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Cause-of-Death Mortality and Socio-Economic Status

A Study of a Portfolio Dynamics

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About the speaker

- **Héloïse Labit Hardy**
- Research Fellow at CEPAR, UNSW, Sydney, Australia
- PhD in Actuarial science from University of Lausanne in Switzerland

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- **ARC Centre of Excellence in Population Ageing Research (CEPAR), UNSW, Sydney, Australia**
- Unique collaboration between academia, government and industry
- Deliver solutions to one of the major economic and social challenges of the 21st century: population ageing.

Acknowledgements - Travel supports

- **Risks - Open Access Journal of Risk Management**
- 2017 Travel Award for postdoctoral researchers

- **31st International Congress of Actuaries 2018**
- Grant for early career researchers

- **ARC Centre of Excellence in Population Ageing Research (CEPAR), UNSW, Sydney, Australia**
- Early Career Research Fellow Travel Scheme

Agenda

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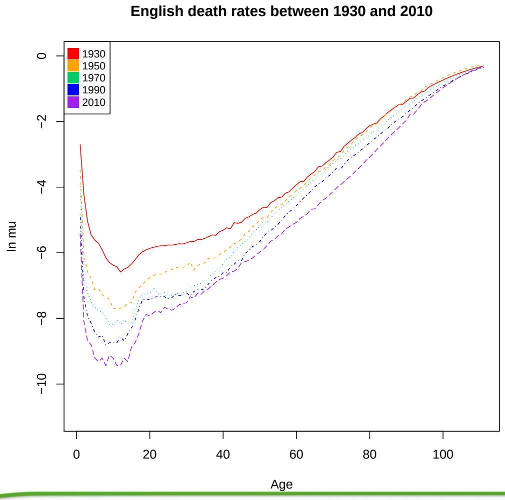
1. Introduction

Context

Source: The Human Mortality Database (HMD)

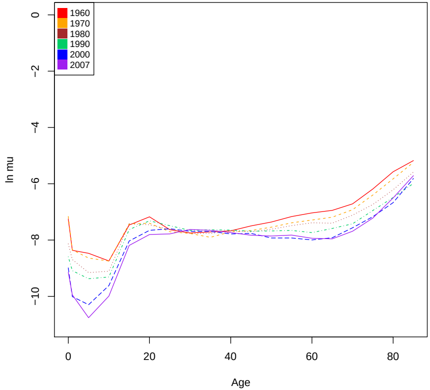
Context



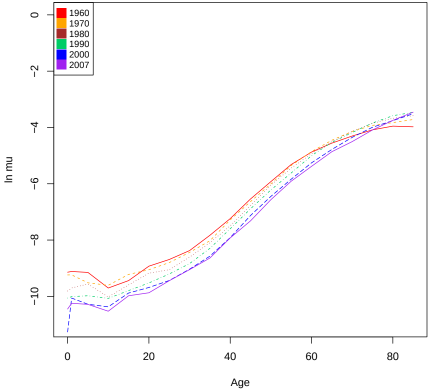
Source: The Human Mortality Database (HMD)

Context

English death rates for males between 1960 and 2007 for external causes



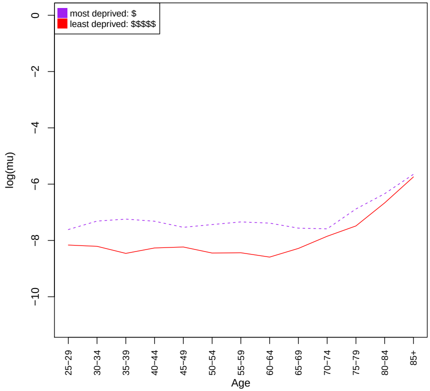
English death rates for males between 1960 and 2007 for cancers



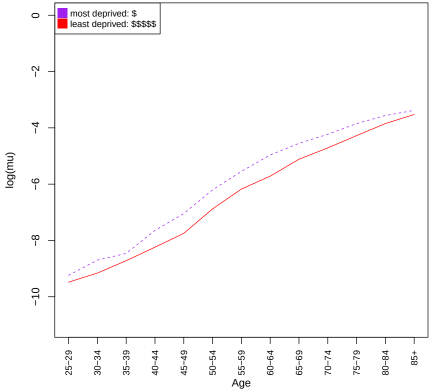
Source: The World Health Organization (WHO)

Context

English death rates for external causes in 2007 (males)



English death rates for cancers in 2007 (males)



Source: The Office for National Statistics (ONS)

Research problem

What could be the impacts of cause-of-death mortality changes?

