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A Comprehensive Analysis of the Patterns of Worldwide Mortality Evolution

- 7th Demographic Conference of „Young Demographers"
- Prague, February 11th, 2016
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- Joint work with Matthias Börger und Jochen Ruß
- Institute for Finance and Actuarial Sciences and University of Ulm, Germany

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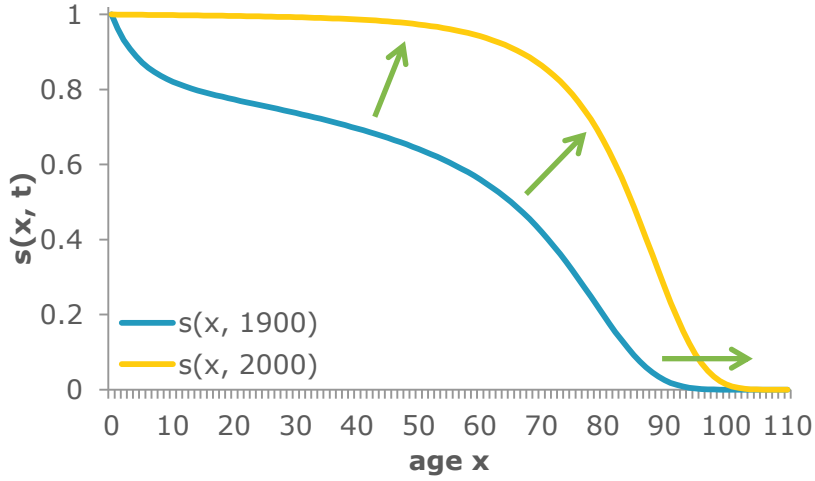
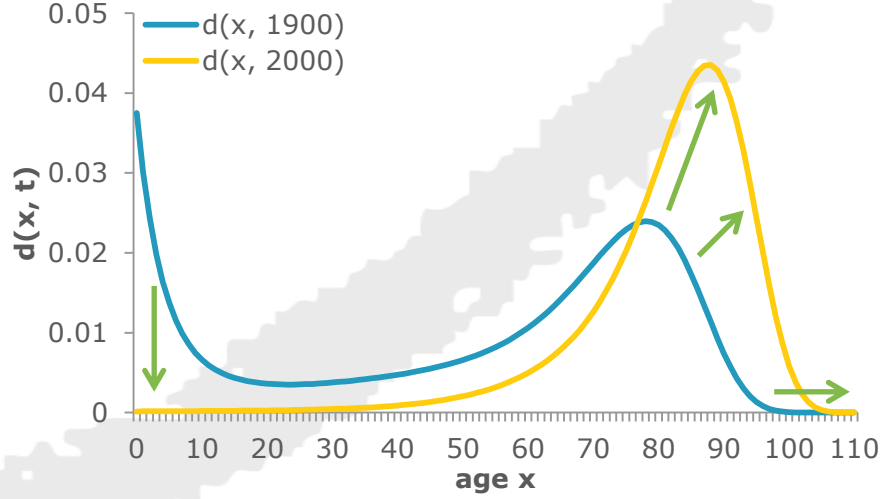
Motivation

- For example, life expectancy increases in most countries all over the world.
- But changes in life expectancy (and other typically used statistics) are only a **consequence of the underlying change of the age distribution of deaths**.

Survival curve of Swedish females 1900 and 2000



Deaths curve of Swedish females 1900 and 2000



- **Questions:**
  - How does the shape of the deaths curve **change over time** and how can we **classify** that?
  - Are there **different evolutions for different countries**? And are there any **common patterns** and/or **exceptions**?

Agenda

Motivation

Data: What do we look at?

Toolkit: How do we compress the data?

The Classification Framework of Börger et al.

Detection of Trends

Results

Summary and Outlook

Data: What do we look at?

