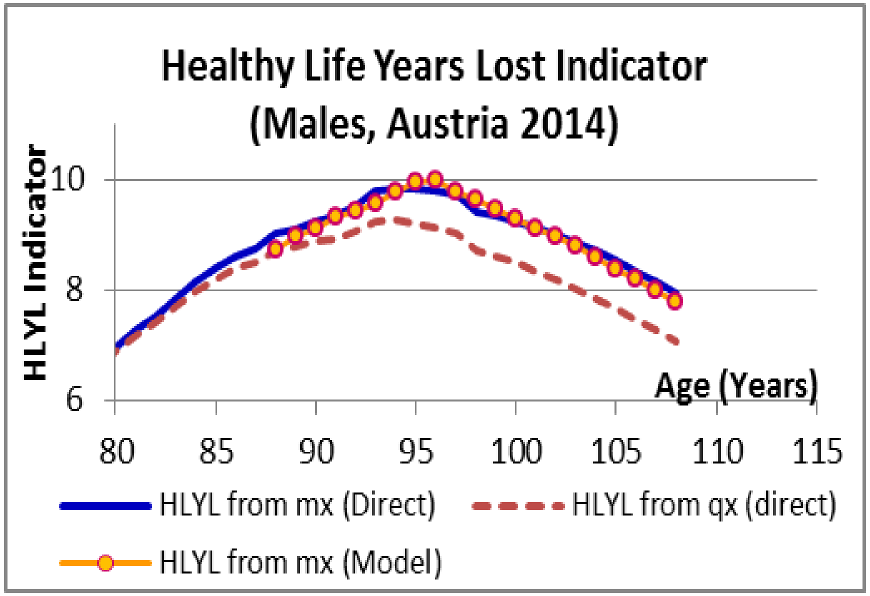
Estimation without a model from *qx*

A similar indicator results by selecting the *qx* data from the life table and using the:

$$b = \frac{E_{total}}{E_{mortality}} = \frac{x\,q_x}{\sum_0^x q_x}$$

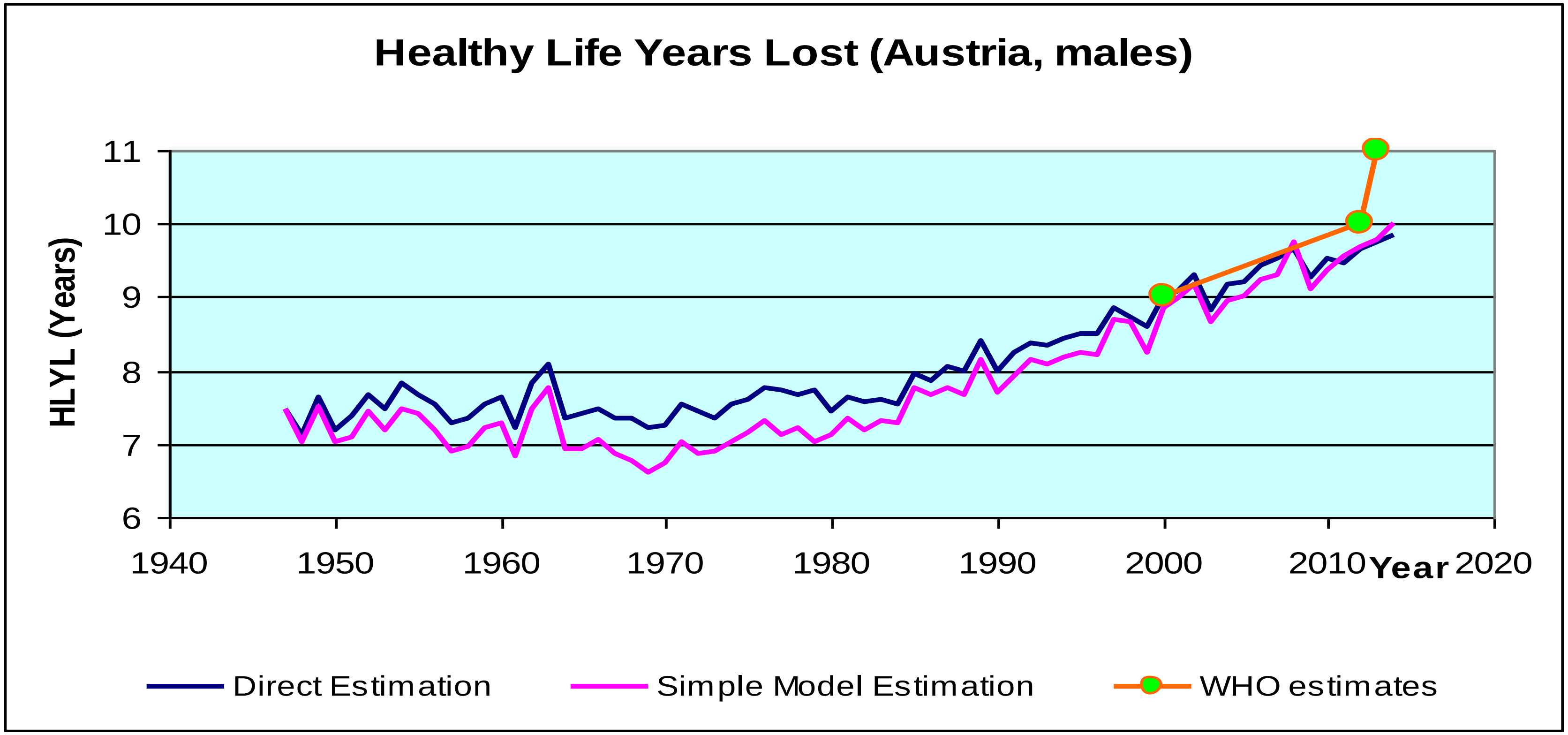
Estimation without a model (Direct estimation)





- **Fig. Estimation of the HLYL indicator (*b*) by the direct method and by the simple model (Full results A and expanded around the maximum B)**

Estimation with and without a model from *mx* (Direct and Model estimation)



- **Fig. Estimation of the HLYL indicator (*b*) by the direct method and by the simple model**

More details: The Gompertz and the Weibull Distributions

$$f_x = e^{-k+bx-e^{-l+bx}}$$

Gompertz (*l* parameter is expressing the HLYL)

Weibull $$f_x = \frac{b}{T}\left(\frac{x}{T}\right)^{b-1} e^{-\left(\frac{x}{T}\right)^{b}}$$

$$H(x) = \left(\frac{x}{T}\right)^{b}$$

Weibull Cumulative Hazard (*b* parameter)

A Second Order Approximation General First Exit Model

- A second order approximation in the following form can improve fitting:

$$f_x = \left(\frac{2}{\sqrt{2\pi}}\right)\left(\frac{|H_x - xH'_x|}{\sqrt{x^3}} - \frac{k\sqrt{x^3}H''_x}{2|H_x - xH'_x|}\right)e^{-\frac{H_x^2}{2x}}$$

- The parameter *k* expresses the level of the influence of the second order correction term. When k=0 the last equation form reduces to the first order approximation.

The Health Function $H(x) = l - (bx)^c$

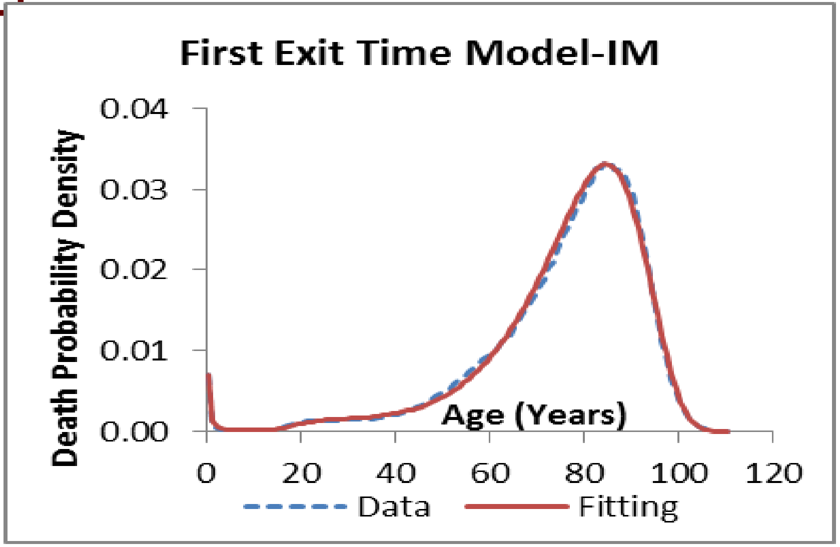
- Insert the 3-parameter (b, l, c) expression introduced by Skiadas and Skiadas [2] for $H(x)$ in the previous general model we find the following 4-parameter IM-model:

