Estimating the impact of a cancer diagnosis on life expectancy by socioeconomic group for a range of cancer types in England

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Relative survival and Flexible parametric models

Excess mortality

$$\begin{matrix}\text{excess}\\ \text{mortality}\end{matrix} = \begin{matrix}\text{observed}\\ \text{mortality}\end{matrix} - \begin{matrix}\text{expected}\\ \text{mortality}\end{matrix}$$

Relative survival

$$\text{relative survival ratio} = \frac{\text{observed survival proportion}}{\text{expected survival proportion}}$$

Flexible parametric survival models

The survival function of a Weibull distribution: $S(t) = \exp(-\lambda t^{\gamma})$

$$\ln\left[H(t|\boldsymbol{x})\right] = \ln\lambda + \gamma \ln t + \boldsymbol{x}\boldsymbol{\beta}$$

A flexible parametric model is given by

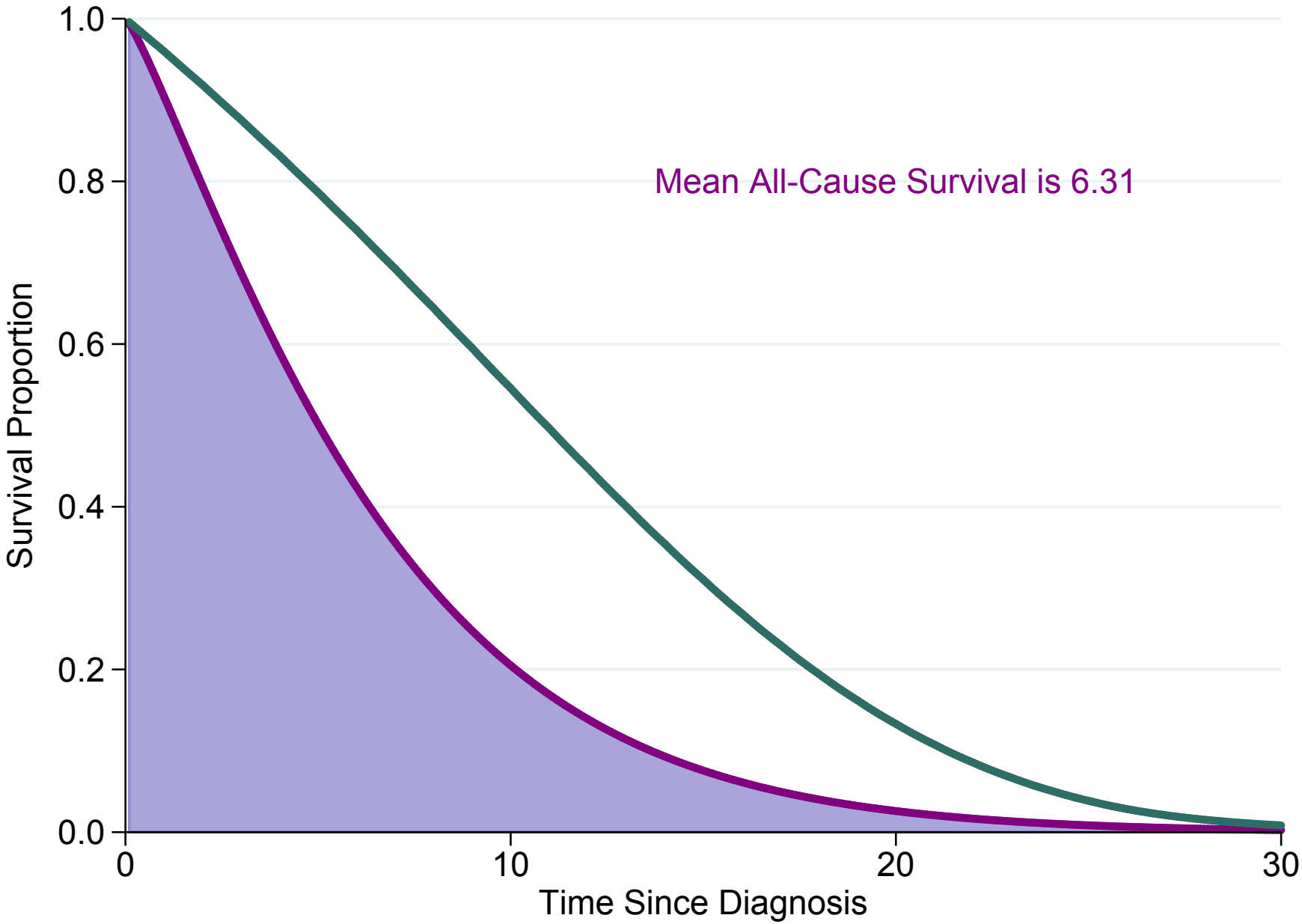
$$\ln\left[H(t|\boldsymbol{x})\right] = s(\ln(t)|\gamma, \boldsymbol{k_0}) + \boldsymbol{x}\boldsymbol{\beta}$$

