Refining cancer insurance pricing: Insights from semi-Markov modelling

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Motivation

Cancer is

- a complex and heterogeneous pathology

A **considerable progress** in understanding this disease due to

- medical research and data analysis

Better **options available** for people previously considered high-risk, e.g. women with breast cancer history

Examine existing models to see if they could lead to

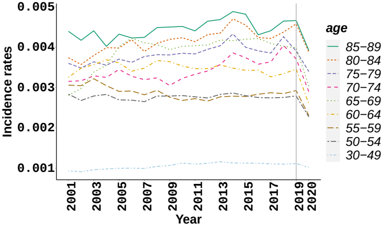
- fairly priced, more inclusive coverage options

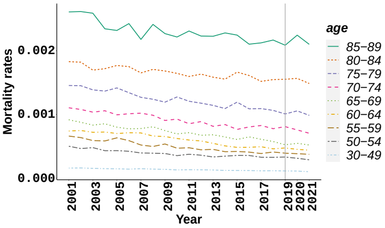
Particular focus on:

Breast cancer (BC) as it is

- **the most common** cancer diagnosed in women
- one of the **leading** causes of death for women
- one of the most **common** conditions amongst critical illness insurance (CII) claims, e.g. 44% of female CII claims in 2014 in the UK

BC incidence and mortality in England

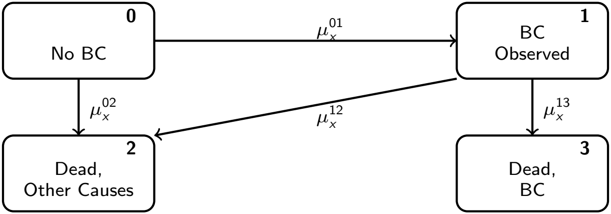




Incidence (left) v. Mortality (right)

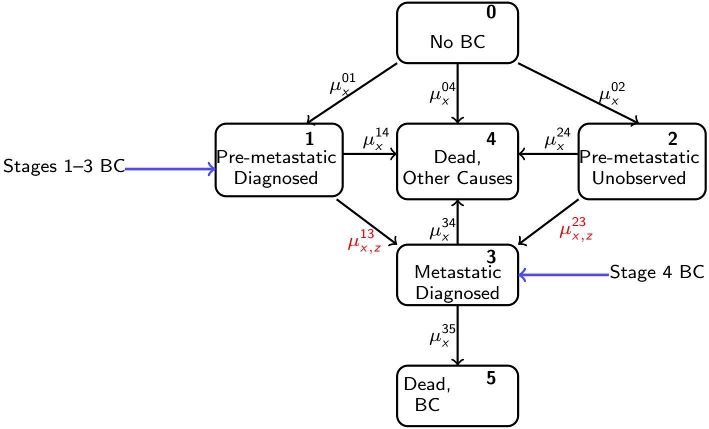
- A significant decline in BC incidence, as low as 25% at ages 60–64, in 2020 as compared to the same period in 2019
- An increase in BC mortality from ages 65+, as high as 7%, in 2020 as compared to the same period in 2019

An industry-based Markov model: M0



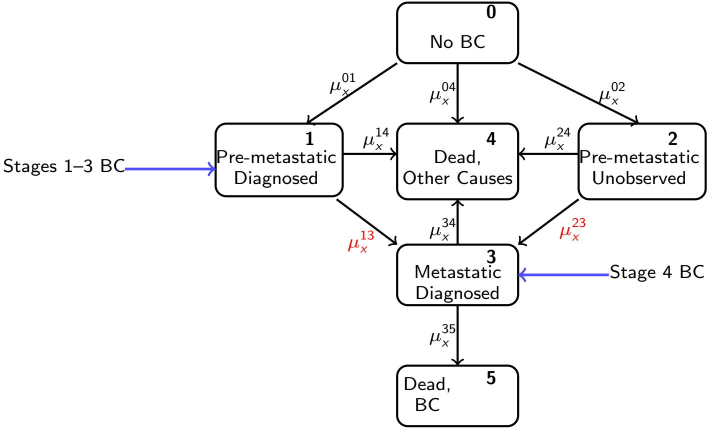
- Applied to CII by the insurance industry (Reynolds and Faye, 2016; Baione and Levantesi, 2018)
- **ONLY** account for observed BC cases
- Do not differentiate between different stages of BC