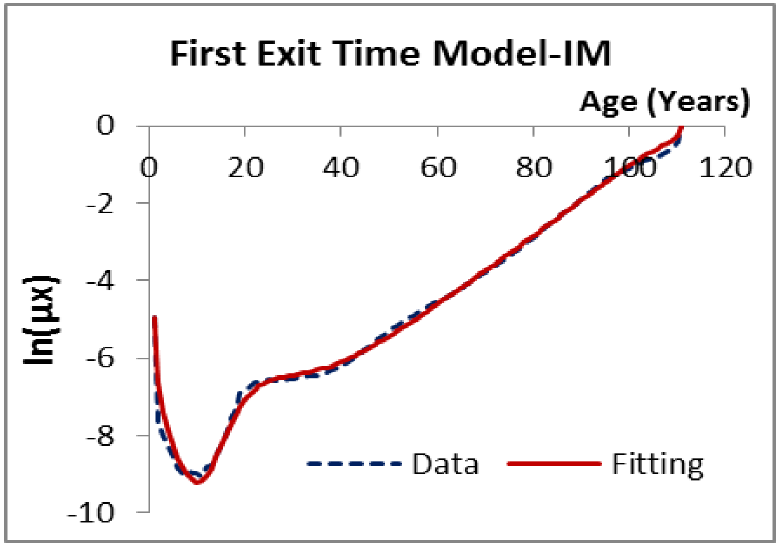
$$f_x = \left(\frac{2}{\sqrt{2\pi}}\right)\left(\frac{\left|l + (c-1)(bx)^c\right|}{\sqrt{x^3}} + \frac{k\sqrt{x^3}c(c-1)b^c x^{(c-2)}}{2\left|l + (c-1)(bx)^c\right|}\right)e^{-\frac{\left(l-(bx)^c\right)^2}{2x}}$$

- **The importance in this model is that the exponent *c* is related to the healthy life years lost by:**
- **HLYL=*c*-0.5+ln(*c*-1)**