Loss in expectation of life

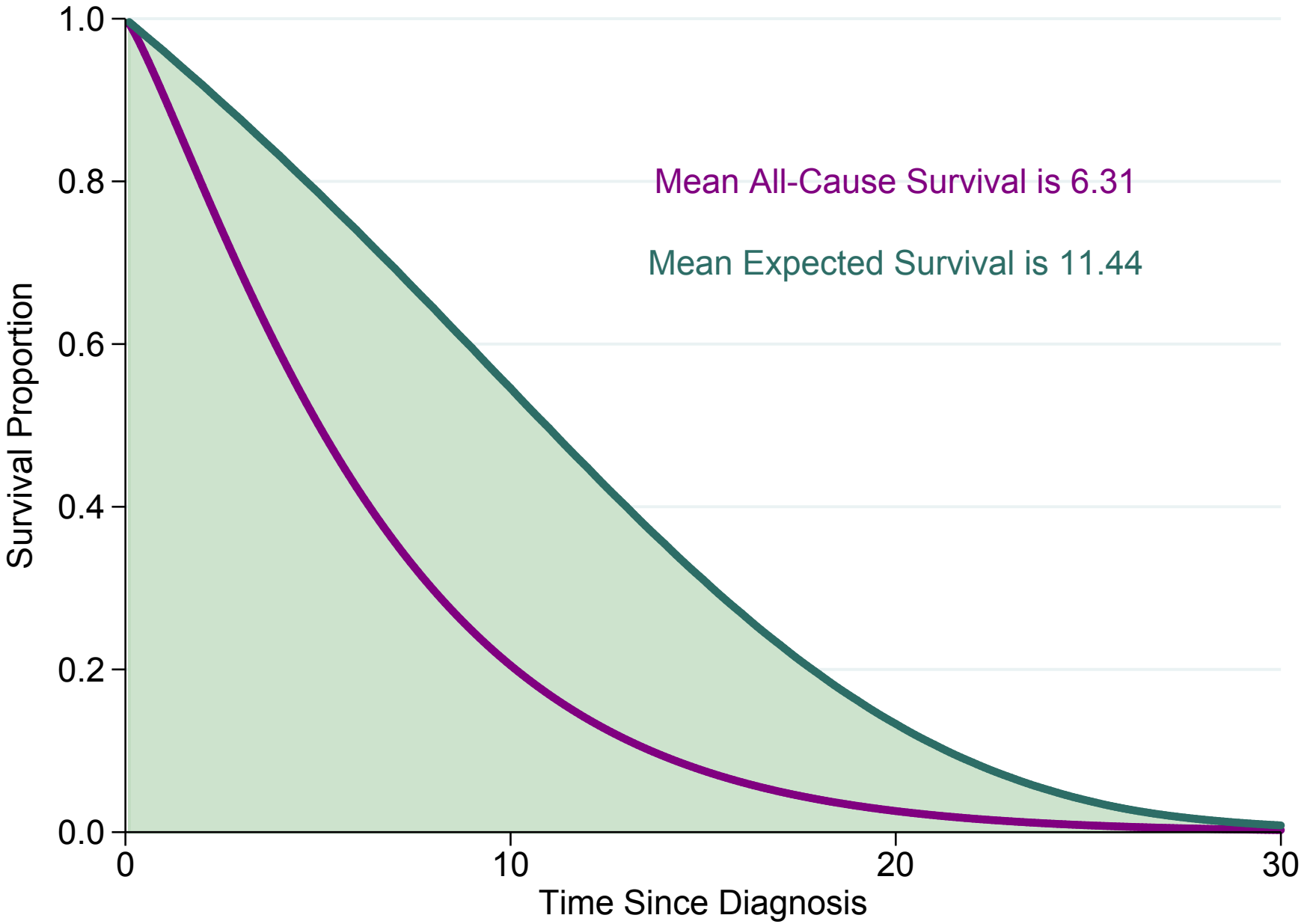
$$LEL(z) = \int_0^{t_{max}} S^*(t, z')dt - \int_0^{t_{max}} S(t, z)dt$$

Loss in expectation of life is calculated as the difference between the mean expected survival (if not diagnosed with cancer) and the mean observed survival (for cancer patients).

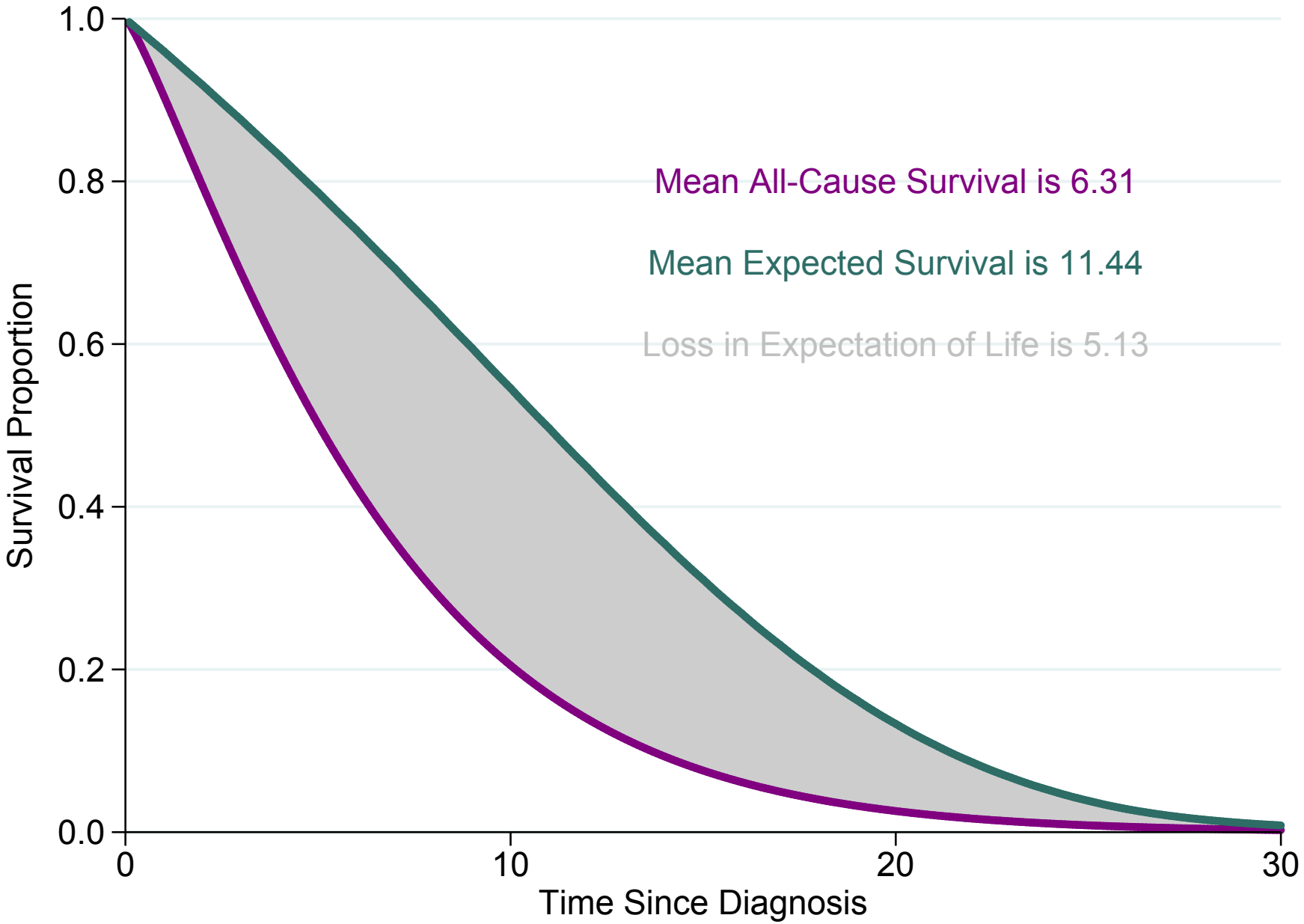
Life expectancy of cancer population



Life expectancy of general population



Loss in expectation of life



Why use loss in expectation of life?

