Actuarial Pricing: A Biostatistics Approach

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Outline

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Aims I

- The "right to forget" has been detailed. Some questions remain:
  1. The thresholds of 10 and 5 years result from negotiations between different parties in France
     - We would like to determine technically correct values for Belgium, *i.e.*, periods after which people who had cancer can be considered as cured
  2. There remains some ambiguity about what is considered as treatment → what marks the end of a therapeutic protocol? → when the patient will start to benefit from this right?
     - For the safety of the mechanism, why not take the diagnosis as the starting point rather than the end of the treatment?
- We would also like to calculate a technically correct premium depending on the type of cancer and the duration of survival at the time of application for insurance

Aims II

- The goal is also to demonstrate that for some types of cancer, the survivors actually have a chance of survival comparable to that of the general population, or pose a moderately increased risk and could therefore be covered in the event of death
    - This involves measuring and quantifying the potential excess mortality so that the premiums claimed reflect the risk in terms of insurance cover in case of death (securing a loan)

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 (Massart, 2018)

Outline

Data

- Data from the Belgian Cancer Registry (BCR)
- Start with minors/children and extend to patients from 18 to 40-50 years old
  - Minors/children are the ones who need this kind of right later in life the most
  - For adults, age range when people are most likely to take a loan
  - Older than 50, non-cancer related deaths increase substantially and older people are less likely to start looking for insurance cover in case of death
- Focus on 2-3 cancers (which ones still to be determined) Criteria are:
  - High number of incidences, with a significant share occurring before the age of 40
  - Cancers with a relatively high survival or cured rate
  - "Well-known" to the public

Outline

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Relative survival

- 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 → impossible to compare relative survival across time (Lenner, 1990)
  - - Dependent on the mortality of the general population → not suitable for cross-country comparisons (Perme et al., 2012)

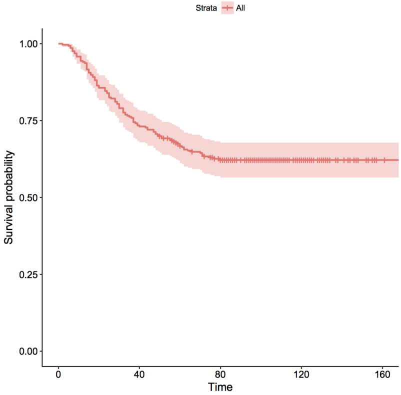
Outline

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 a survival function.[1] This plateau corresponds to cured subjects:

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

Cure models: example



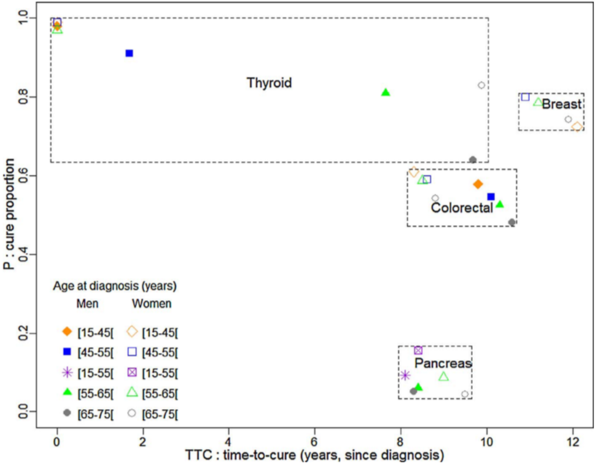
Time-to-cure

- 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?

Outline

Loss of expectancy

- Measured as the difference between the life expectancy if the patient had not been diagnosed with cancer (estimated using mortality data for the general population) and the observed life expectancy for cancer patients (Andersson et al., 2013)
- The loss of expectancy is then:

$$\# \text{ years lost} * \text{"value" of life (e.g., annual salary, etc.)}$$

Outline

Esteve et al. (1990) model I

- We have seen that 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
  - If the cause of death is unknown, estimated using relative survival
    - 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)

Esteve et al. (1990) model II

- But these methods still overestimate long-term net survival for groups with heterogeneous life expectancies

- 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 research project attempts to:
  1. Develop a method to adequately estimate the threshold after which a patient can be considered as cured, and
  2. Find a proper way to adapt the pricing of insurance cover in case of death to each category of risk, disease, person, etc.
- The most appropriate approach still has to be chosen among the ones considered: relative survival, cure models, loss of expectancy, Esteve et al. (1990) or a combination of two
- We will start soon with cancer registry data provided by the Belgian Cancer Registry

Thank you!

Questions?

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