- The **Human Mortality Database (HMD)** provides mortality data for
  - 42 different populations and
  - for females and males all over the world.
  - For 34 populations the data history is longer than 40 years.
- We calculate **death curves** for each
  - population,
  - sex,
  - starting age, and
  - calendar year, where we have data.

We analyze the **changes of these deaths curves over time** and **compare them to each other**.

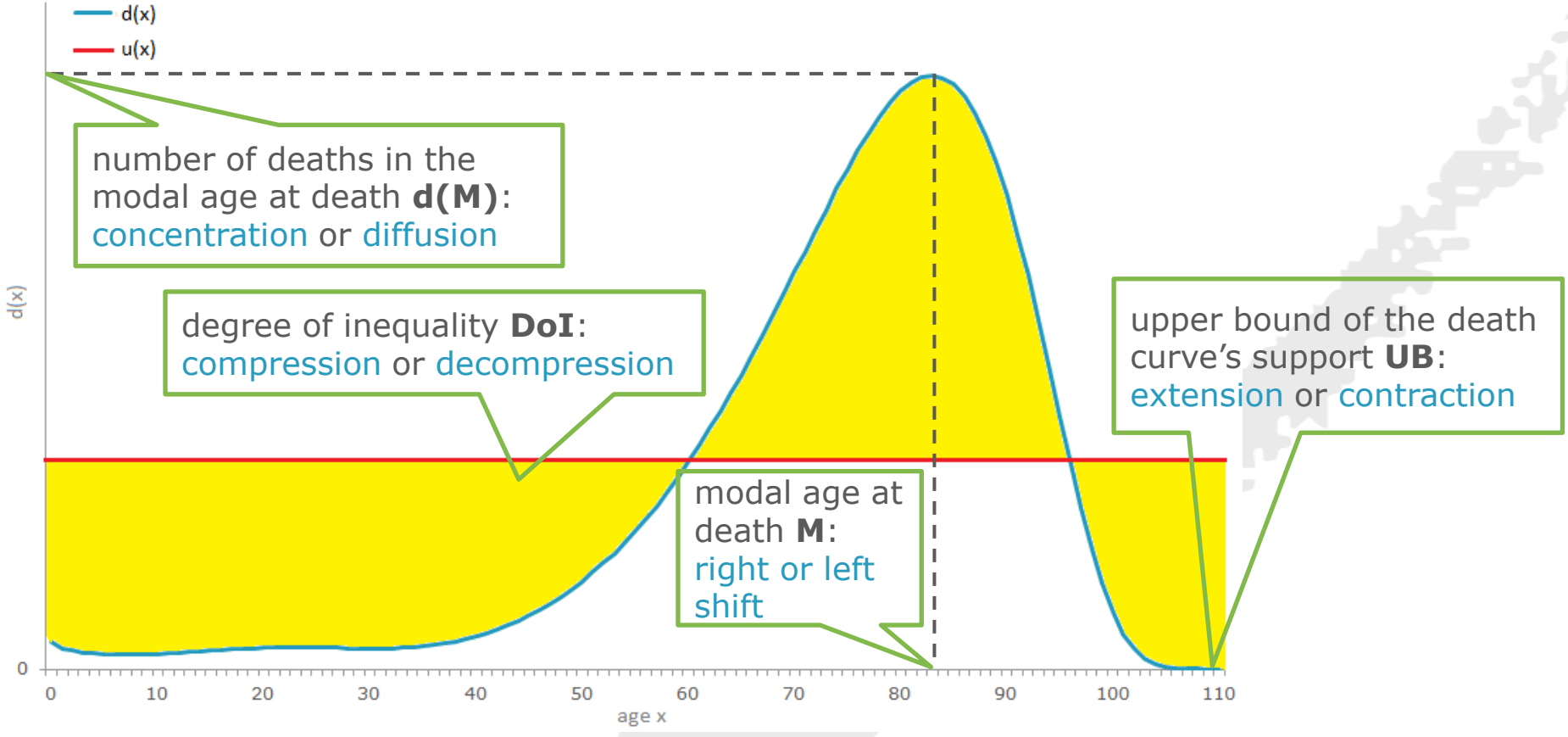
Toolkit: How do we compress the data?