More details: The SKI-IM Model

Fitting the 4-Parameter Model

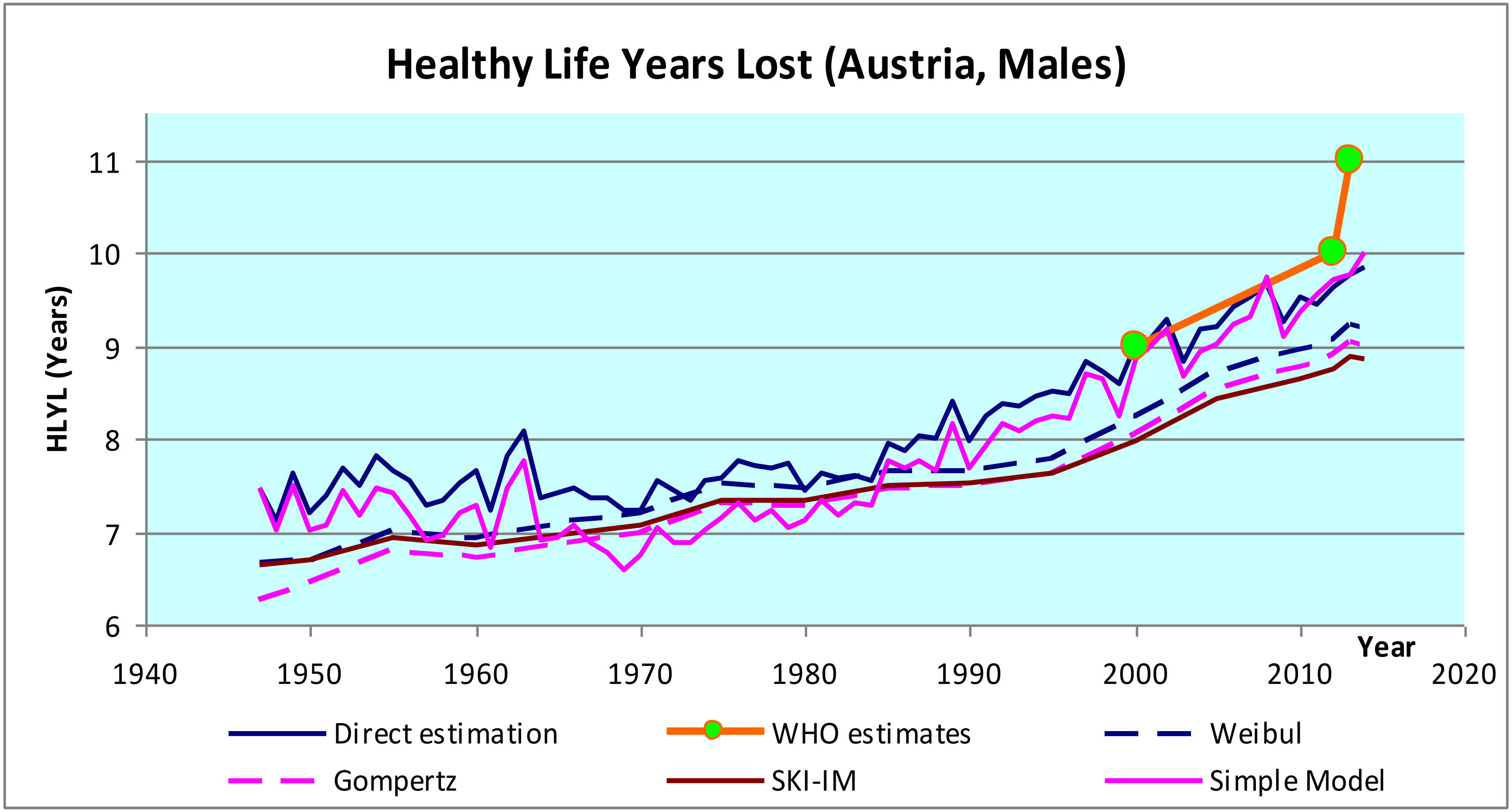




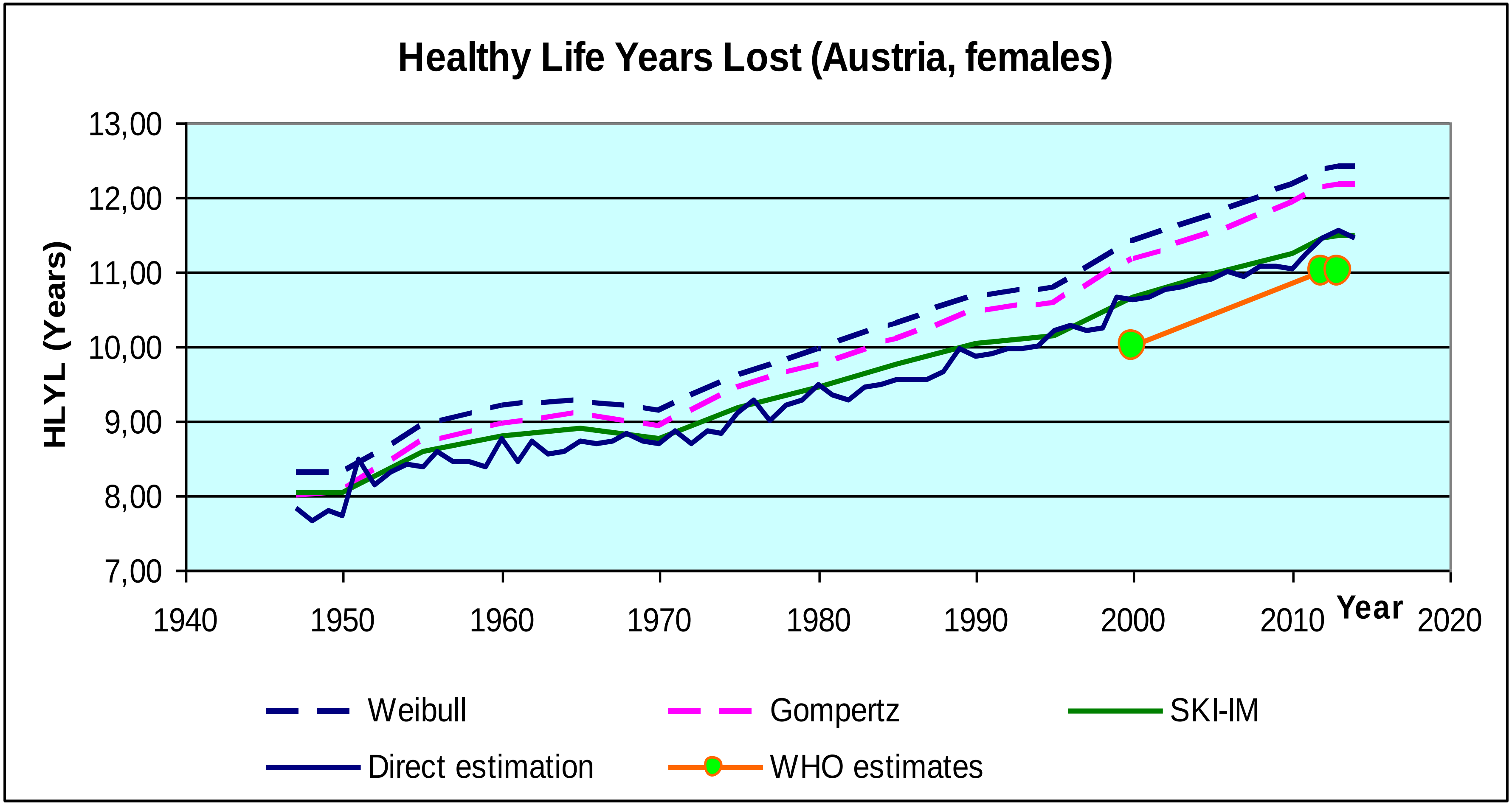
Total Methods and Models used

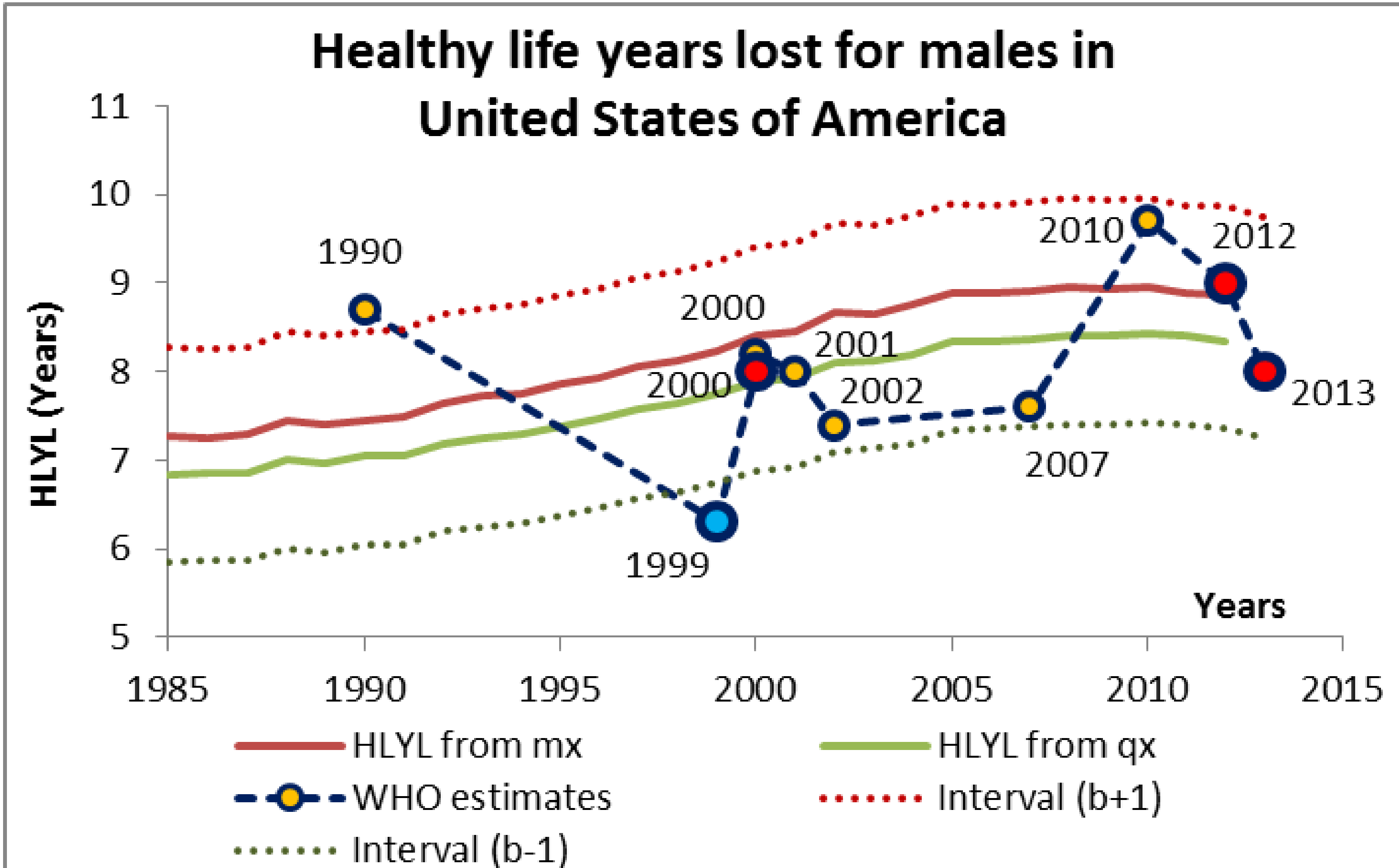
1. Direct estimation
2. Simple Model
3. Gompertz Model
4. Weibull Model
5. SKI-IM Model

Estimation with and without a model from *mx* (Direct, SKI-IM, Weibull and Gompertz)

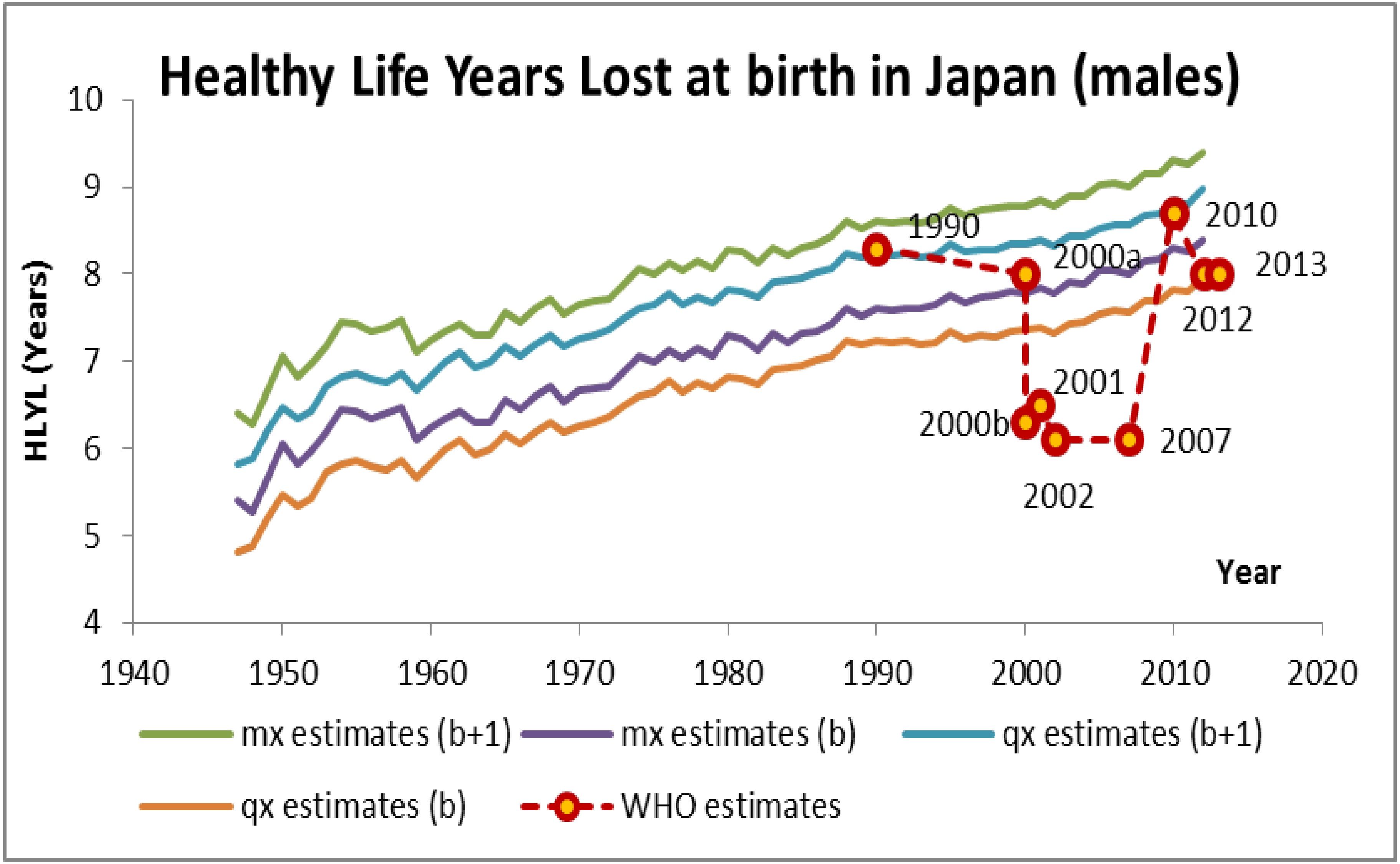


Estimation with and without a model from *mx* (Direct, SKI-IM, Weibull and Gompertz)

