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Cause-of-Death Mortality and Socio-Economic Status: A Study of a Portfolio Dynamics

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joint project with S. Arnold

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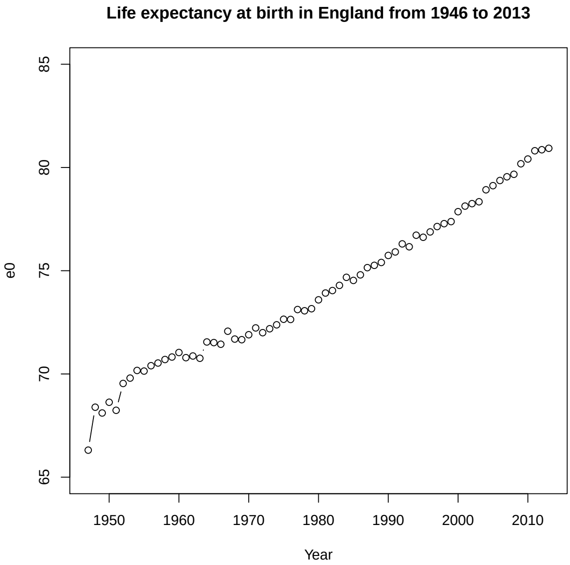
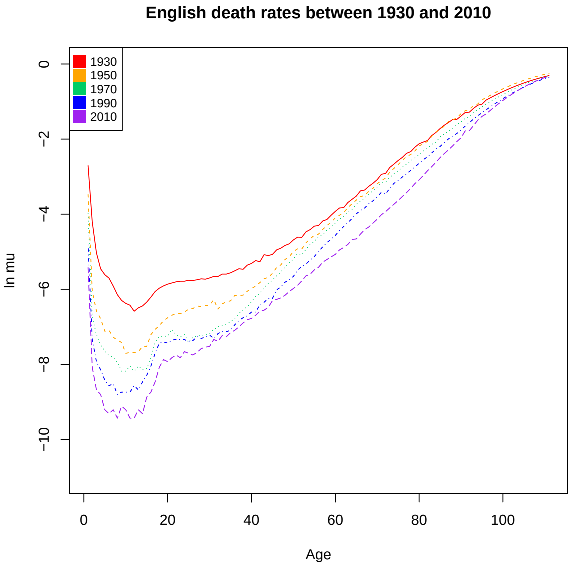
Context



Source : The Human Mortality Database (HMD)

Context



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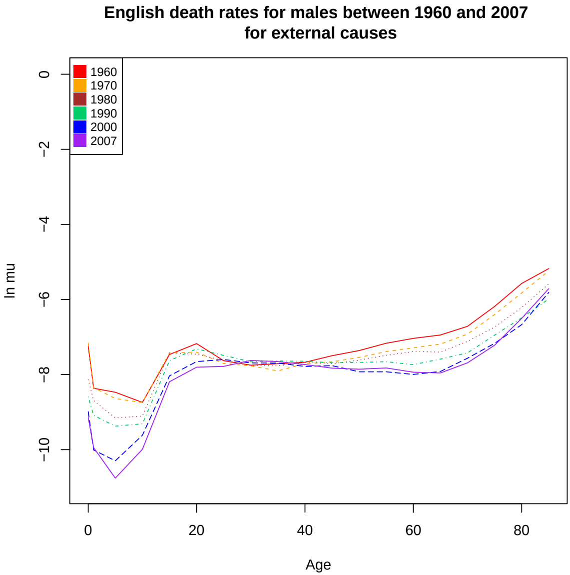

Source : The Human Mortality Database (HMD)

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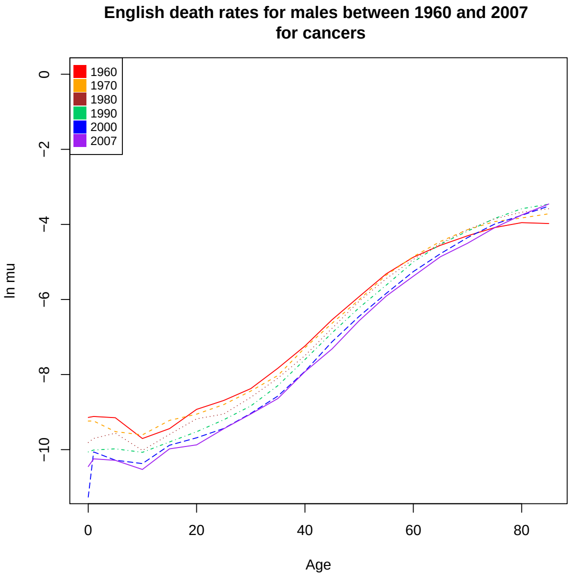