The Classification Framework (1)

- There exists a variety of literature on the question how the age distribution of deaths changes over time.
- We have identified some shortcomings there (for details, see Börger et al. 2016):
  - Often the established **scenarios were defined imprecisely**, e.g. compression, extension, rectangularization, …
  - Some of these scenarios were supposed to be **mutually exclusive**, which is demonstrably false.
  - Several often used **statistics are insufficient** or even **misleading**.
  - Often effects caused by the **choice of a certain age range** under observation were not considered.
- We recently introduced a **unique classification system** for mortality evolution patterns , which…
  - … rules out the shortcomings which we mentioned above,
  - … uniquely classifies any kind of change in the age distribution of deaths,
  - … is based on 4 statistics.

Toolkit: How do we compress the data?

The Classification Framework (2)

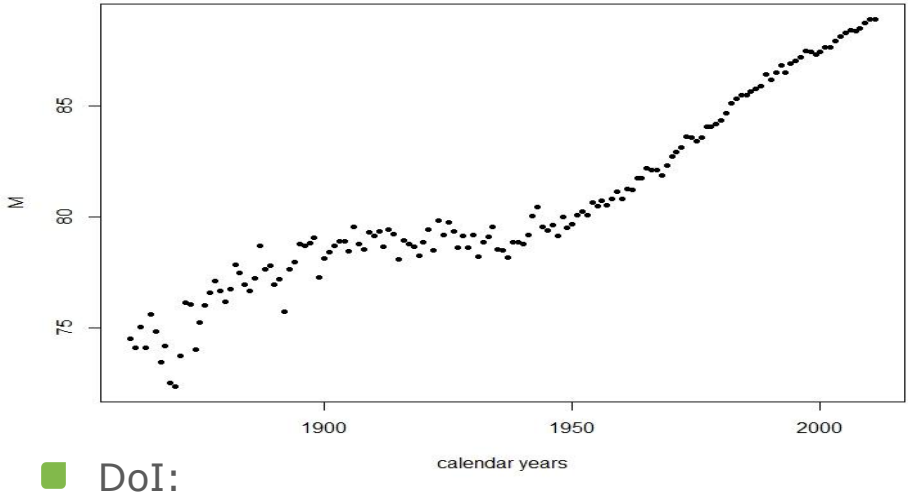


- Each scenario is defined by a **4-dimensional vector** where each component can have three specifications (increasing, neutral, decreasing)
- This allows for 3^4=**81 different scenarios**.

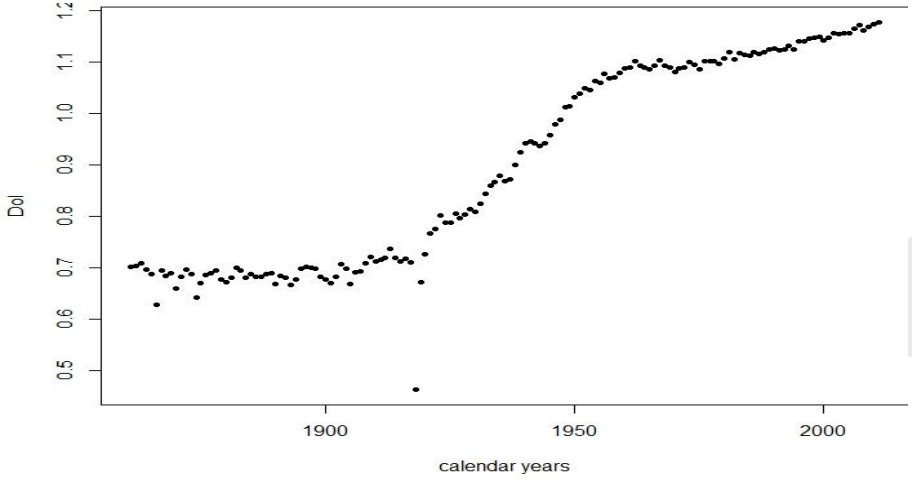
Toolkit: How do we compress the data?