- Common reported metrics are relevant at a particular point in follow-up time after diagnosis, such as 1 or 5-year relative survival.
- Relative survival is not an easy to understand measure and makes communication of results difficult.
- Loss is expectation of life is a more intuitive measure that looks over the whole of the remaining life time.

Useful questions

- **Quantify disease burden in the society** "how many life-years are lost due to the disease?"
- **Quantify differences between socio-economic groups or countries** "how many life-years would be gained if England had the same cancer patient survival as Sweden?"
- **Quantify the impact a cancer diagnosis has on a patient's life expectancy**.

Other measures

Proportion of life lost

- Loss in expectation of life is a highly age dependent measure.
- Using the proportional, rather than absolute scale, for the impact on life expectancy improves comparability across age and deprivation groups.

$$\text{proportion of life lost} = \frac{\text{loss in expectation of life}}{\text{life expectancy for the general population}}$$

Total population life years lost

Total population life years lost due to a cancer diagnosis is estimated by multiplying the number of patients diagnosed with cancer in a specific year by the loss in expectation of life.

How do we extrapolate observed survival?

- Andersson et al. showed that it is possible to consistently extrapolate cancer survival using a recently established approach using flexible parametric excess mortality models.
- The basic idea is that it is easier to extrapolate relative survival than observed survival.
- As time since diagnosis increases the expected mortality rate dominates.

$$LEL(z) = \int_0^{t_{max}} S^*(t, z')dt - \int_0^{t_{max}} S(t, z)dt$$

$$LEL(z) = \int_0^{t_{max}} S^*(t, z')dt - \int_0^{t_{max}} S^*(t, z') \times R(t, z)dt$$

Data

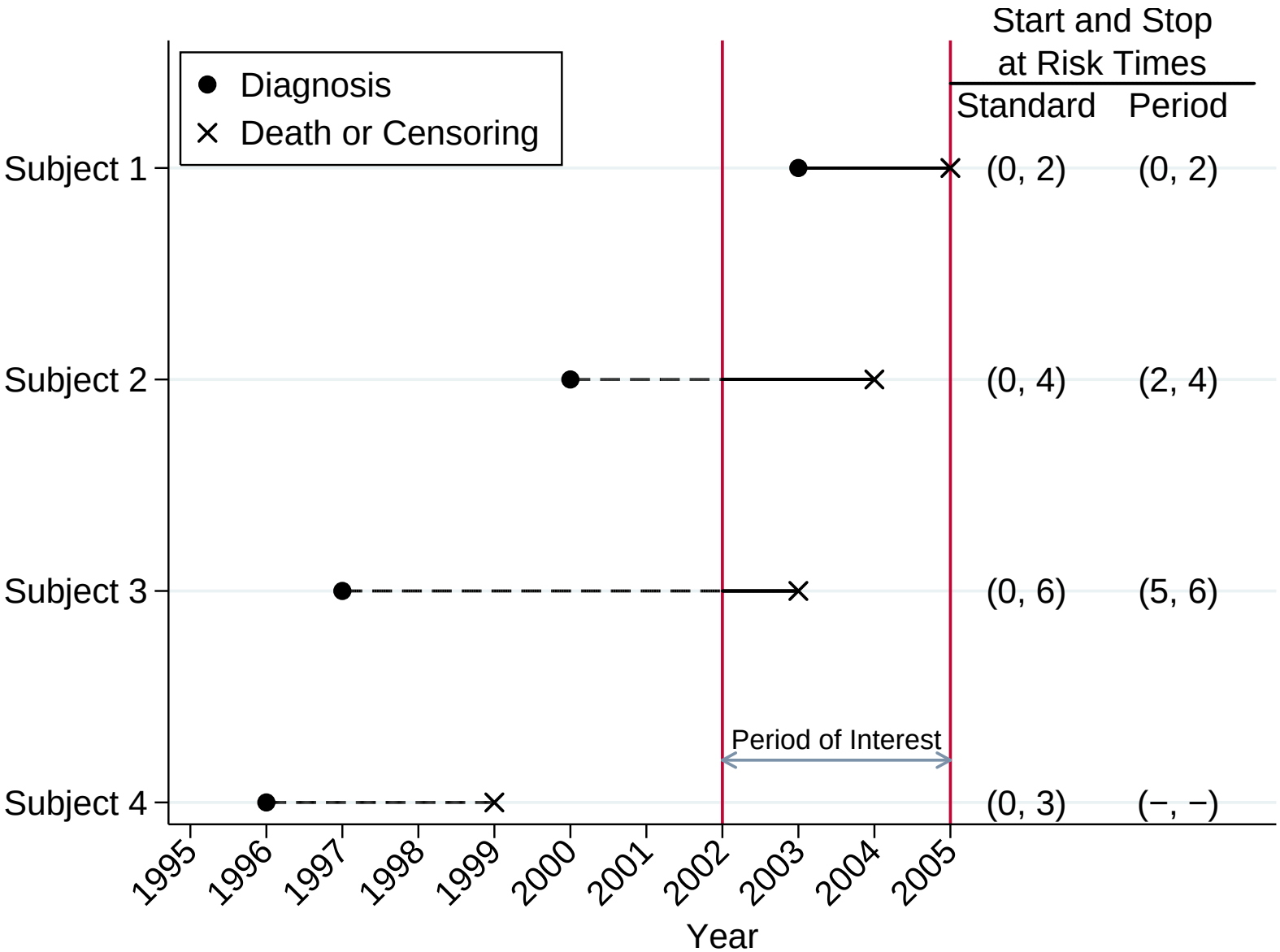
Cancer type		N (Age)
Lung	*Males*	291,414 (71.3)
	Females	212,010 (71.5)
Colon	*Males*	154,332 (70.9)
	Females	146,065 (72.8)
Rectum	*Males*	105,966 (69.0)
	Females	66,796 (71.0)
Melanoma	*Males*	61,597 (61.7)
	Females	70,274 (58.6)
Bladder	*Males*	100,821 (72.9)
	Females	39,021 (75.1)
Stomach	*Males*	67,787 (71.6)
	Females	36,484 (74.4)
Prostate	*Males*	487,858 (71.6)
Breast	*Females*	583,493 (62.7)
Ovarian	*Females*	88,827 (64.0)