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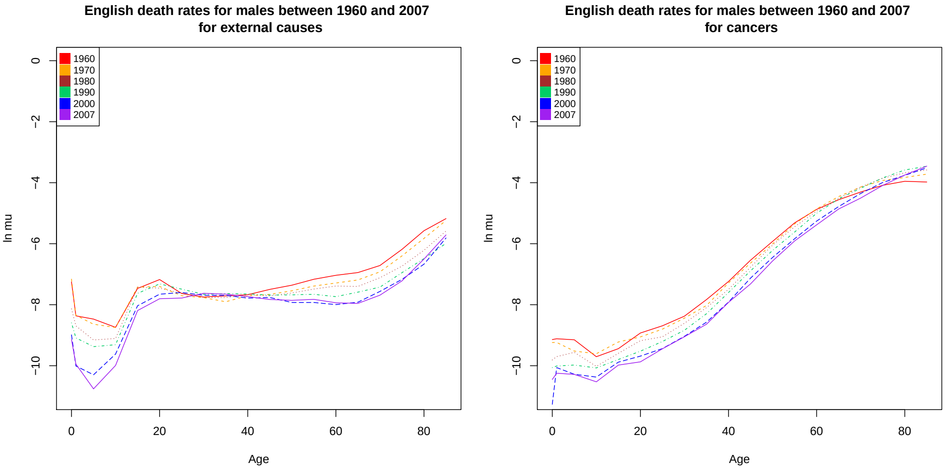
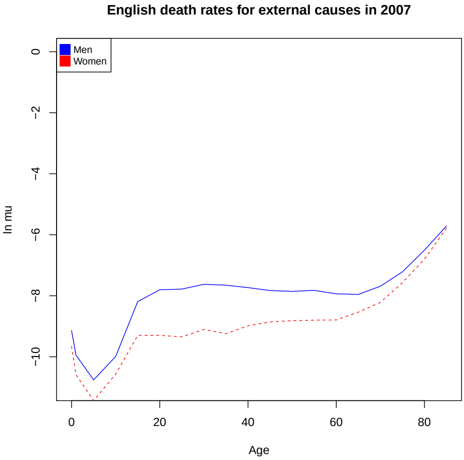


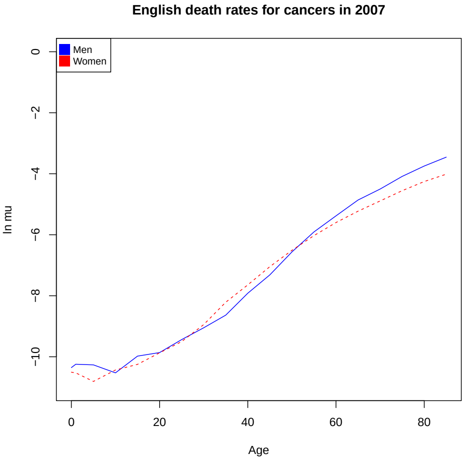
Source : The World Health Organization (WHO)

Research problem

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

Context





Source : The World Health Organization (WHO)

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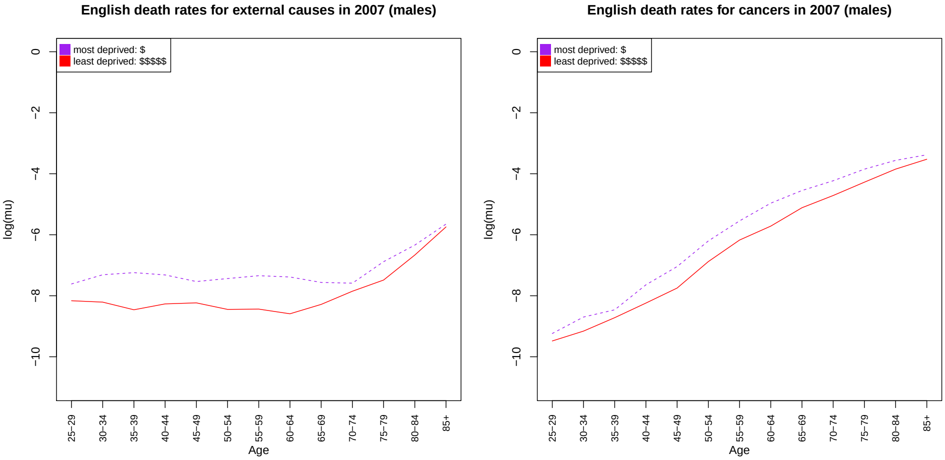