Detection of Trends – Examples: M and DoI for Swedish females, starting age 0

- M:



- DoI:



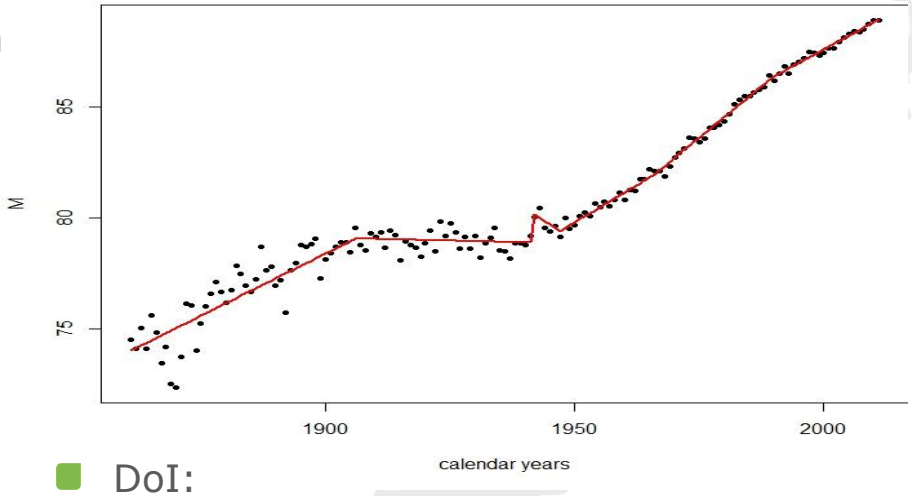
- When we compute these statistics on real data, we can get such plots.
- We can observe three things:
  - We must find **a formalization** of the statements "increasing", "neutral" , and "decreasing".
  - We have to find a method, with which we can explicitly **identify changes** in the trend.
  - We observe **heteroscedasticity**.

Toolkit: How do we compress the data?

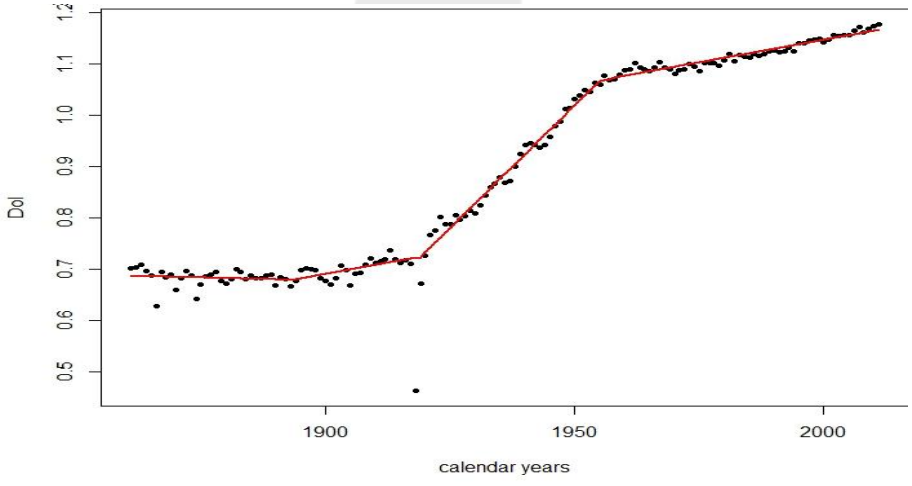
Detection of Trends - Examples: M and DoI for Swedish females, starting age 0

- Muggeo (2003) proposed a method, with which historical data can be fitted with a **continuous and piecewise linear curve**.
  - We minimize the **Akaike Information Criterion (AIC)** to find the best trade-off between goodness of fit and number trend changes. The AIC has the advantage to be time invariant.
- This method was modified by Börger et al. (2015), such that it considers **heteroscedasticity** in the input data.
- With a test for significance we determine the **trend of the statistics in this intervals** and can classify it in the three categories "increasing", "neutral", and "decreasing".