Statistical analysis

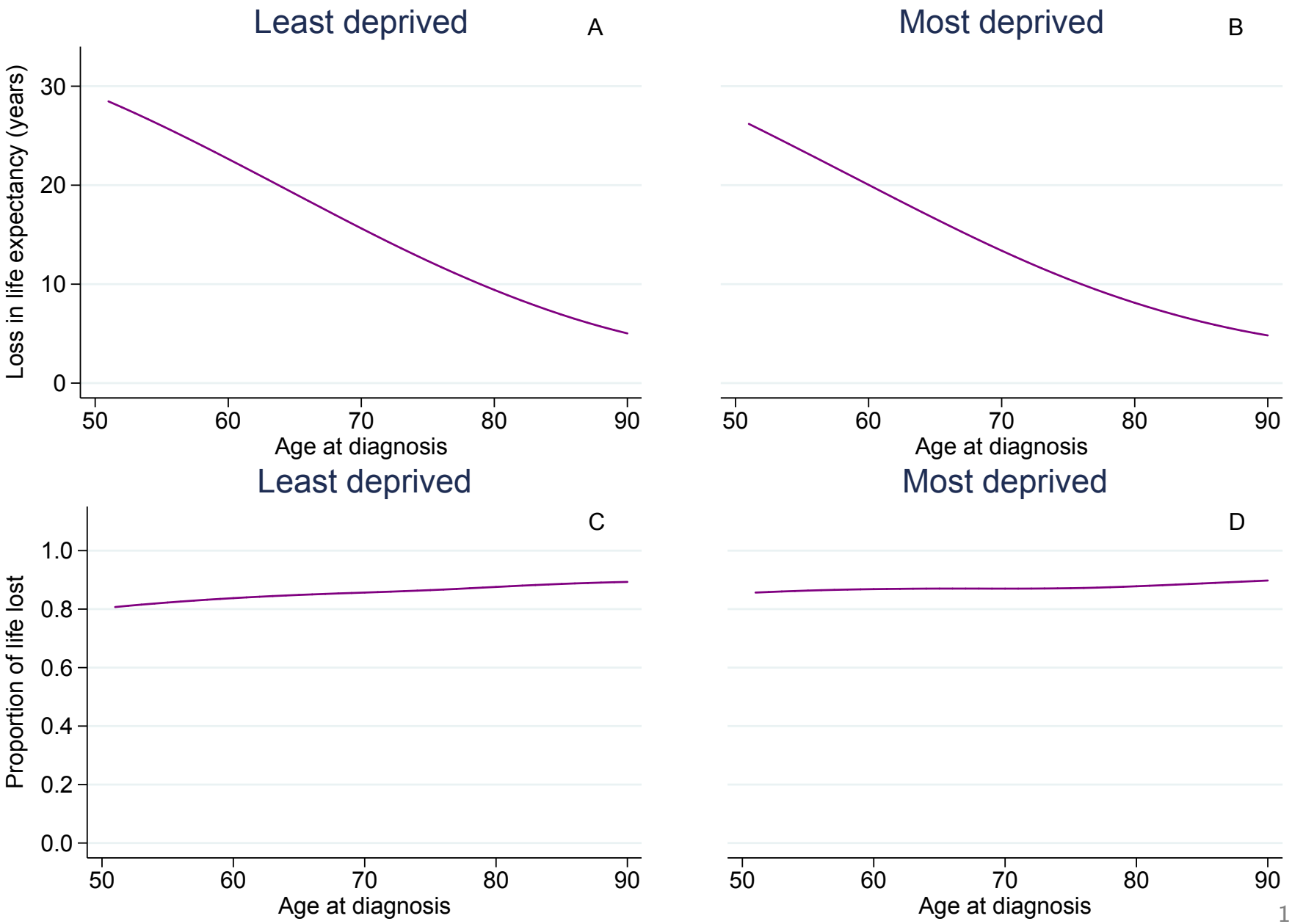
- We fitted a flexible parametric relative survival model for each cancer type.
  - baseline excess hazard: 5 degrees of freedom
  - age (continuous but non-linear): 3 degrees of freedom
  - deprivation and age at diagnosis were assumed to be time-dependent : 5 degrees of freedom [1]
- Interaction between age and deprivation.
- Analysis was performed separately for females and males.
- We incorporated the background risk of death due to other causes, to estimate the expected survival, using lifetable data stratified by sex, age,year and deprivation-group.
- A period analysis with a period window between years 2007 and 2013 was conducted.

[1] Except for lung cancer for males and females, bladder cancer for females and melanoma for females in which 3, 2, 3 and 3 degrees were used respectively