Source : The Office for National Statistics (ONS)

Objective

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

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

- 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.*

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

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

  - $g_j^{\epsilon}(y,t,u)$ 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)

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

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

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

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

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

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

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

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

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

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

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

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

- 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 :

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

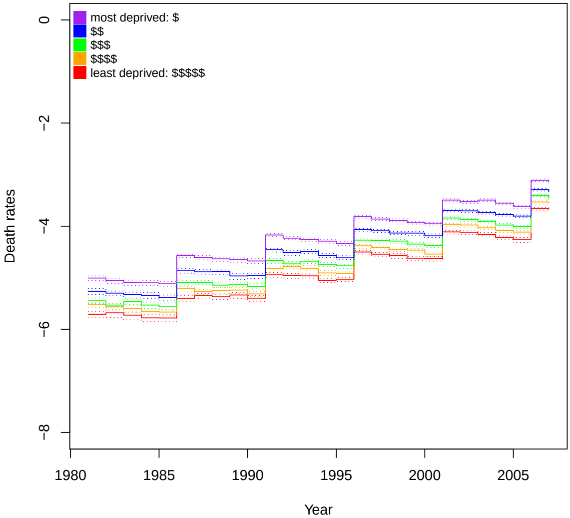
- By summing, the aggregated cohort dynamics in an open portfolio is also defined by deaths and arrivals :

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

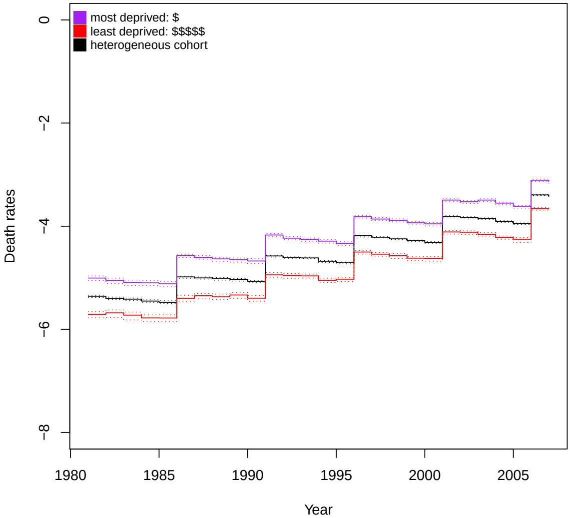
$$\Rightarrow d^{\epsilon}(y,t) = \frac{\sum_{j=1}^{l}\left(\int_0^{t-t_0}\mu_j^{\epsilon}(y,t,u)g_j^{\epsilon}(y,t,u)\mathrm{d}u\right)}{\sum_{j=1}^{l}\left(\int_0^{t-t_0}g_j^{\epsilon}(y,t,u)\mathrm{d}u\right)}$$

- 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+"

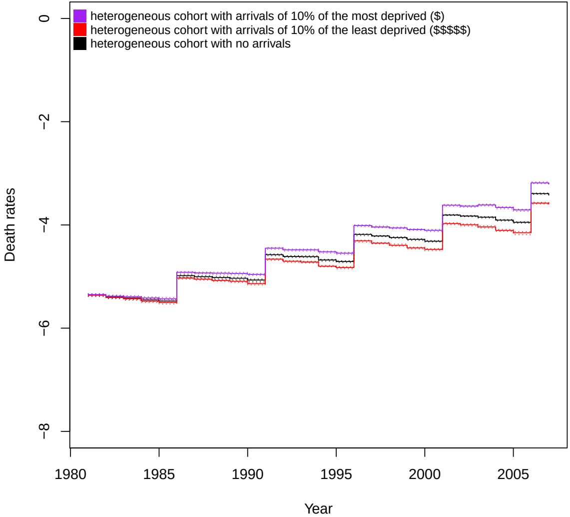
English cohort death rates per socio-economic category for females of age 50 in 1981 with 95% confidence intervals