What could be impacts of mortality changes following the socio-economic composition? for an insurance portfolio?

Objective

⇒ Study impacts of changes in cause-of-death mortality on an insurance portfolio composed with different socio-economic categories

- Model portfolio dynamics
  - By taking into account deaths, arrivals and seniority:
    - with cause-of-death rates depending on age, time, gender and socio-economic category
  - Provide a general framework to address the issue
- Application to English data
- Arnold, S., and Labit Hardy, H. 2016. Cause-of-Death Mortality and Socio-Economic Status: A Study of a Portfolio Dynamics *working paper.*

Agenda

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2. Portfolio Dynamics Model

2.1 Closed Portfolio

2.2 Open Portfolio

2.3 Portfolio Dynamics with Medical Selection

Framework

- Let us characterize the policyholders by the gender ϵ, the year of birth y and the socio-economic status j:

$$g^{\epsilon}(t) = \sum_{y_{min}}^{y_{max}} g^{\epsilon}(y,t) = \sum_{y_{min}}^{y_{max}} \sum_{j=1}^{I} g_j^{\epsilon}(y,t) = \sum_{y_{min}}^{y_{max}} \sum_{j=1}^{I} \int_0^{t-t_0} g_j^{\epsilon}(y,t,u)du$$

  - $g_j^{\epsilon}(y,t,u)$ is the total number of policyholders at time t with gender ϵ, socio-economic status j, year of birth y and seniority u

- Model the heterogeneous cohort dynamics and the aggregated cohort death rate: $g^{\epsilon}(y,t)$, $d^{\epsilon}(y,t)$
- Reference: Bensusan, Boumezoued, El Karoui and Loisel (working paper)

2.1 Closed Portfolio

- For a closed portfolio, policyholders in the sub-cohort with socio-economic category j evolve only according to deaths:

$$\frac{dg_j^\epsilon(y,t)}{dt} = g_j'^\epsilon(y,t) = -\mu_j^\epsilon(y,t)g_j^\epsilon(y,t). \tag{1}$$

- In this sense, the aggregated cohort dynamics in a closed portfolio is also defined only by deaths:

$$\frac{dg^\epsilon(y,t)}{dt} = g'^\epsilon(y,t) = -d^\epsilon(y,t)g^\epsilon(y,t) \tag{2}$$

$$\Rightarrow d^\epsilon(y,t) = \frac{\sum_{j=1}^m \mu_j^\epsilon(y,t)g_j^\epsilon(y,t)}{\sum_{j=1}^m g_j^\epsilon(y,t)}$$

  - $g_j^\epsilon(y,t)$: survivors from the initial sub-cohort

2.2 Open Portfolio

- For an open portfolio, policyholders in the sub-cohort with socio-economic category j evolve according to deaths, arrivals and cancellations (B_j):

$$\frac{dg_j^{\epsilon}(y,t)}{dt} = g_j'^{\epsilon}(y,t) = -\mu_j^{\epsilon}(y,t)g_j^{\epsilon}(y,t) + B_j^{\epsilon}(y,t). \tag{3}$$

- By summing, the aggregated cohort dynamics in an open portfolio is also defined by deaths, arrivals and cancellations:

$$\frac{dg^{\epsilon}(y,t)}{dt} = g'^{\epsilon}(y,t) = -d(y,t)g^{\epsilon}(y,t) + B^{\epsilon}(y,t) \tag{4}$$

$$\Rightarrow d^{\epsilon}(y,t) = \frac{\sum_{j=1}^{m}\mu_j^{\epsilon}(y,t)g_j^{\epsilon}(y,t)}{\sum_{j=1}^{m}g_j^{\epsilon}(y,t)}$$