- M:

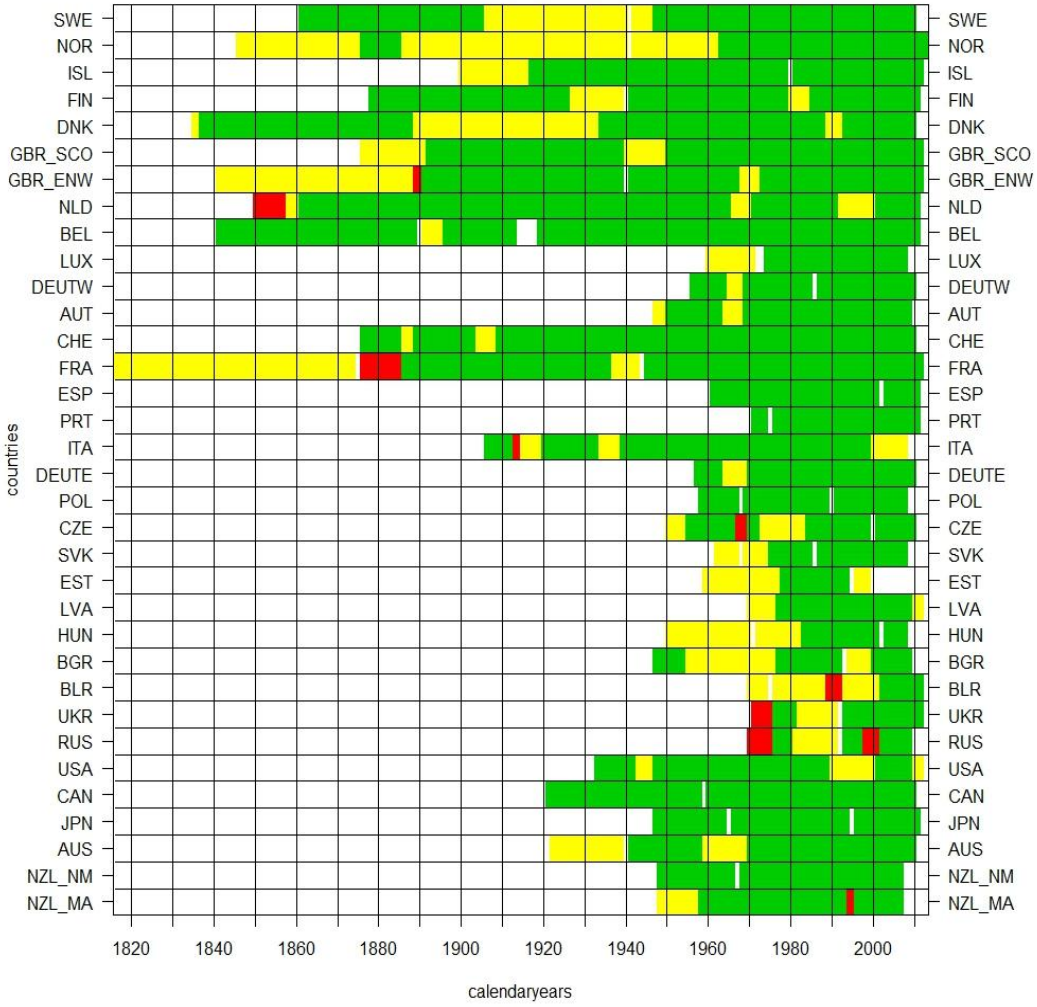


- DoI:



Results

Females, starting age 0, M



left-shift

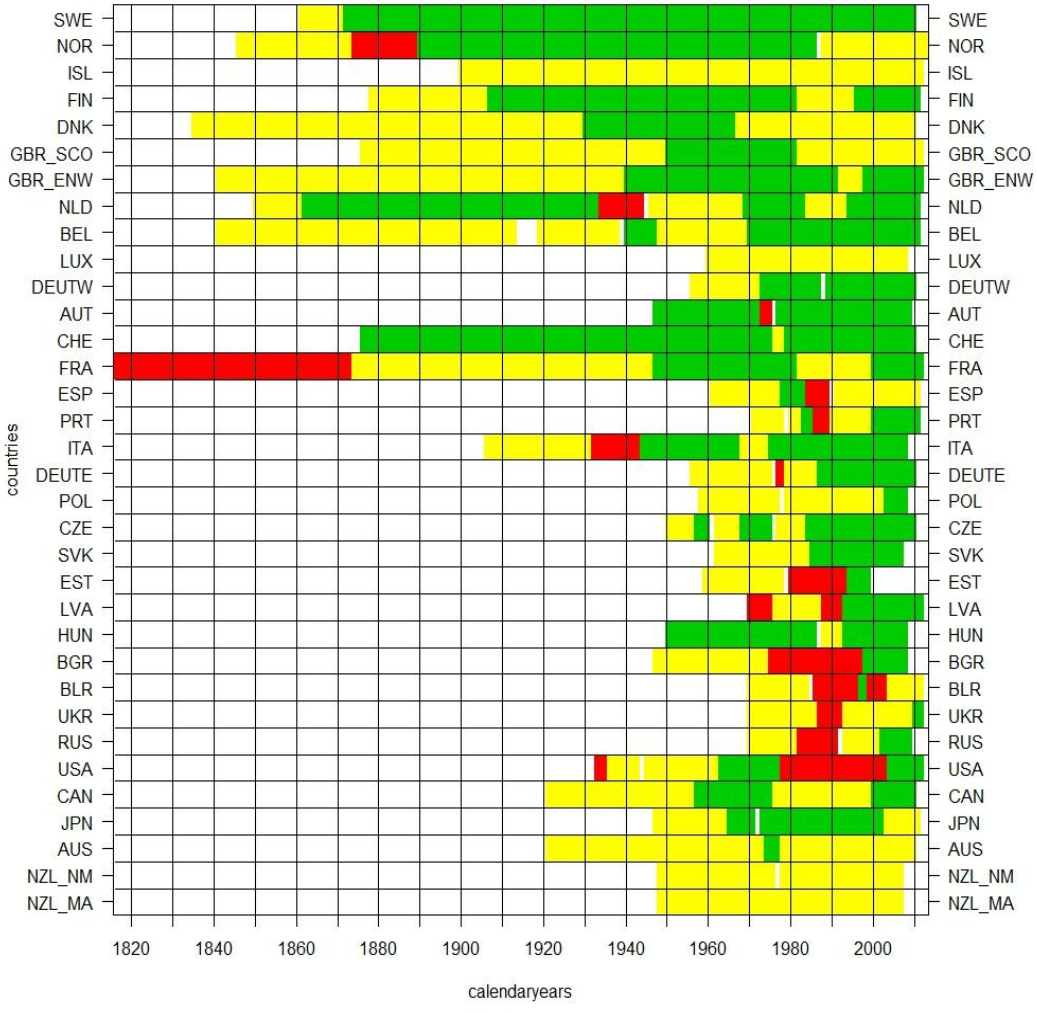
neutral

right-shift

- **Right shift** seems to be an **almost global trend** for the last decades.
  - But some East European countries experience left shift or at least no shift after 1970 and around 1990.