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

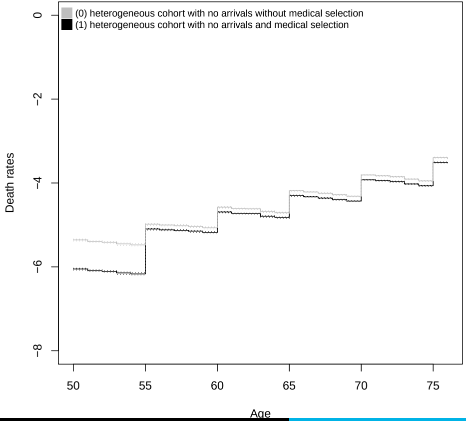


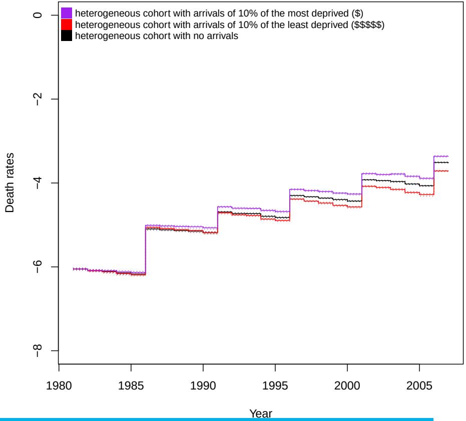
Cohort death rates per socio-economic composition for females of age 50 in 1981 with 95% confidence intervals for open portfolios



Medical Selection

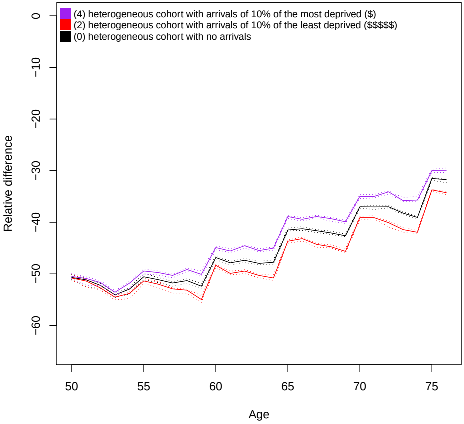
Cohort death rates per socio-economic composition for females of age 50 in 1981 with 95% confidence intervals with medical selection (−50% for 5 years)

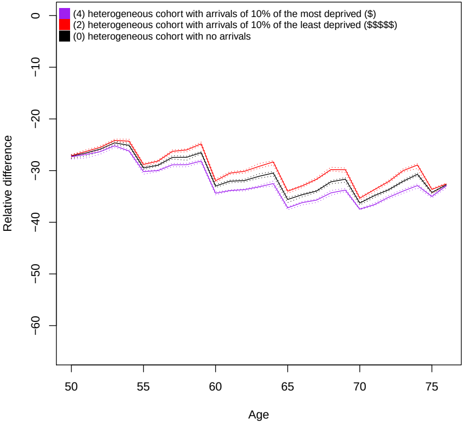




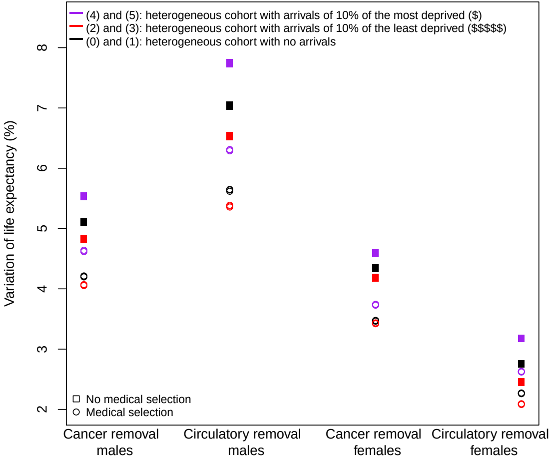
Causes removal

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)





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

- 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 :

  $\Rightarrow$ **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

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thank you!