Life and Health Actuarial Pricing: a Biostatistics Approach

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Outline

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Context I

- It is a common belief that patients having suffered from a cancer have a lower probability of survival
  - ↪ Due to this aggravated risk the insurance industry is reluctant to grant insurance coverage in case of death
- However, survival and life expectancy of cancer patients have been increasing over the last decades (and will keep increasing)
- In regard to this, France passed *"the right to forget"*:[1]
  - The right for a person subscribing to a contract **not** to declare a previous cancer after 10 years after the end of the therapeutic protocol
  - Reduced to 5 years for minors

[1] Sapin and Touraine (2017)

Context II

- But some questions remain:
  1. The thresholds of 10 and 5 years are arbitrary and does not reflect survival of the diseased persons
  2. Some ambiguity about what is considered as treatment $\rightarrow$ what marks the end of a therapeutic protocol? $\rightarrow$ when the patient will start to benefit from this right?
  3. (This right is very binary and not flexible at all)

Outline

Aims I

- The aim of this thesis is threefold:
  1. Develop a method to adequately **estimate the threshold** after which cancer patients can be considered as cured
  2. Find a proper way to **adapt the actuarial pricing of life insurance products** depending on the type of cancer and the duration of survival at the time of application for insurance
  3. Demonstrate that for some types of cancer, the survivors actually have a chance of survival comparable to that of the general population and could therefore be covered in the event of death

Outline

Significance

- More incidences (number of new cases) due to the increased population, aging population and better diagnostic methods
- Higher prevalence (number of cases within a period) due to prolonged survival of people who had cancer thanks to decreasing cancer mortality
- "Survivorship": more and more long-term survivors still pay for a life beyond cancer and are treated the same way as newly diagnosed patients who have indeed very high risk of dying of cancer[2]
- New bill introduced on September 14 to establish the right to forget in Belgium

[2] Massart (2018)

Outline

Data I

- Data from the Belgian Cancer Registry (BCR)
- Focus on patients from 20 to 40-50 years old
  - ↪ Range when people are most likely to take a loan
  - ↪ Older than 50, non-cancer related deaths increase substantially and not always easy to distinguish cause of death
- Focus on cancer(s) with:
  - High number of incidences, with a significant share before 40 years old
  - High survival or cured rate
  - "Well-known" to the public

Data II

$\Rightarrow$ At the moment, melanoma:

- 5-year relative survival: 93% for women, 87% for men
- incidences start at 10-15 years old

- Variables:
  1. Sex
  2. Date of birth
  3. Date of diagnosis
  4. Date of death
  5. Censoring indicator
  6. Stage (I-IV)
  7. Region