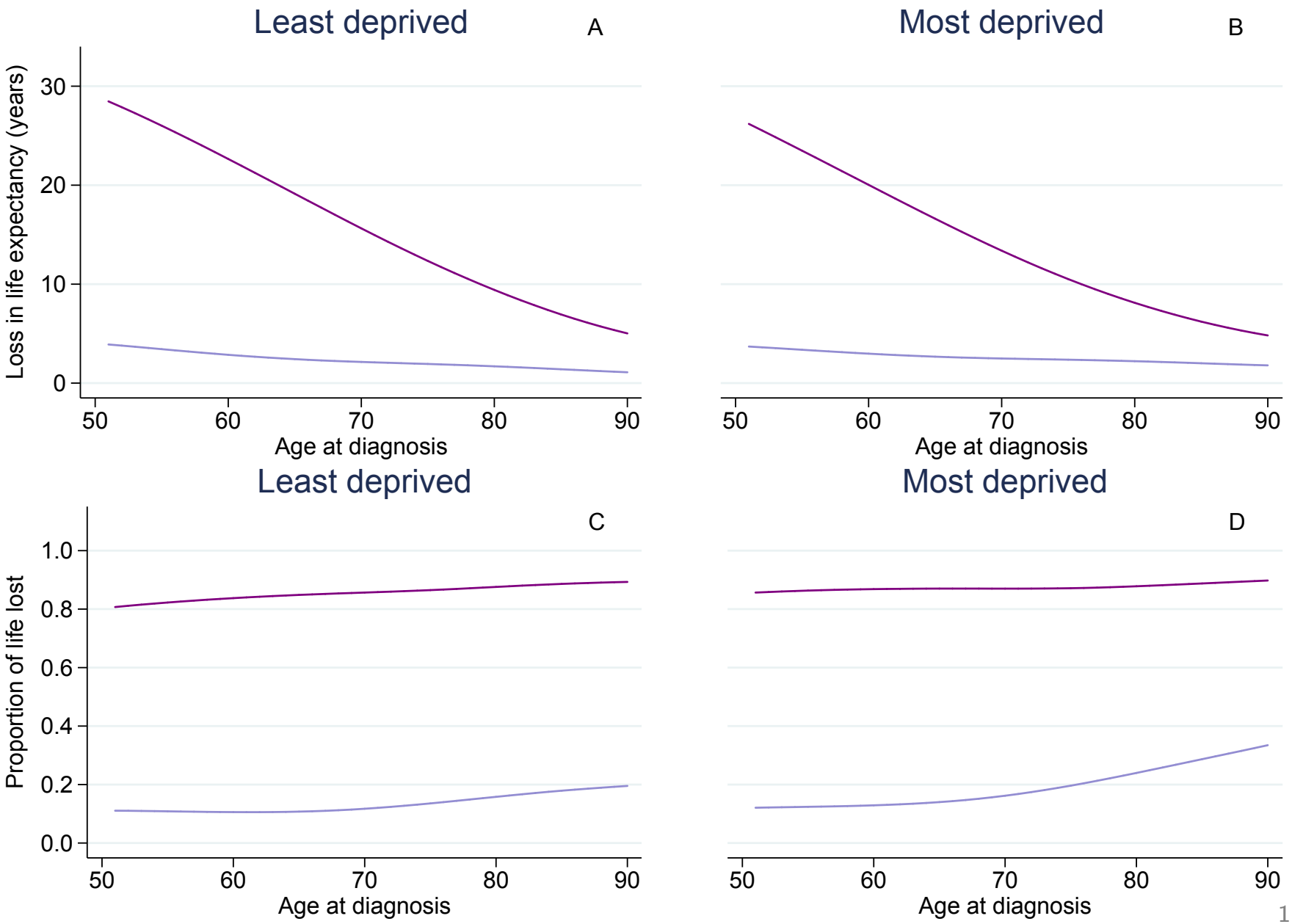
Illustration of period analysis for 4 patients