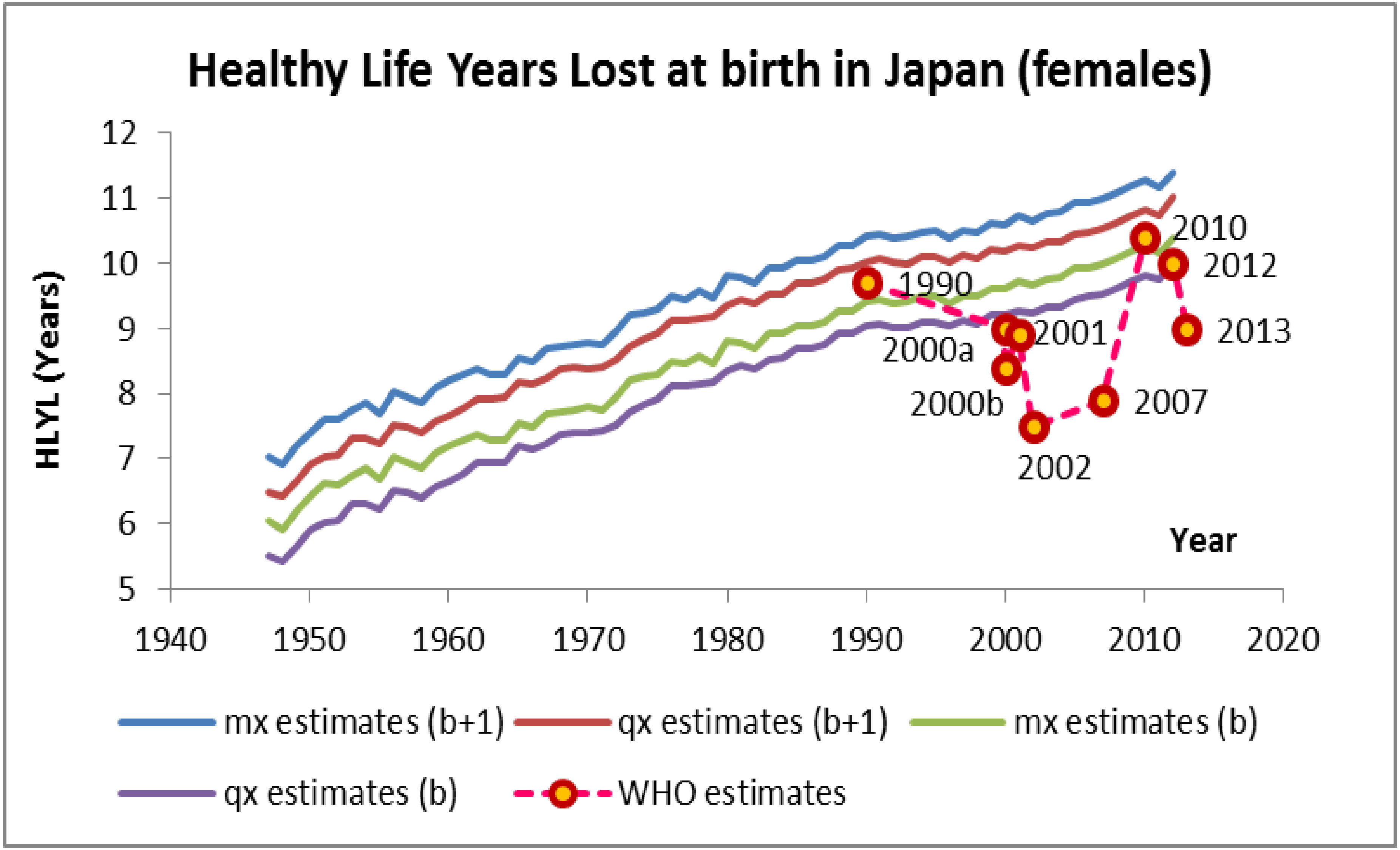




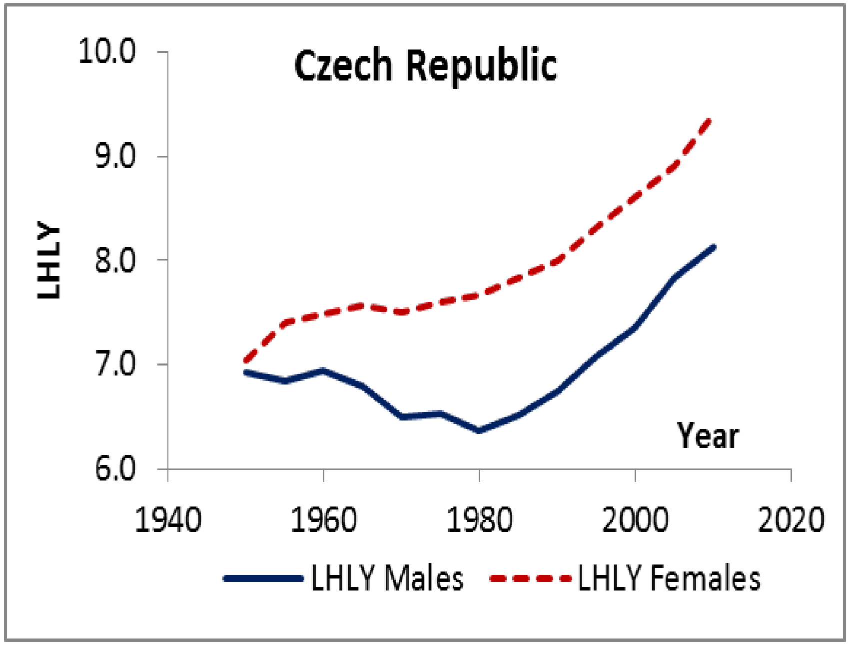
Healthy life years lost for males in United States of America
HLYL (Years)
11
10
9
8
7
6
5
1985
1990
1995
2000
2005
2010
2015
Years
1990
1999
2000
2000
2001
2002
2007
2010
2012
2013
HLYL from mx
HLYL from qx
WHO estimates
Interval (b+1)
Interval (b-1)



Healthy Life Years Lost at birth in Japan (males)
10
9
8
7
6
5
4
HLYL (Years)
1990
2000a
2010
2013
2012
2001
2000b
2007
2002
Year
1940
1950
1960
1970
1980
1990
2000
2010
2020
mx estimates (b+1)
mx estimates (b)
qx estimates (b+1)
qx estimates (b)
WHO estimates


Healthy Life Years Lost at birth in Japan (females)
HLYL (Years)
Year
1990
2000a
2000b
2001
2002
2007
2010
2012
2013
mx estimates (b+1)
qx estimates (b+1)
mx estimates (b)
qx estimates (b)
WHO estimates