Outline

Outline

Relative survival I

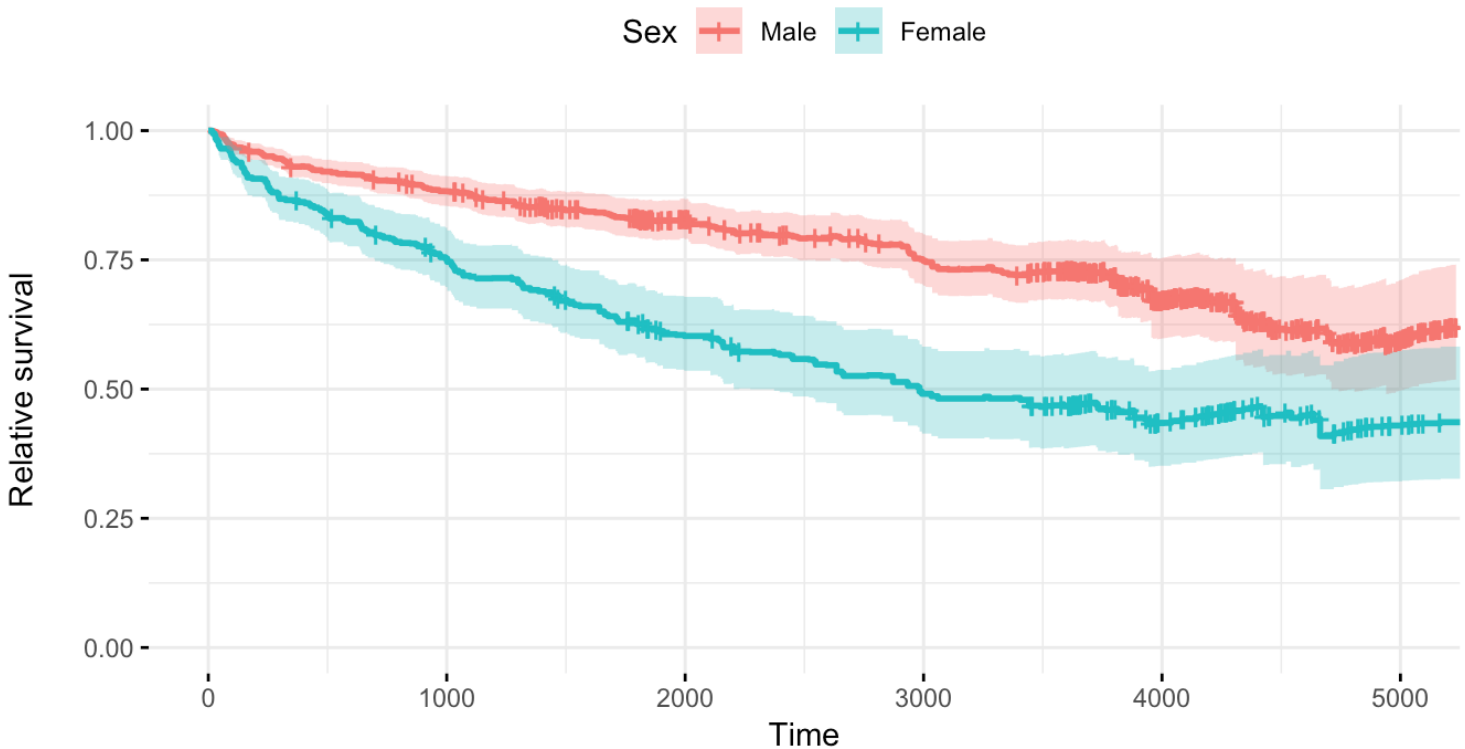
- Defined as the ratio of the observed survival of the cancer patients to the expected survival of a comparable group from the population (Dickman et al., 2004):

$$r(t) = \frac{\text{observed survival}}{\text{expected survival}} = \frac{S(t)}{S^*(t)} \tag{1}$$

- Pros and cons:
  - \+ Standard measure of patient survival for population-based cancer registries so well documented in the literature
  - \+ No need to know the cause of deaths (which is often inaccurate or unavailable)
  - \- Dependent on factors such as changing diagnostic criteria and improved diagnostics methods $\rightarrow$ impossible to compare relative survival across time (Lenner, 1990)
  - \- Dependent on the mortality of the general population $\rightarrow$ not suitable for cross-country comparisons (Perme et al., 2012)

Relative survival II

- `relsurv::rdata`
- compared to belgian population



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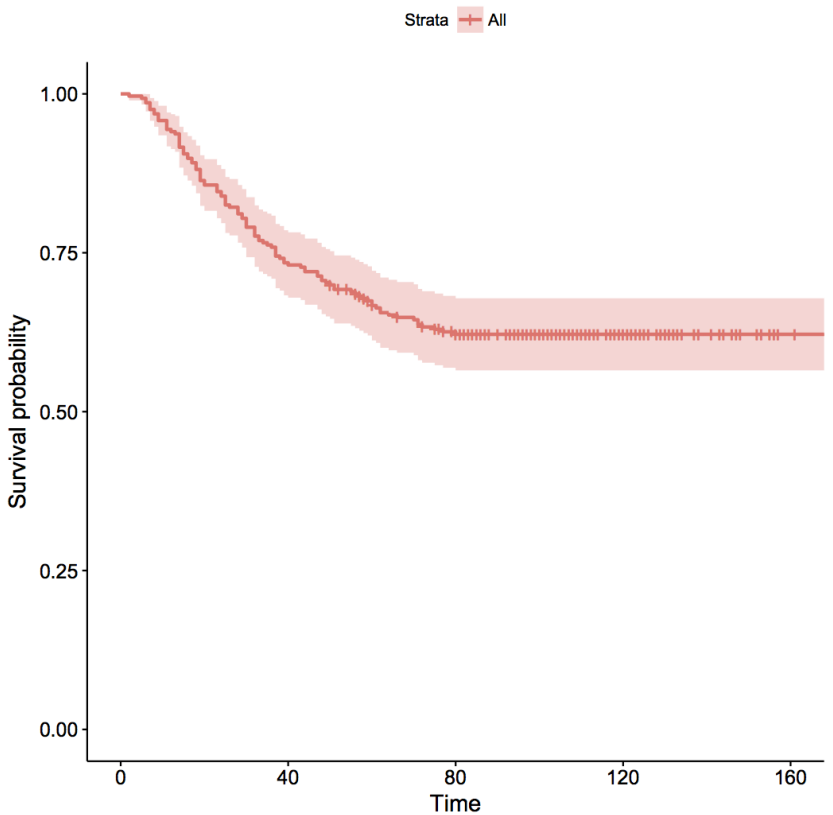
Cure models