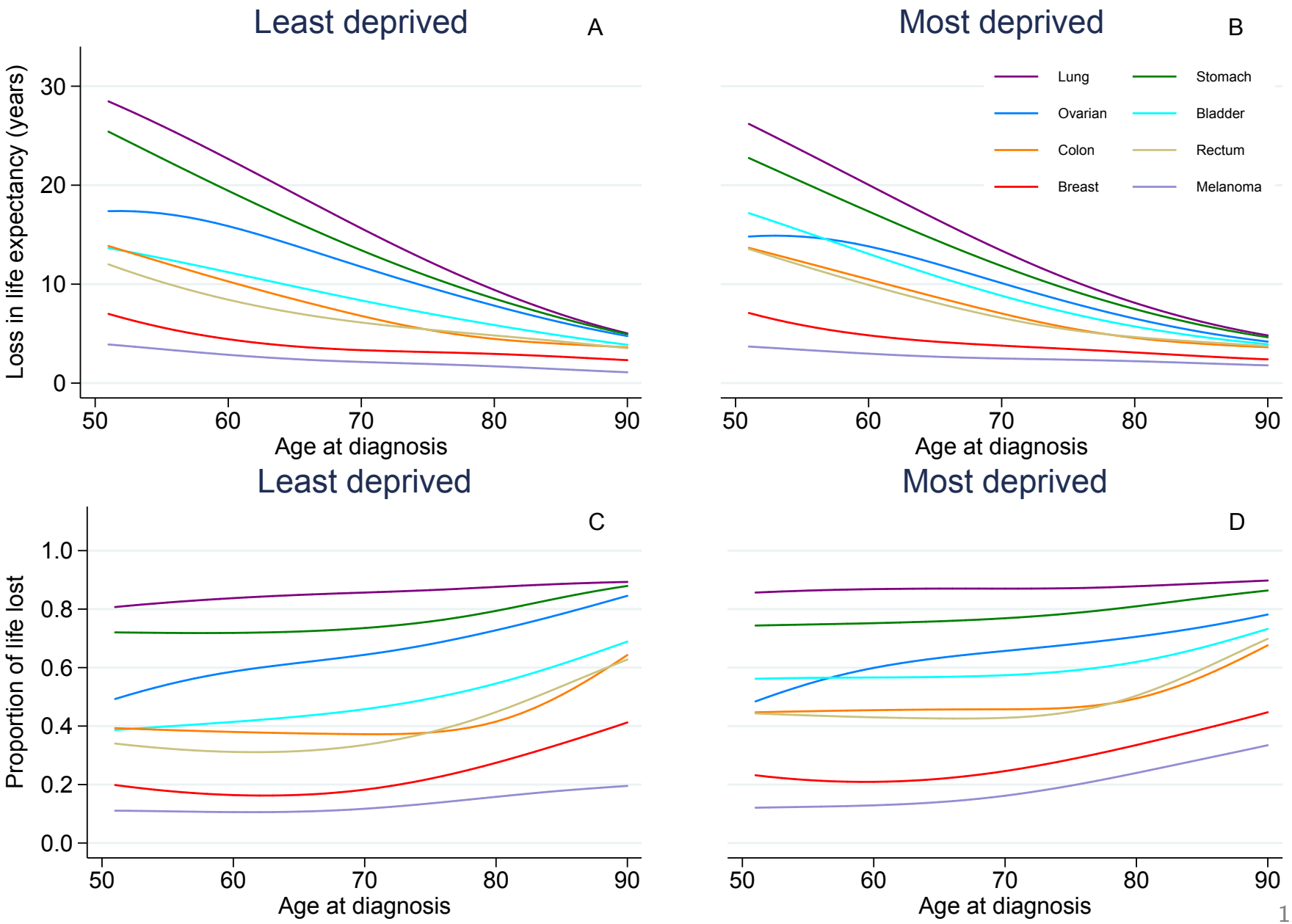
Lung cancer - Females



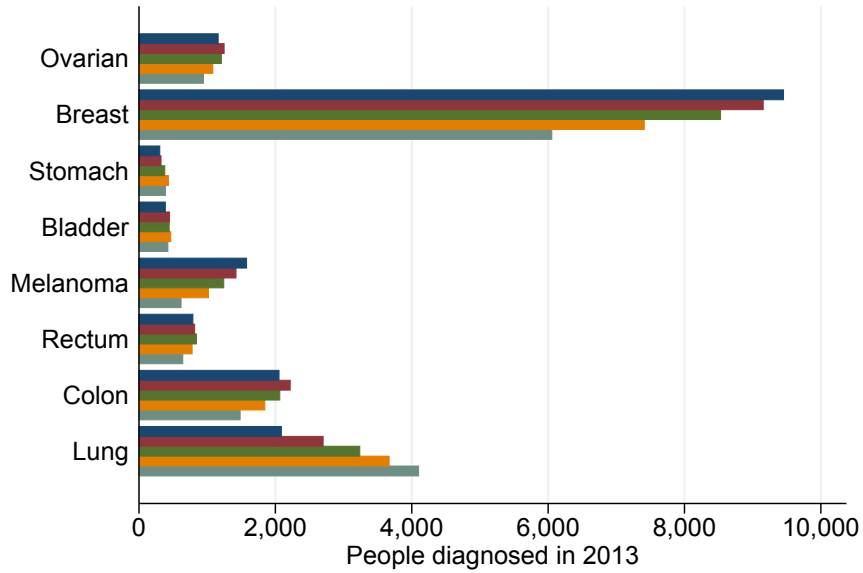
Lung cancer and Melanoma - Females

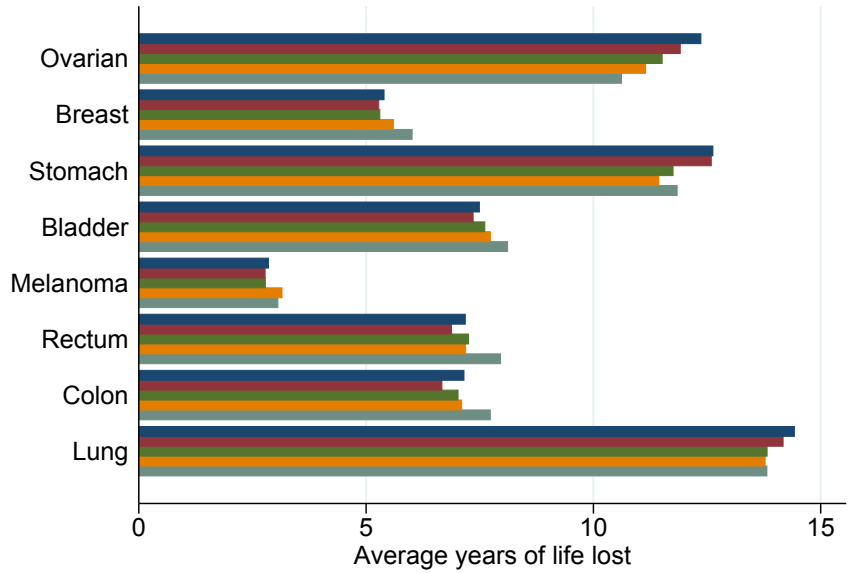


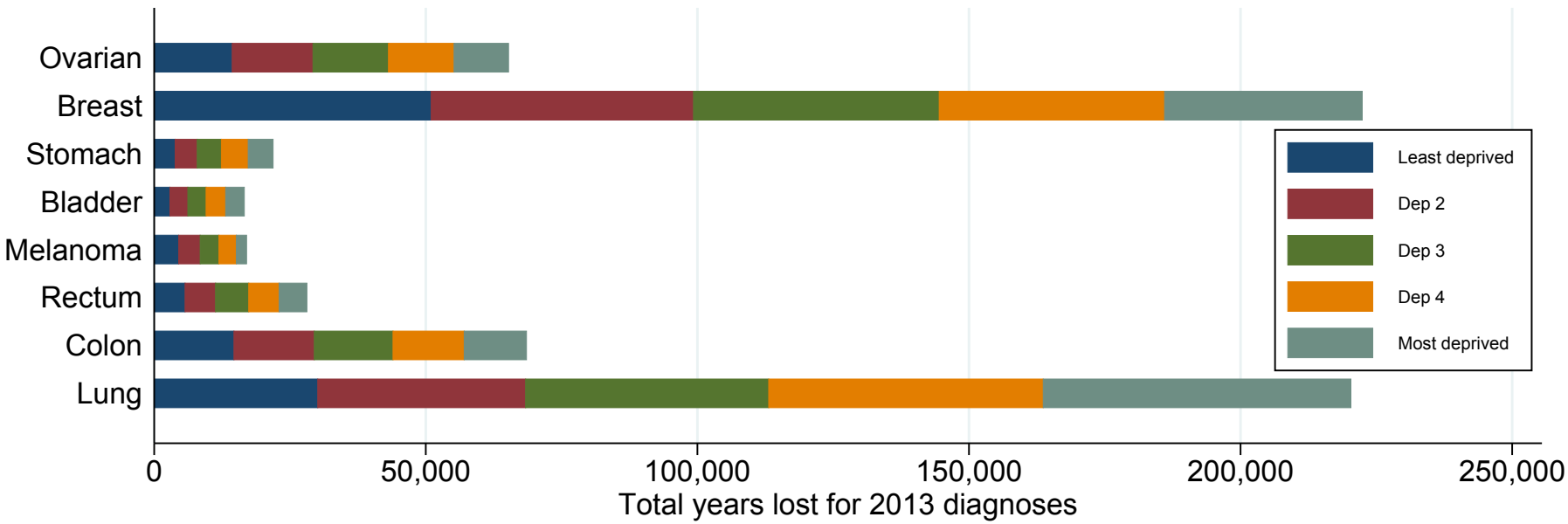
All cancer types - Females

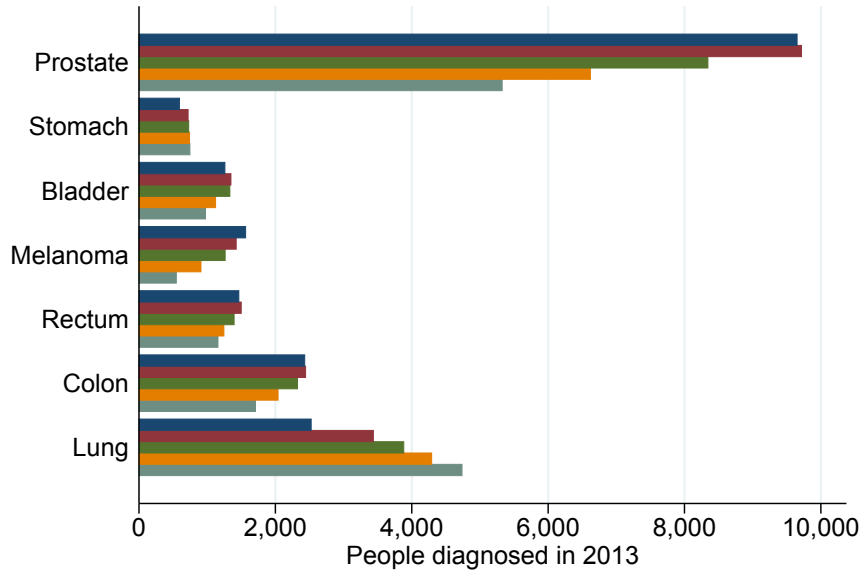


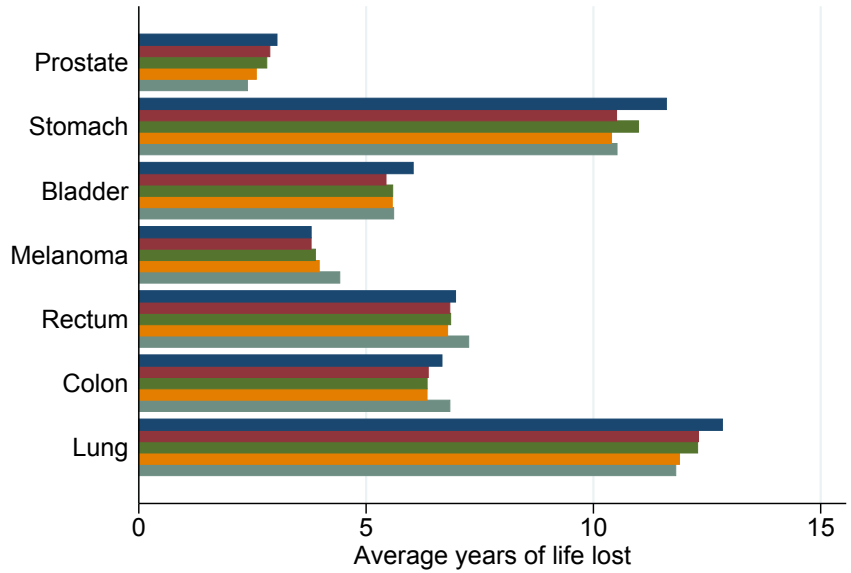
		Least Deprived	*2*	*3*	*4*	*Most Deprived*
Lung	*LEL (years)*	14.42	14.17	13.82	13.78	13.82
	Proportion of life lost (%)	86.07	86.75	86.75	87.03	87.26
Melanoma	*LEL (years)*	2.85	2.78	2.78	3.15	3.06
	Proportion of life lost (%)	11.73	12.47	12.37	14.30	14.05


Ovarian
Breast
Stomach
Bladder
Melanoma
Rectum
Colon
Lung
0
2,000
4,000
6,000
8,000
10,000
People diagnosed in 2013


Ovarian
Breast
Stomach
Bladder
Melanoma
Rectum
Colon
Lung
0
5
10
15
Average years of life lost


Ovarian
Breast
Stomach
Bladder
Melanoma
Rectum
Colon
Lung
Least deprived
Dep 2
Dep 3
Dep 4
Most deprived
0
50,000
100,000
150,000
200,000
250,000
Total years lost for 2013 diagnoses