  - $g_j^{\epsilon}(y,t)$: survivors from the initial sub-cohort + arrivals

2.3 with Medical Selection

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- Medical Selection:
  - to measure health status of potential new policyholders (health declaration, questionnaire or medical examination)
  - results in some reduced mortality over a few years
- Deterministic Model:
  - Policyholders at time t with socio-economic category j, gender ϵ, year of birth y and seniority u evolve according to deaths, arrivals (B_j), McKendrick-Von Foerster equation:

$$\begin{cases} (\partial_t + \partial_u) g_j^{\epsilon}(y,t,u) = -\mu_j^{\epsilon}(y,t,u) g_j^{\epsilon}(y,t,u), \\ g_j^{\epsilon}(y,t,0) = B_j^{\epsilon}(y,t) \\ g_j^{\epsilon}(y,t_0,u) = g_{0j}^{\epsilon}(y,u) \end{cases}$$

2.3 with Medical Selection

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- By summing, the aggregated cohort dynamics in an open portfolio is also defined by deaths and arrivals:

$$\frac{\mathrm{d}g^{\epsilon}(y,t)}{\mathrm{d}t} = g'^{\epsilon}(y,t) = -d(y,t)g^{\epsilon}(y,t) + B^{\epsilon}(y,t).$$

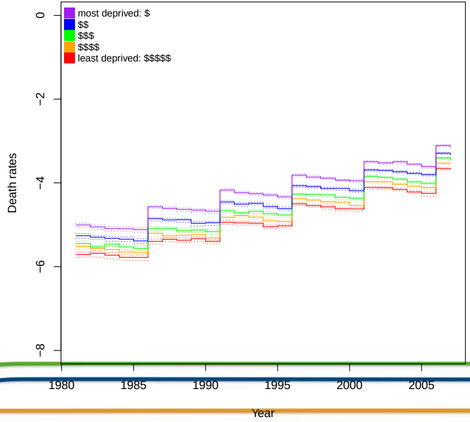
$$\Rightarrow d^{\epsilon}(y,t) = \frac{\sum_{j=1}^{I}\left(\int_0^{t-t_0} \mu_j^{\epsilon}(y,t,u)g_j^{\epsilon}(y,t,u)\mathrm{d}u\right)}{\sum_{j=1}^{I}\left(\int_0^{t-t_0} g_j^{\epsilon}(y,t,u)\mathrm{d}u\right)}$$

3.1 Data

- Data provided by the Office for National Statistics (ONS)
  - England
  - Cause-of-death rates
    - depending on age, year, gender and socio-economic category
  - Over the period 1981 to 2007
  - By age-class of 5 years from age 25 to "85+"

3.1 Data

English cohort death rates per socio-economic category for females of age 50 in 1981 with 95% confidence intervals



3.1 Data

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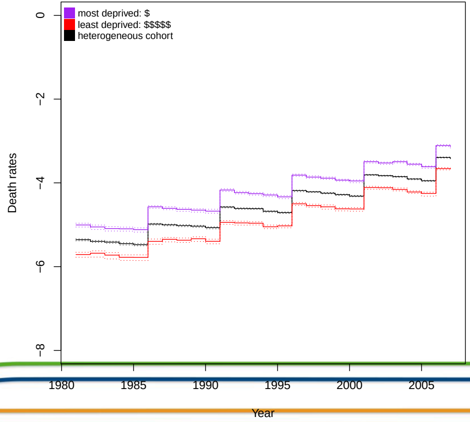
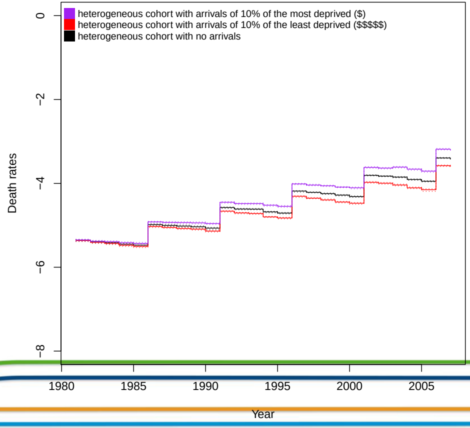