- Cure models refer to survival models when a fraction of the subjects will never develop the event of interest (death from cancer in our case)
- Illustrated by a "plateau" in the tail of the survival function. This plateau corresponds to cured subjects:

Cure models: example[3]



[3] Data from Wang et al. (2005).

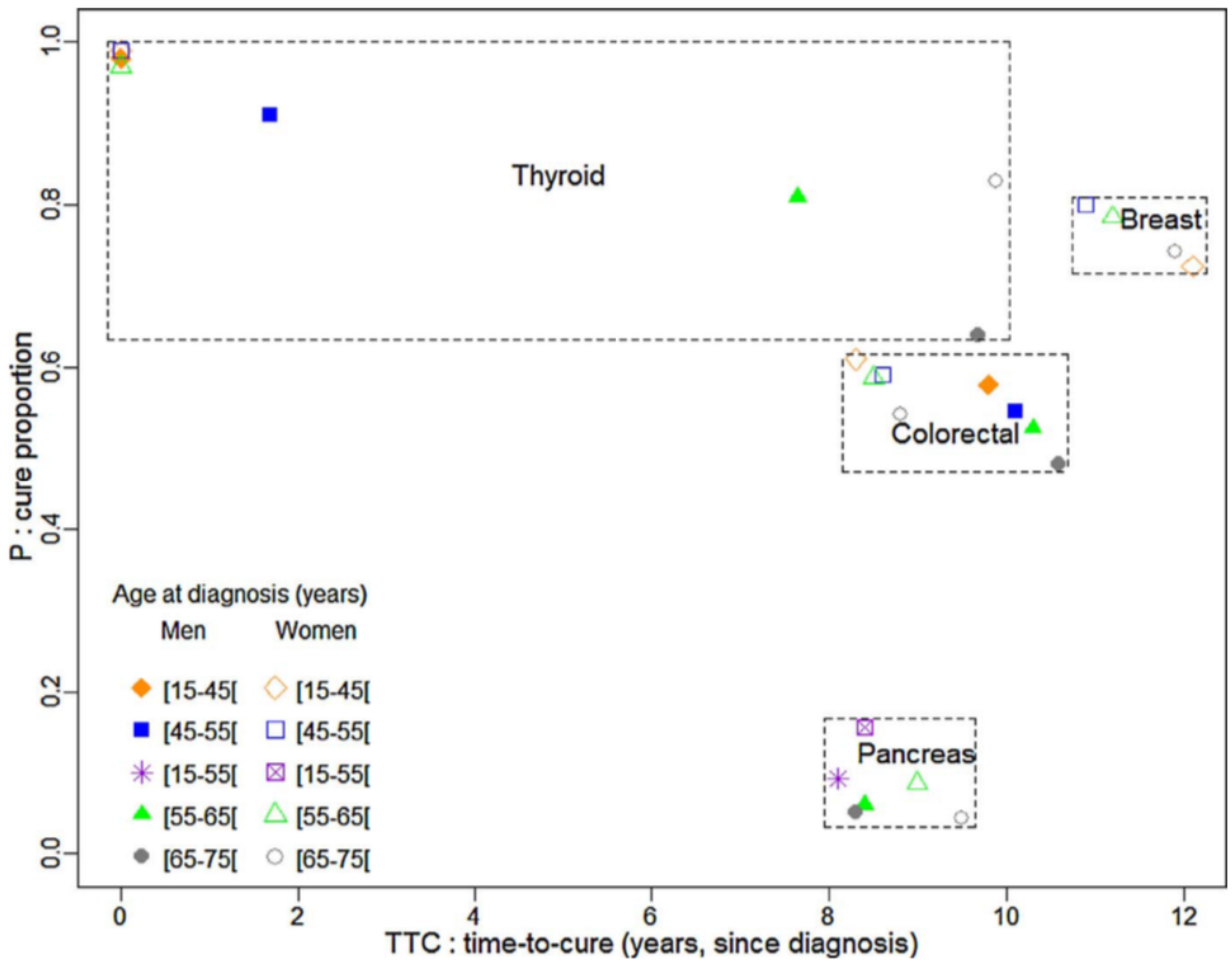
Time-to-cure

- More recently, Boussari et al. (2018) use cure models to estimate the time-to-cure (TTC)
- Let $P(t)$ be the probability of being cured at a given time t after diagnosis
- TTC is then formally defined as the time from which the probability of being cured reaches

$$P(t) > 1 - \epsilon$$

Results from Boussari et al. (2018) I

$\epsilon = 5\%$



Results from Boussari et al. (2018) II

$\epsilon = 5\%$

- Thyroid: for men aged < 45 and women < 65, $P(t)$s were $> 95\%$ just after diagnosis so the estimated TTC was 0 (+)
- Breast (women only): TTC is between 11 and 12 years after diagnosis, which is above the threshold of 10 years currently applied (-)
- Colorectal: for all women, TTC was slightly below 10 years (+), whereas for all men, TTC is slightly above 10 years (-)
- Pancreatic: Regardless of age, TTC was 9 years for women and 8 years for men (+)

Discussion about these results

- Main advantage: TTC is a useful (and simple) indicator to set the time after which a person who had cancer should not be penalized anymore (i.e., how many years before the "right to forget" should be applied?)
- On the other hand, we see a short TTC for aggressive cancers such as pancreatic cancer and a long TTC for less aggressive and more common cancers such as breast cancer. Is this what we want?

(*Note*: Presentation by the authors on November 16)

Outline

Loss of expectancy

- Loss of expectancy is:

$$YLL * u,$$

where YLL is the expected years of life lost and u a measure of utility or value of one year for one person (e.g., annual per capita income, etc.)

- YLL is based on comparing the age of death of cancer patients to an external standard life expectancy curve, and can incorporate time discounting and age weighting (Aragón et al., 2008)
- Average YLL: $\frac{YLL}{\text{number of deaths}}$ is also used to control for the large number of deaths among older people and thus highlights premature causes of death

Outline