Prostate
Stomach
Bladder
Melanoma
Rectum
Colon
Lung
0
2,000
4,000
6,000
8,000
10,000
People diagnosed in 2013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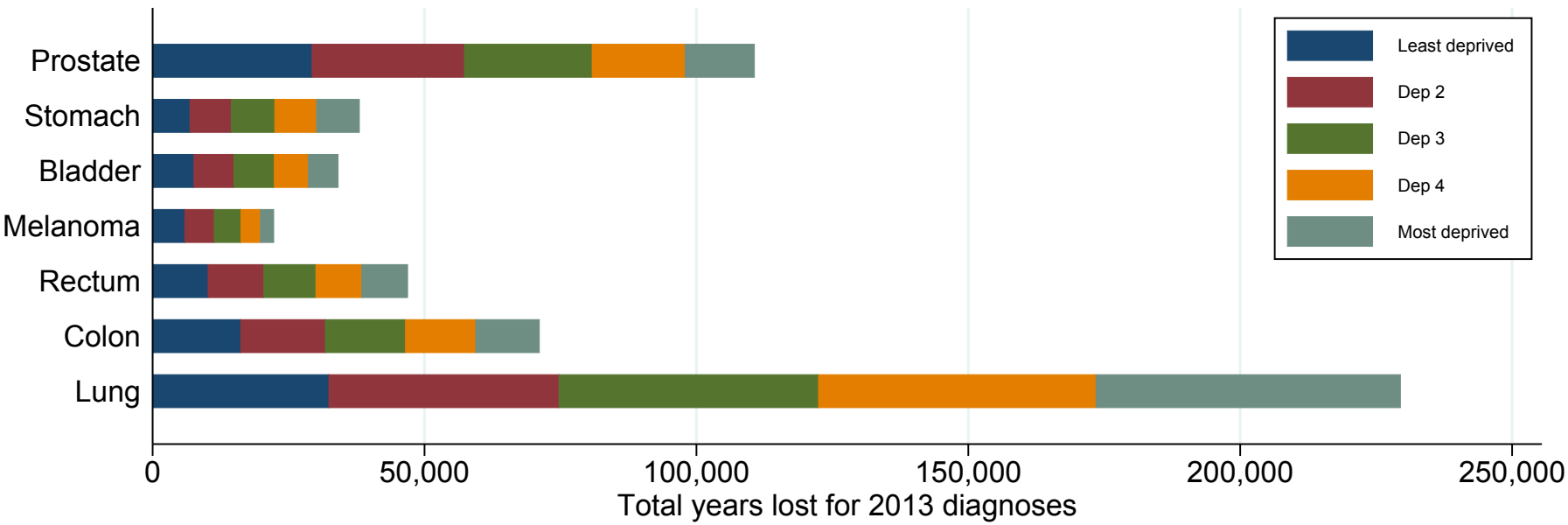
Average years of life lost


Prostate
Stomach
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Rectum
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Lung
Least deprived
Dep 2
Dep 3
Dep 4
Most deprived
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50,000
100,000
150,000
200,000
250,000
Total years lost for 2013 diagnoses

Conclusions

- Estimation of loss in expectation of life, either on the absolute or proportional scale, is easy both at individual or population level. It is an intuitive measure that can be easily interpreted and makes communication of cancer survival straightforward.
- It can be a measure of great interest for *public health*, *clinicians* and *patients*
- Total number of life years lost estimates the total burden of cancer in the society and can be used to address the types of cancer who affect the population the most. It could be especially useful for people who work on *decision making in healthcare policies*.

Selected References I

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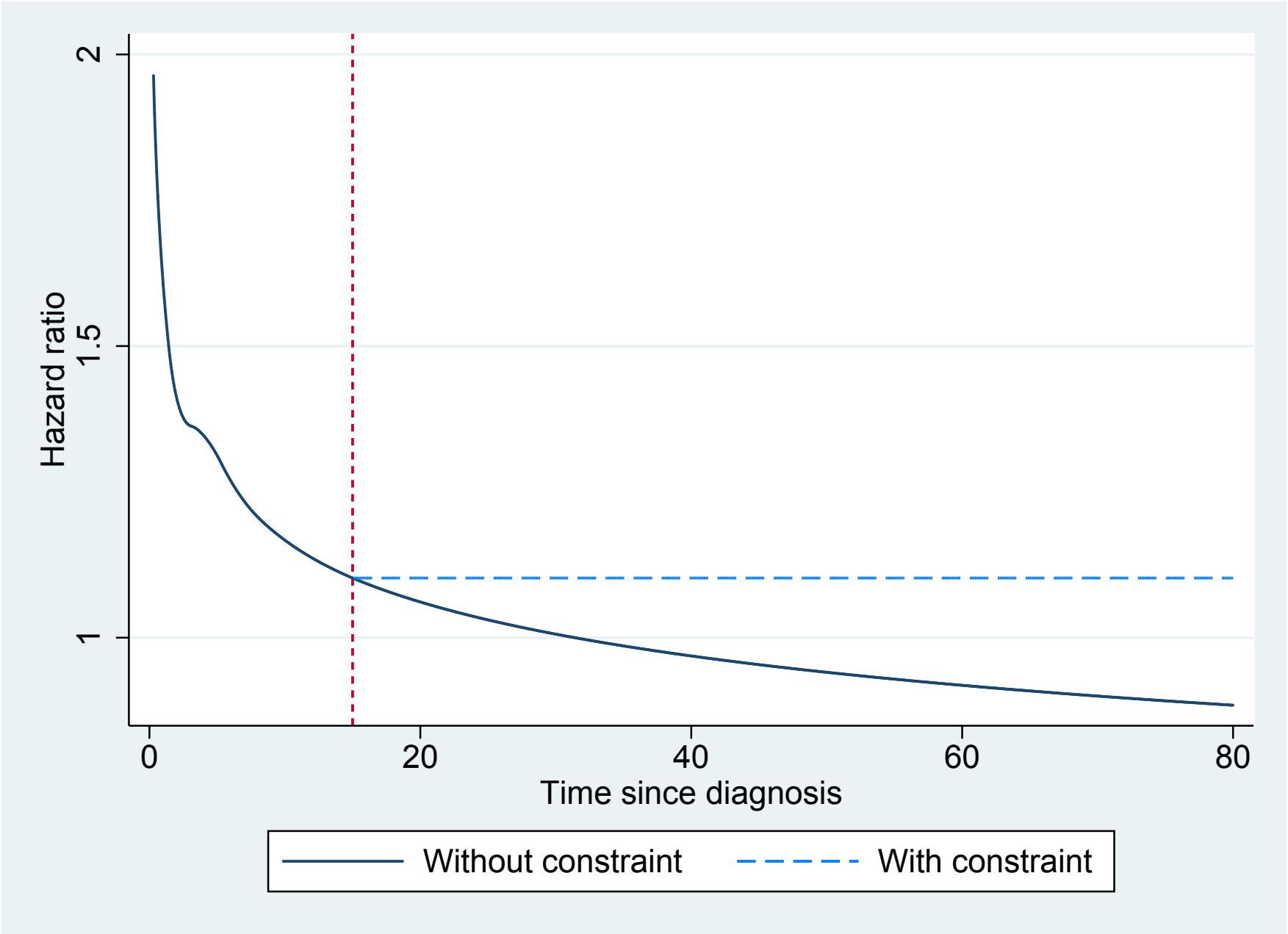
65 years old - Breast cancer - split at 15 years



Compare approaches with/without constraint: loss in life expectancy (females)