A semi-Markov model: M1



- Duration dependence in 'Pre-metastatic Diagnosed' and 'Pre-metastatic Unobserved'

A special case of the semi-Markov model: M2



- NO duration dependence in 'Pre-metastatic Diagnosed' AND 'Pre-metastatic Unobserved'

Models M0 – M2: key transition intensities

Age	μ_x^{01} in M0	μ_x^{01} in M1&M2	μ_x^{02} in M0 μ_x^{04} in M1&M2	μ_x^{13} in M0 μ_x^{35} in M1&M2
30–49	0.00106	0.00086	0.00084	0.16739
50–54	0.00277	0.00224	0.00228	0.24005
55–59	0.00287	0.00233	0.00363	0.24005
60–64	0.00349	0.00282	0.00588	0.28060
65–69	0.00393	0.00318	0.00952	0.28060
70–74	0.00345	0.00280	0.01643	0.36002
75–79	0.00384	0.00311	0.02987	0.40000
80–84	0.00417	0.00338	0.05496	0.49711
85–89	0.00447	0.00362	0.10112	0.50000

- μ_x^{01} : ONS/NHS Digital data, 81% of new BC registrations in M1&M2, England, 2001–2019
- μ_x^{02} or μ_x^{04} : ONS data, deaths from other causes, England, 2001–2019
- μ_x^{13} or μ_x^{35} : BC deaths by age within 12 months after Stage 4 BC diagnosis (Zhao et al., 2020)

Key transition intensities: a simple model

Generalised additive models to observed transition intensities, μ, as

$$g(E(\mu)) = \kappa + \sum_{p} s_p(x_p)$$

- κ : intercept
- $g(.)$: a smooth monotonic link function
- μ : modelled as the sum of smooth functions, $s(.)$, of covariate(s) x
- Maximum age is accepted to be 90

  ...i.e. a policy is in force for at most 40 years for a 50 year old insured

Critical illness and life insurance products

We consider

- single benefit in an insurance contract:

  a specialised CII

  OR

  a specialised life insurance (LI)

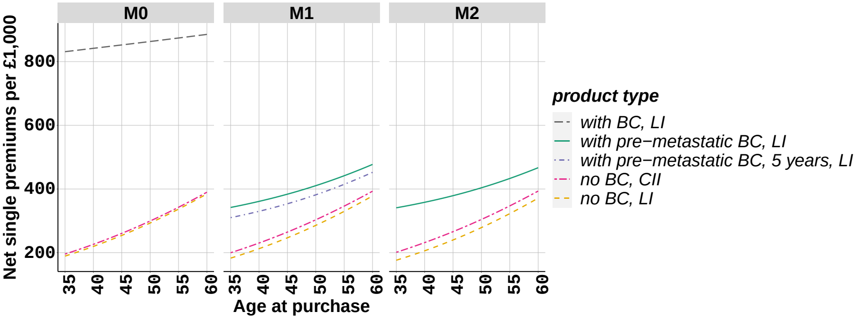
- benefit to be payable at the time of

  1. BC diagnosis or death from other causes in the CII contract
  2. death from any causes in the LI contract; and

- the LI contract can be purchased

  with pre-metastatic BC

Net single premiums: whole life insurance



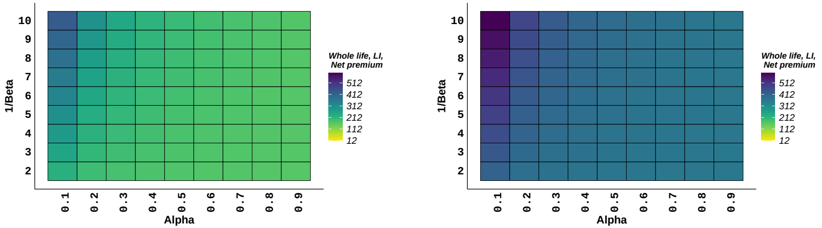
Whole life insurance contracts for $i = 4\%$ when $\alpha = 0.6$ and $\beta = 1/7$

- Premiums, no BC, CII $>$ Premiums, no BC, LI
- Premiums, diagnosed with pre-metastatic BC at the time of purchase, LI $>$ Premiums, no BC, LI
- Premiums, diagnosed with pre-metastatic BC at the time of purchase, LI $>$ Premiums, diagnosed with pre-metastatic BC 5 years before purchase, LI (Impact of duration or time spent with pre-metastatic BC? Vulnerability?)