Esteve et al. (1990) model I

- Relative survival is helpful because we do not need the cause of death
  - ↪ However, we cannot use it for comparisons between populations and time
- Net survival, defined as a measure of patient survival corrected for other causes of death (Dickman et al., 2004), allows such comparisons
  - ↪ BUT it is not suitable for populations which lack homogeneity in covariates because it influences either net survival or mortality from other causes
- Alternatives have been proposed to correct this bias (Hakulinen, 1977, 1982)
  - ↪ But these methods still overestimate long-term net survival for groups with heterogeneous life expectancies

Esteve et al. (1990) model II

- Esteve et al. (1990) proposed a maximum likelihood method for computing net survival when causes of death are not known (or inaccurate) and populations to be compared have different life expectancies:

$$\lambda_c(t, z) = exp(\beta z) \sum_{k=1}^{m} \tau_k I_k(t), \tag{2}$$

where $I_k(t)$ is the indicator function for the kth interval and τ_k is the net mortality rate in that interval for patients with $z = 0$

Outline

Combination of two approaches

- Another possibility would be to combine Esteve et al. (1990) model with the TTC from Boussari et al. (2018)
- Note: all approaches have similar grounds in the sense that we can see them as based on survival probability ratios, or as life expectancy ratios, or as mortality ratios

Outline

Conclusion

- This thesis attempts to:
  1. Develop a method to adequately estimate the threshold after which cancer patients can be considered as cured
  2. Find a proper way to adapt the actuarial pricing of life insurance products depending on the type of cancer and the duration of survival at the time of application for insurance
  3. Demonstrate that for some types of cancer, the survivors actually have a chance of survival comparable to that of the general population and could therefore be covered in the event of death
- Most appropriate approaches still have to be chosen among the ones considered: relative survival, cure models, loss of expectancy, Esteve et al. (1990) or a combination of two
- Start soon with cancer registry data provided by the Belgian Cancer Registry

Thank you!

Questions?

References I

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