Loss of Healthy Life Years



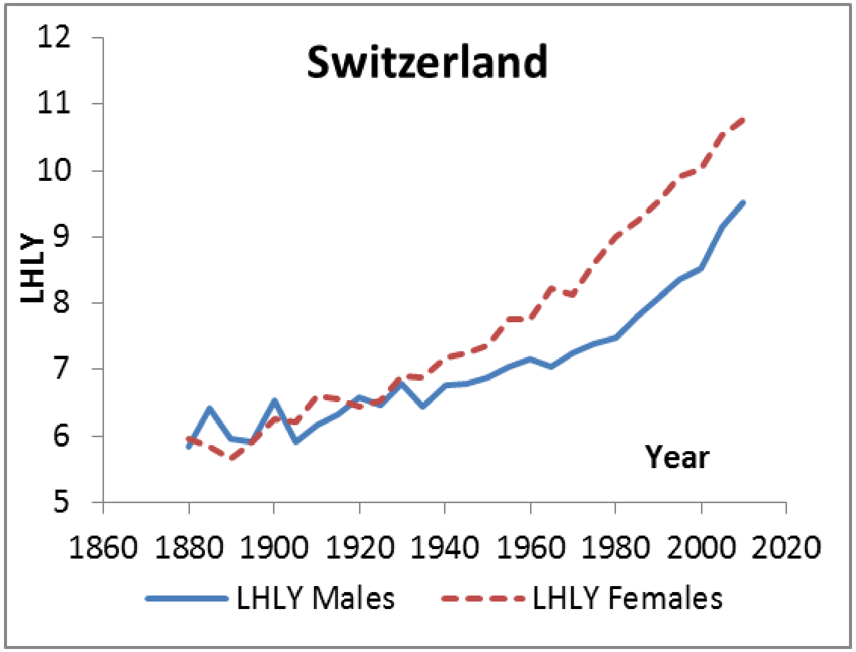
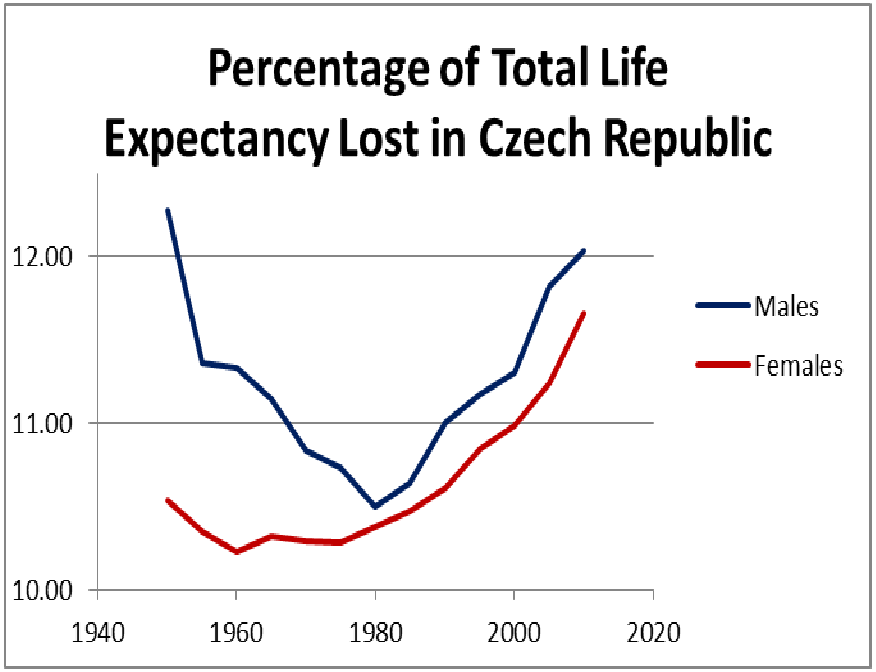


Fig. 2A. Loss of Healthy Life Years in Czech Republic (1950-2010)

Fig. 2B. Loss of Healthy Life Years in Switzerland (1880-2010)

Percentage of Life Expectancy Lost



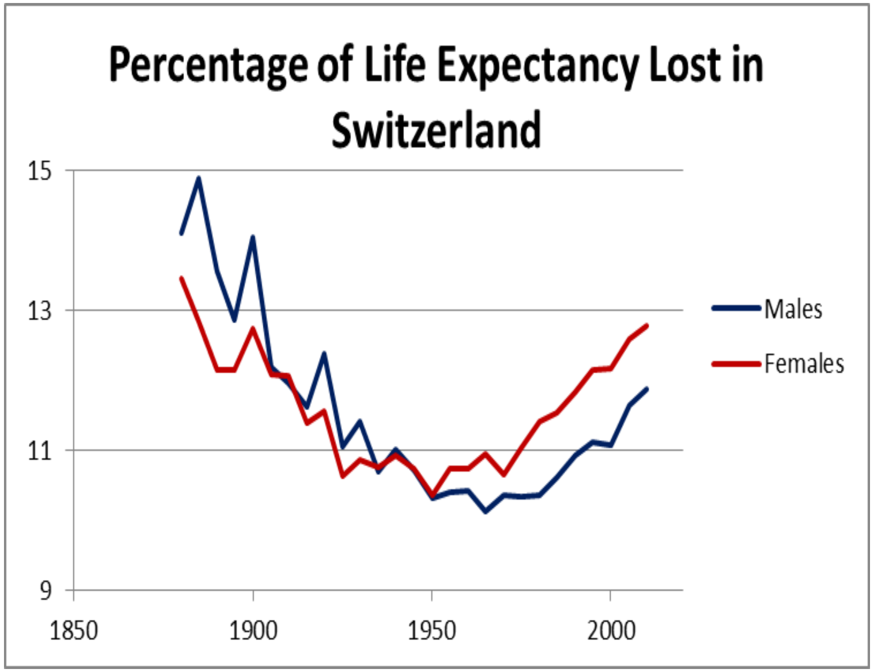
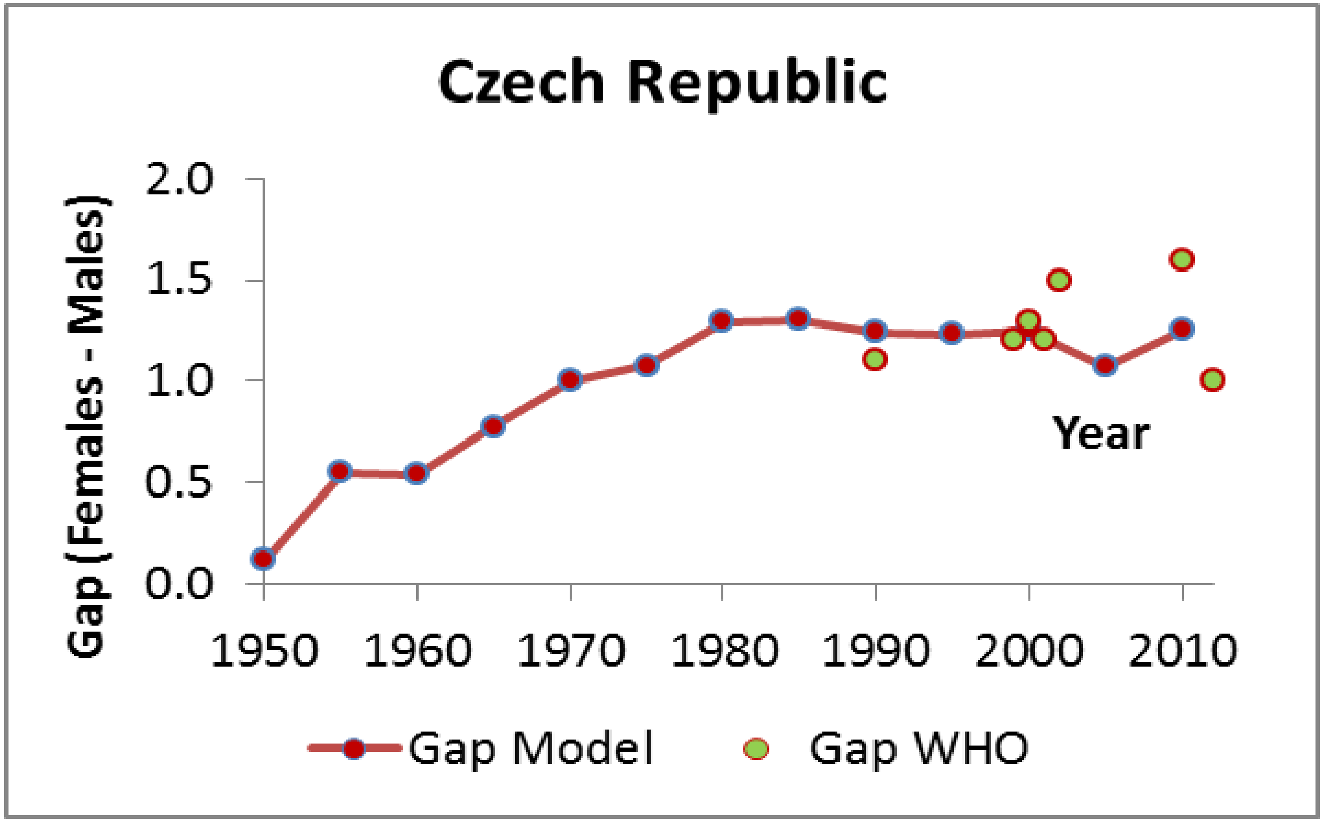