3.2 Results

Cohort death rates per socio-economic composition for females of age 50 in 1981 with 95% confidence intervals for open portfolios



3.2 Results

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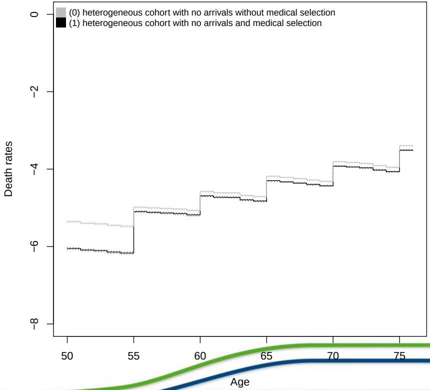
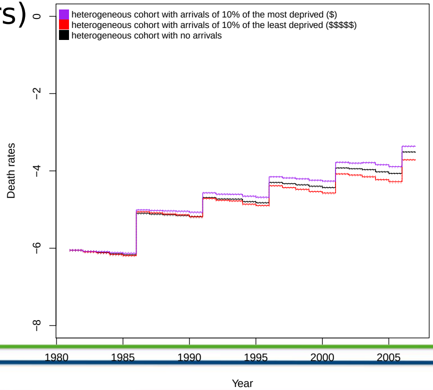
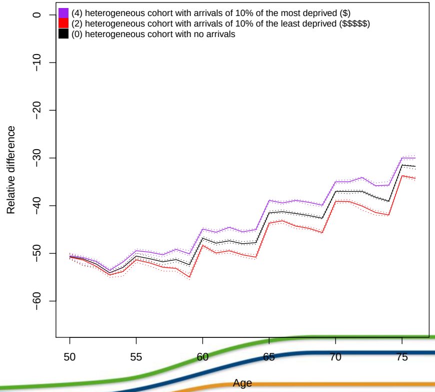
Cohort death rates per socio-economic composition for females of age 50 in 1981 with 95% confidence intervals with medical selection (−50% for 5 years)

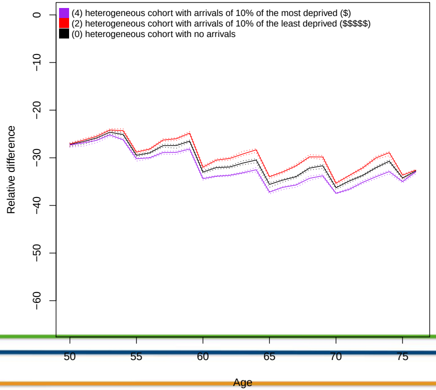




3.2 Results

Relative difference of death rate per socio-economic composition for females of age 50 in 1981 with 95% confidence intervals (left for cancer removal, right for circulatory diseases removal)





3.2 Results

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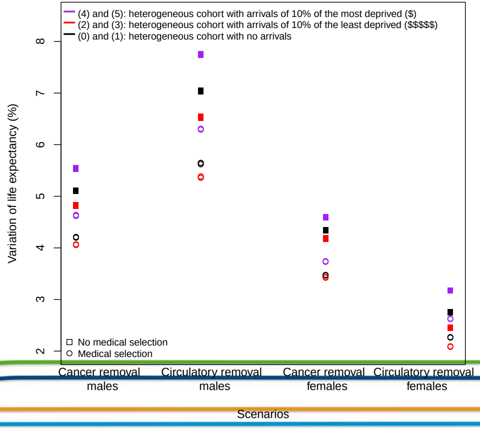
Impact of cause-of-death mortality changes on the 25-th year temporary complete life expectancy at age 50 in 1981, with 95% confidence interval



Concluding remarks

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- With a population dynamics model, we study impacts of cause-of-death changes on a portfolio mortality comprising different socio-economic categories, for a closed and an open portfolio, with medical selection :
  ⇒ Following the portfolio structure, cause-of-death mortality changes can have different impacts on the aggregated mortality
  - Having medical selection reduces impacts of cause-of-death elimination on the life expectancy
- To go further
  - Data smoothing; Stochastic approach
  - Study aggregated mortality of a whole heterogeneous population composed with different social status

Thank you very much for your attention!

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