Life and Health Actuarial Pricing: a Biostatistics Approach

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Context

• It is generally thought that **patients having suffered from a cancer have a lower probability of survival** compared to healty people. However, survival and life expectancy of cancer patients have been increasing over the last decades and we can reasonably assume that they will keep increasing in the future thanks to medical and technological progress

- In Belgium: ↪ Due to this aggravated risk and the relatively small number of patients wishing to take out insurance coverage in case of death, the **insurance industry is reluctant to grant such a guarantee**
- In France: ↪ France passed a law referred as **"the right to forget"**, that is, the **right for a person subscribing to a contract not to declare a previous cancer** after a period of 10 years after the end of the therapeutic protocol. This period is reduced to 5 years for minors

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** → what marks the end of a therapeutic protocol? → when the patient will start to benefit from this right?
3. (This right is very binary and not flexible at all)

Aims

• The aim of the project 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, and
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

• This involves measuring and quantifying the potential excess mortality so that the premiums claimed reflect the risk in terms of financial services

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)

• **New bill** introduced on September 14, 2018 to establish the right to forget in Belgium

Data

• Data from the **Belgian Cancer Registry** (BCR)

• Focus on **patients from 20 to 40-50** years old:

↪ Age 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 the cause of death

• Focus on cancer(s) with:

- **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

⇒ At the moment, **melanoma** (5-year relative survival: 93% for women and 87% for men and incidences start at 10-15 years old

Methodologies (1/2)

Relative survival:

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

where $S(t)$ is the observed survival of the cancer patients and $S^*(t)$ is the expected survival of a comparable group from the general population

• *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**

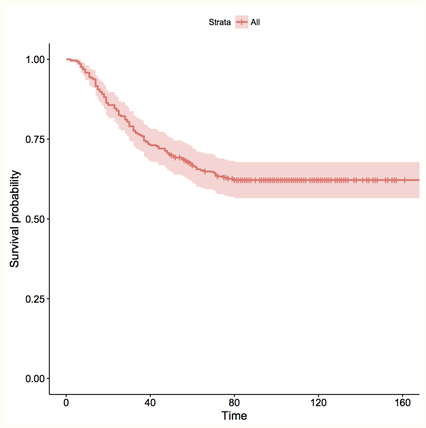
- Dependent on the mortality of the general population → **not suitable for cross-country comparisons**

Methodologies (2/2)

Cure models and time-to-cure:

• 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.[a] This plateau corresponds to cured subjects:



• 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

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

• *Pros and cons:*

+ 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?)

- **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?

Loss of expectancy:

$$YLL * u$$

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 (Aragòn 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

Esteve et al. (1990) model:

• 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**:

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

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 $z = 0$

• The **log-likelihood** may be written

$$L(\beta, \tau) = -\sum_{i=1}^{n} \Lambda_c(t_i, z_i) + \sum_{i=1}^{n} \delta_i log[\lambda_c(t_i, z_i) + \lambda_e(t_i + x_i, z_{1i})],$$

where $\Lambda_c(t_i, z_i)$ is the net cumulative hazard rate up to t_i

Combination of approaches:

• Another possibility would be to combine Esteve et al. (1990) model with the TTC from Boussari et al. (2018)

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

Still to be done

• 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

• We will start soon with cancer registry data provided by the Belgian Cancer Registry

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