Fig. 3.The gap between males and females for Czech Republic



Healthy Life Expectancy

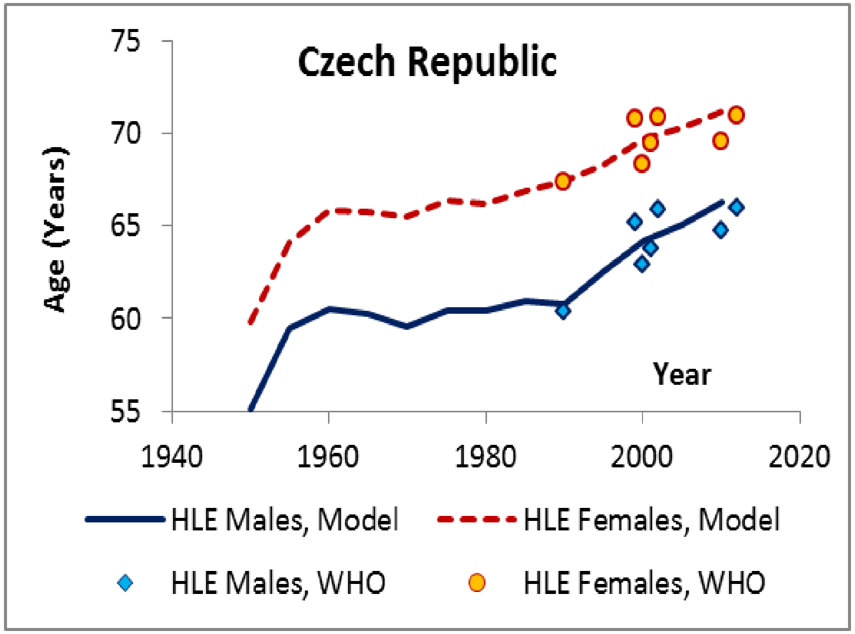


Fig. 4A. Healthy Life Expectancy in Czech Republic (1950-2010)

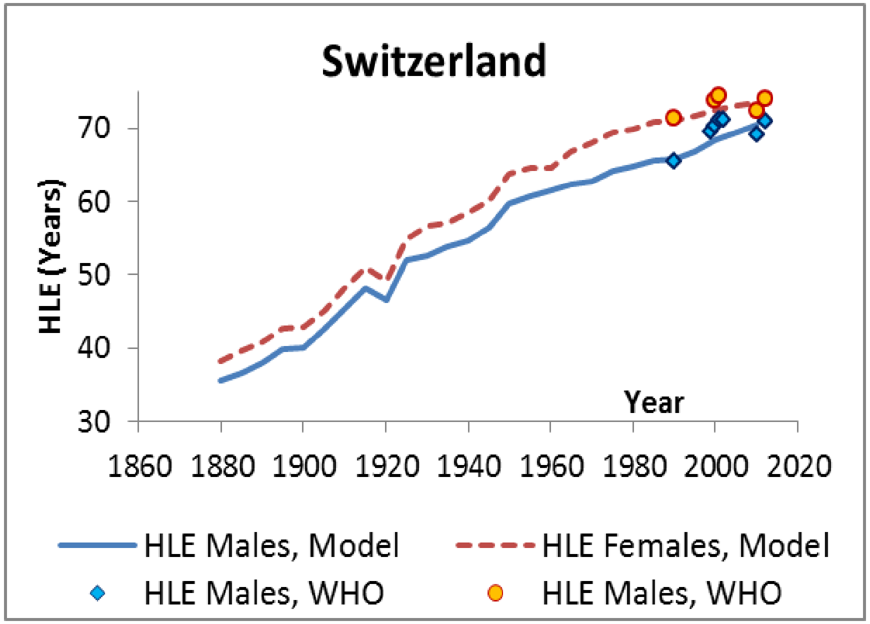
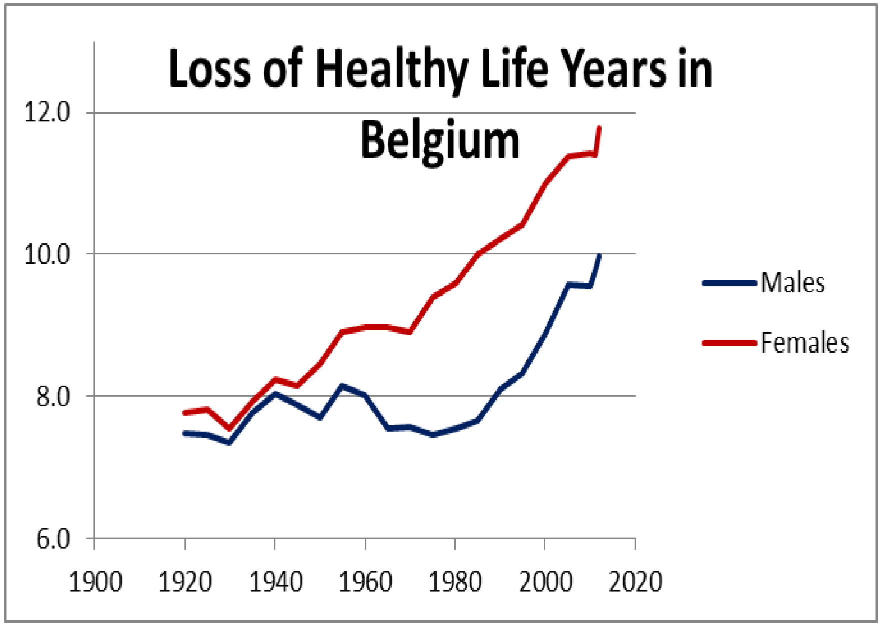
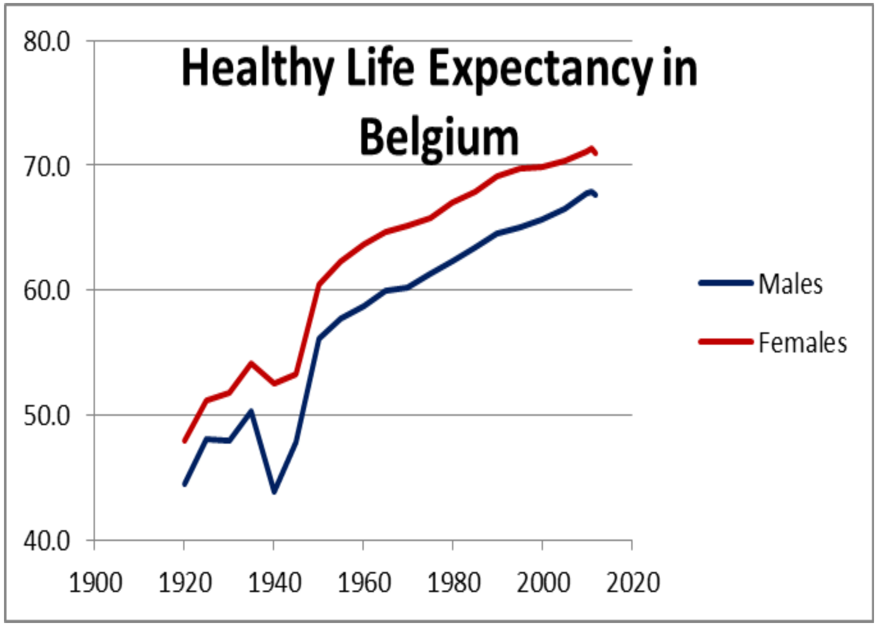