What insights we gain from different models

- Differences across the models due to
  - number of departures from 'No BC'
  - definition of rates of transition μ_x^{01}
- Duration dependence in the semi-Markov model, M1, enables
  - a more flexible pricing methodology
  - results aligned with medical literature
- The post-cancer mortality from BC under the industry-based model, M0, linked to the risk of dying from metastatic BC
  - leading to very high LI prices for a woman with BC
  - suggesting sensitivity to this assumption

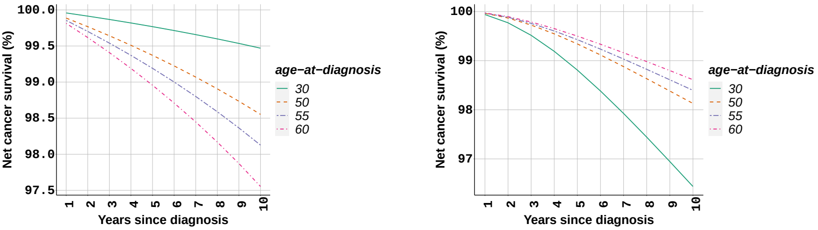
Whole life insurance premiums per £1000 : No BC



Aged 35, $i = 4\%$ (left) v. Aged 60, $i = 4\%$ (right)

- Change in α :
  - 10% $\Rightarrow$ a health system with notably poor BC diagnosis
  - 90% $\Rightarrow$ high BC diagnosis
- Change in β :
  - $1/2 \Rightarrow$ a higher-level access to BC treatment
  - $1/10 \Rightarrow$ a lower-level access to BC treatment
- Greater sensitivity in the model results in extreme cases, e.g. $\alpha < 0.4$ or $1/\beta > 5$

Post-cancer mortality from BC: M0 v. M2



BC survival under M0 (left) v. Pre-metastatic BC under M2 (right)

- Baseline scenario in M2 is carried out when $\alpha = 0.6$ and $\beta = \frac{1}{7}$
- Net Survival: **ONLY** consider 'Dead, BC' as cause of death **AFTER** BC diagnosis
- An unusual age pattern in pre-metastatic BC net survival
- The risk of death from BC under M0 to be similar to a woman with early BC diagnosis
  - **NOT** capturing the age pattern in BC net survival as expected

Summary

- New medical technologies improve cancer survival
- Flexible models are relevant to medical underwriting of related insurance contracts
- A valuable model relating to delays in the provision of BC diagnostic and treatment services
  - also relevant to meet the needs of women with medical history of BC
- Duration dependence matters in actuarial applications
- Smaller differences across premiums under different models with an increasing age and a longer time to maturity
- Measuring parameter and model uncertainty?
- Accounting for time trend in cancer incidence, type-specific mortality, and the risk of developing metastatic BC?

More details in:

1. Arık, A., Cairns, A., Dodd, E., Macdonald, A.S., Shao, A., Streftaris, G. Insurance pricing for breast cancer under different multiple state models, https://arxiv.org/abs/2311.15975.
2. Arık, A., Cairns, A., Dodd, E., Macdonald, A.S., Streftaris, G. The effect of the COVID-19 health disruptions on breast cancer mortality for older women: A semi-Markov modelling approach, Scandinavian Actuarial Journal, 2024.
3. Arık, A., Cairns, A., Dodd, E., Macdonald, A.S., Streftaris, G. Estimating the impact of the COVID-19 pandemic on breast cancer deaths among older women, Living to 100 Research Symposium, 16 February 2023, conference monograph.
4. Arık, A., Dodd, E., Cairns, A., Streftaris, G. Socioeconomic disparities in cancer incidence and mortality in England and the impact of age-at-diagnosis on cancer mortality, PLOS ONE, 2021.
5. Arık, A., Dodd, E., Streftaris, G. Cancer morbidity trends and regional differences in England - a Bayesian Analysis, PLOS ONE, 2020.

Thank You!

Questions?

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