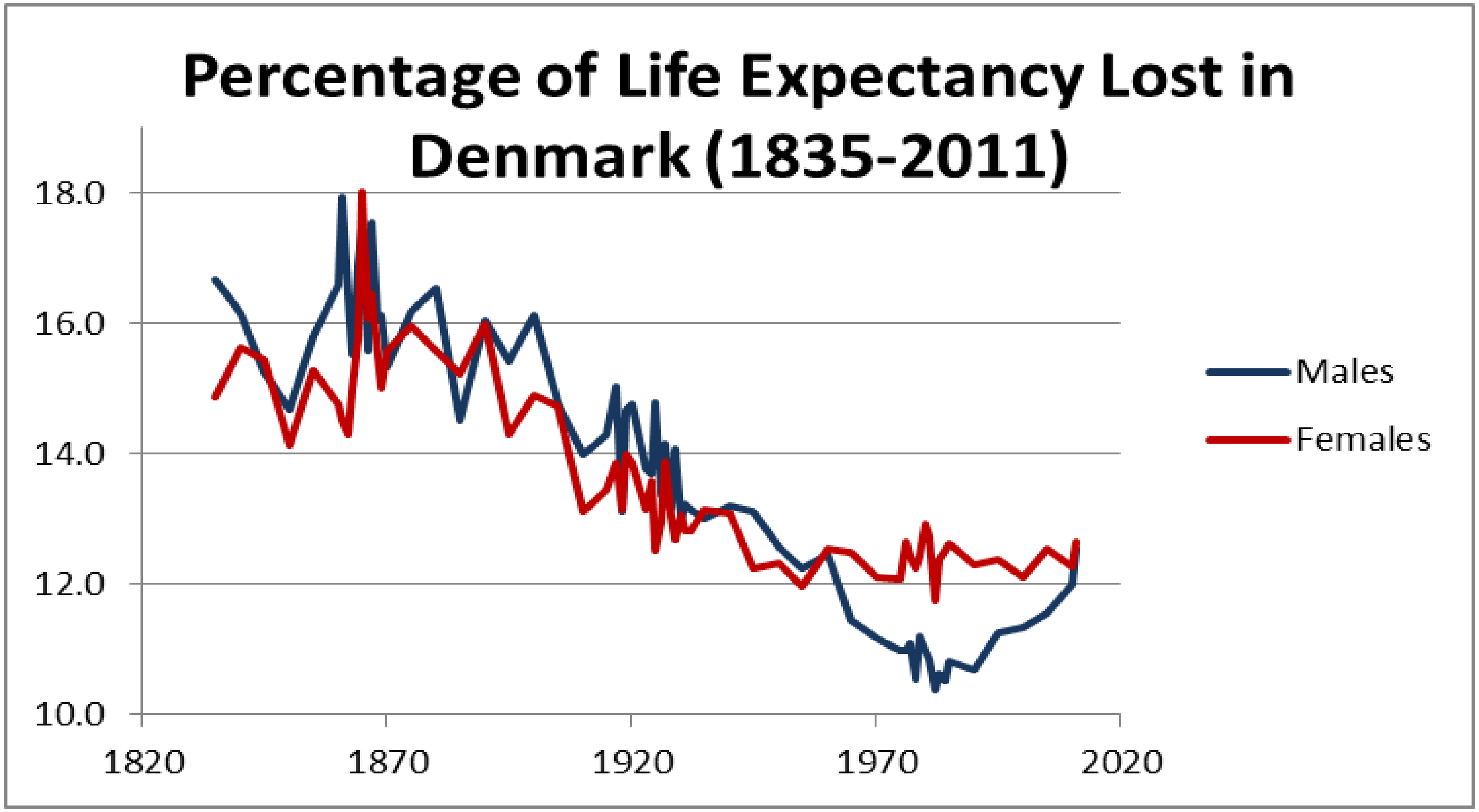
Fig. 4B. Healthy Life Expectancy in Switzerland (1880-2010)

Loss of Healthy Life Years and Healthy Life Expectancy in Belgium

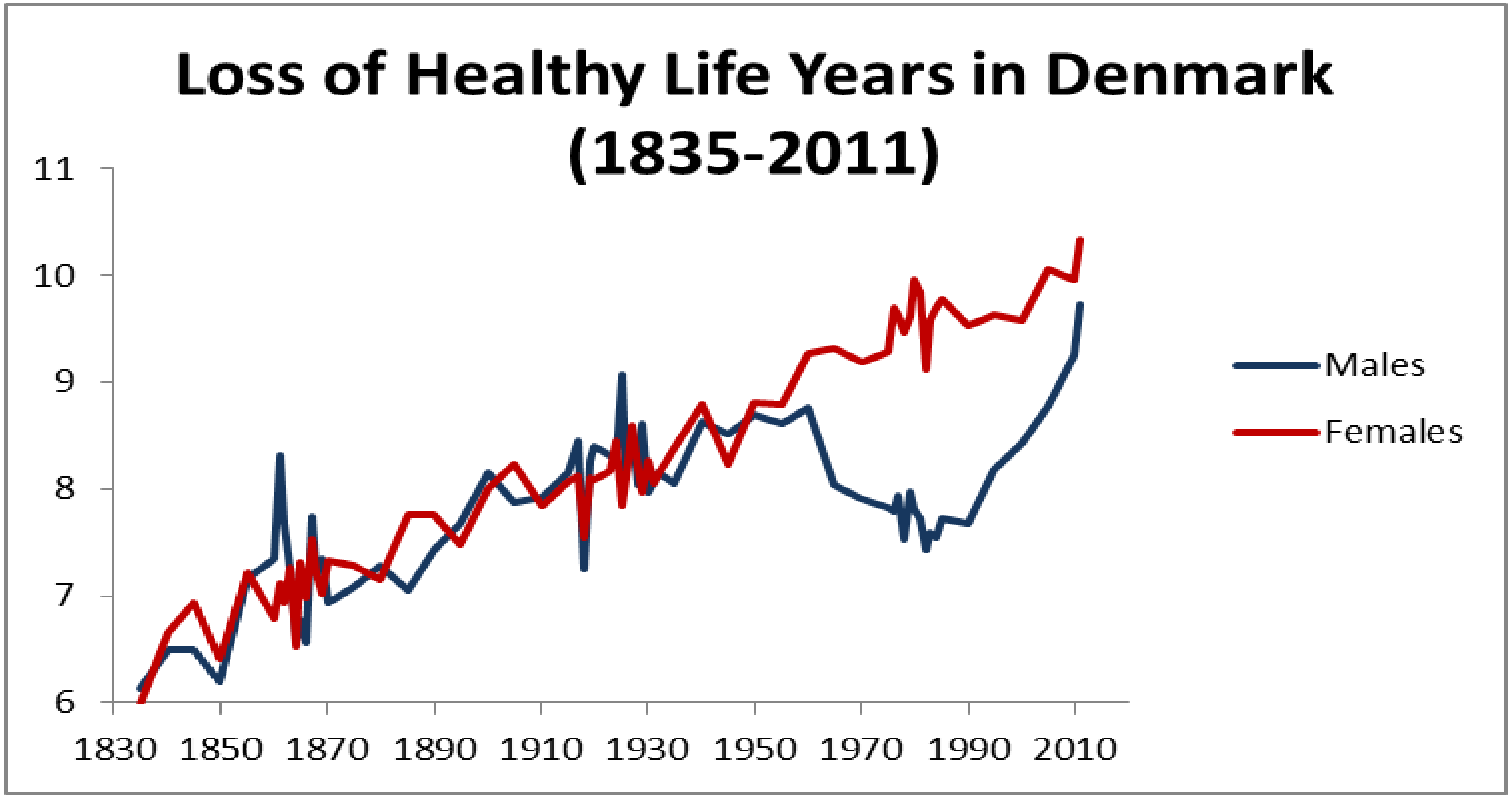




Percentage of Life Expectancy Lost



Loss of Healthy Life Years



Development Christos H Skiadas 3 November 2015 This program produces estimates of Healthy Life Expectancy (HLE) with our Model to compare with the World Health Organization (HALE) estimates

Please introduce mortality mx in column C (from C12 to C33, 22 data points). You will receive imediately the health indicators

Import data from the World Health Organization data base at http://apps.who.int/gho/data/view.main.LT61950?lang=en

An example for Switzerland appears in columns AR to BA (select mx=nMx data and paste in C12)

The maximum number of data points introduced is 22. The program will calculate automatically the model parameters b and T

The Model $\mu_x = \left(\frac{x}{T}\right)^b$

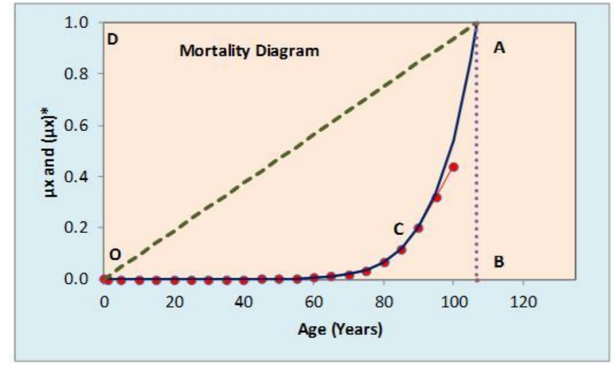
Loss of Healthy Life Years (LHLY)=Etotal/Emortality = (ODAB)/(OCAB)=(b+1)=	10.4
Healthy Life Expectancy (HLE)=Life Expectancy (LE)-(LHLY)=	70.4

Verifying the HALE measures of the Global Burden of Disease Study: A New Mortality Model for Estimating the Loss of Healthy Life Years and the Healthy Life Expectancy from the Abridged Life Table (0 -100) Provided by the World Health Organization (WHO)

The Abridged Life Table Including Life Expectancy, Loss of Healthy Life Years and Healthy Life Expectancy Estimation

Data Intoduction			Life Expectancy Estimation					Healthy Life Expectancy Estimation			
Age Category	Mortality		100.000 population Sx and Number of Deaths dx		Survivorship	Tx=S(Lx)	Life Expectancy	Mortality from fitting T=	Loss of Healthy Life Years (at birth = b+1)	Healthy Life Expectancy HLE	Linear Model
	20							106.8	10.4	70.41	b=1
x	μx	qx	Sx	dx	Lx	Tx	ex	(μx)*	LHLY	HLE	Linear
0	0.003919	0.00390	100000	390	99,649	8,077,053	**80.8**	0.0000	**10.4**	**70.4**	0.000
1	0.000176	0.00070	99610	70	398,298	7,977,404	80.09	0.0000	**10.3**	69.8	0.009
5	0.000068	0.00034	99540	34	497,613	7,579,106	76.14	0.0000	**9.9**	66.3	0.047
10	0.000095	0.00047	99506	47	497,410	7,081,493	71.17	0.0000	**9.4**	61.8	0.094
15	0.000357	0.00178	99458	177	496,849	6,584,083	66.20	0.0000	**8.9**	57.3	0.140
20	0.000423	0.00211	99281	210	495,881	6,087,234	61.31	0.0000	**8.4**	52.9	0.187
25	0.000481	0.00240	99071	238	494,761	5,591,353	56.44	0.0000	**7.9**	48.5	0.234
30	0.000537	0.00268	98833	265	493,504	5,096,592	51.57	0.0000	**7.4**	44.1	0.281
35	0.00069	0.00344	98568	339	491,993	4,603,088	46.70	0.0000	**7.0**	39.7	0.328
40	0.001247	0.00622	98229	611	489,618	4,111,095	41.85	0.0001	**6.5**	35.4	0.375
45	0.001854	0.00923	97618	901	485,839	3,621,477	37.10	0.0003	**6.0**	31.1	0.421
50	0.00301	0.01494	96718	1,445	479,976	3,135,638	32.42	0.0008	**5.5**	26.9	0.468
55	0.005098	0.02517	95273	2,398	470,369	2,655,662	27.87	0.0020	**5.0**	22.9	0.515
60	0.007933	0.03889	92875	3,612	455,344	2,185,293	23.53	0.0045	**4.5**	19.0	0.562
65	0.012876	0.06237	89263	5,568	432,394	1,729,949	19.38	0.0096	**4.1**	15.3	0.609
70	0.019901	0.09479	83695	7,933	398,642	1,297,555	15.50	0.0192	**3.6**	11.9	0.656
75	0.035588	0.16340	75762	12,380	347,860	898,913	11.87	0.0367	**3.1**	8.8	0.702
80	0.065744	0.28232	63382	17,894	272,176	551,053	8.69	0.0671	**2.6**	6.1	0.749
85	0.11737	0.45372	45488	20,639	175,844	278,878	6.13	0.1183	**2.1**	4.0	0.796
90	0.202867	0.63057	24849	15,669	77,239	103,034	4.15	0.2020	**1.6**	2.5	0.843
95	0.322161	0.75711	9180	6,950	21,574	25,795	2.81	0.3351	**1.1**	1.7	0.890
100	0.437535	1	2230	2,230	4,220	4,220	1.89	0.5415	**0.7**	1.2	0.937
105				100,000				0.8549			0.983
106.8								1.0000			1.000
106.8								1.0000			1.000
106.8								1.0000			1.000
106.8								1.0000			1.000
106.8								1.0000			1.000
106.8								1.0000			1.000
106.8								1.0000			1.000
106.8											0.000

Demographics 2016 International conference http://www.smtda.net/demographics2016.html



Max Curvature of (μx)* at Age:	77.53	Years

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www.cmsim.net

Comparing WHO (HALE) Results

Sex/Region	Healthy Life Expectancy at Birth						Life Expectancy at Birth (LE)			
	2000			2012			2000		2012	
	WHO (HALE)	Mortality Model	HSM Model	WHO (HALE)	Mortality Model	HSM Model	WHO	Mortality Model	WHO	Mortality Model
Both sexes combined										
World	58.0	58.4	**58.2**	61.7	62.5	**61.9**	66.2	66.2	70.3	70.3
High income countries	67.3	**67.1**	67.0	69.8	**69.6**	69.2	76.0	76.0	78.9	78.9
African Region	43.1	**42.8**	42.8	49.6	49.9	**49.6**	50.2	50.2	57.7	57.7
Region of the Americas	64.9	65.7	**65.4**	67.1	67.7	**67.2**	73.9	73.9	76.4	76.3
Eastern Mediterranean Region	55.4	56.9	**56.6**	58.3	59.7	**59.4**	64.9	64.9	67.8	67.8
European Region	63.9	**63.9**	**63.9**	66.9	67.2	**67.0**	72.4	72.4	76.1	76.0
South East Asian Region	54.2	56.3	**55.6**	58.5	60.6	**60.0**	62.9	63.0	67.5	67.5
Western Pacific Region	64.8	**63.9**	**64.2**	68.1	**67.3**	67.5	72.3	72.3	75.9	75.9
Males										
World	56.4	**56.6**	**56.2**	60.1	60.4	**60.0**	63.9	63.9	68.1	68.0
High income countries	64.7	64.1	**64.2**	67.5	**67.0**	**67.0**	72.4	72.3	75.8	75.7
African Region	42.4	41.6	**42.3**	48.8	**48.6**	**48.6**	49.0	49.0	56.3	56.3
Region of the Americas	62.7	63.1	**62.5**	64.9	65.1	**64.6**	70.8	70.8	73.5	73.5
Eastern Mediterranean Region	54.8	55.7	**55.6**	57.4	58.2	**57.9**	63.6	63.6	66.1	66.1
European Region	60.7	**60.4**	61.1	64.2	**64.3**	64.5	68.2	68.2	72.4	72.4
South East Asian Region	53.5	55.4	**54.6**	57.4	59.2	**58.6**	61.6	61.7	65.7	65.7
Western Pacific Region	63.0	61.8	**62.0**	66.6	65.2	**65.7**	70.0	70.0	73.9	73.9
Females										
World	59.7	60.3	**59.9**	63.4	64.3	**64.1**	68.5	68.5	72.7	72.6
High income countries	70.0	**69.7**	69.6	72.0	71.8	**72.1**	79.6	79.5	82.0	81.9
African Region	43.8	**43.8**	43.5	50.4	51.2	**50.5**	51.4	51.4	59.0	59.1
Region of the Americas	67.2	68.0	**67.8**	69.1	69.9	**69.8**	77.0	76.9	79.3	79.2
Eastern Mediterranean Region	56.1	58.2	**57.8**	59.2	61.3	**61.0**	66.4	66.4	69.7	69.6
European Region	67.1	67.6	**67.3**	69.6	70.0	**69.7**	76.7	76.6	79.6	79.6
South East Asian Region	55.0	57.2	**56.4**	59.7	62.0	**61.7**	64.3	64.4	69.4	69.4
Western Pacific Region	66.7	65.7	66.1	69.8	68.9	**69.1**	74.8	74.8	78.1	78.0

References

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Conclusions

The results show that

the HALE estimates from WHO are very close to those obtained by the suggested models and methodologies.

Even more, as the new methods are based only on the information included in the mortality expression mx, are extremely useful not only because of their simplicity but also

for the ability to have HALE estimates in all the historical periods as far as life table data exist.

Work in Progress

The methods and the models used estimate quite well the healthy life years lost (HLYL) to severe and moderate disability and consequently the healthy life expectancy (HLE) as

HLE = LE - HLYL

The estimation of the healthy life years lost to light disability is another interesting problem.

We will present our results in a future meeting.

THANK YOU!