Results

Females, starting age 0, UB



contraction

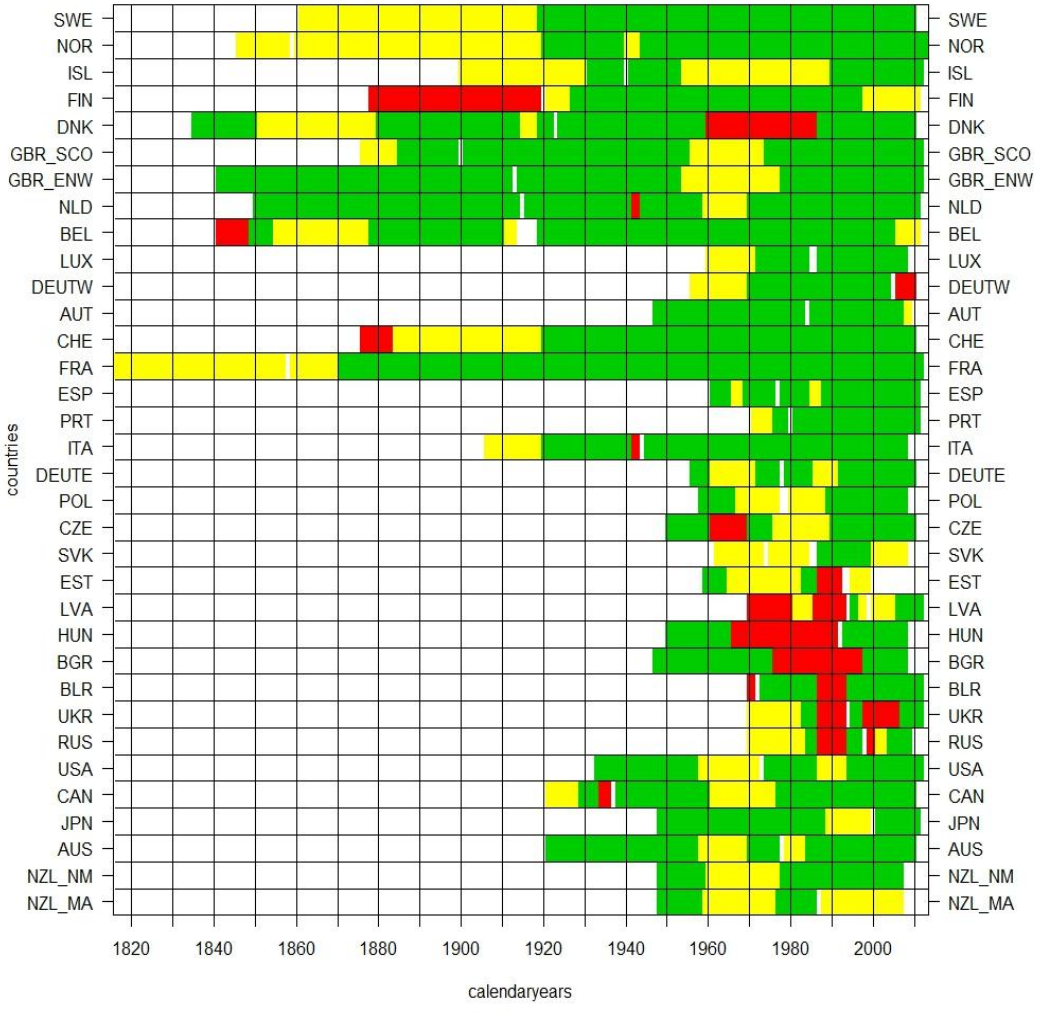
neutral

extension

- No global trend concerning extension / contraction.
- For example, in the second half of the 20th century, we observe...
  - ... **extension** in most Central European countries,
  - ... **no change** in Australia and New Zealand, but also for Luxembourg or Iceland,
  - ... **contraction** in the USA and some East European countries for some years.

Results

Females, starting age 0, DoI



decompression

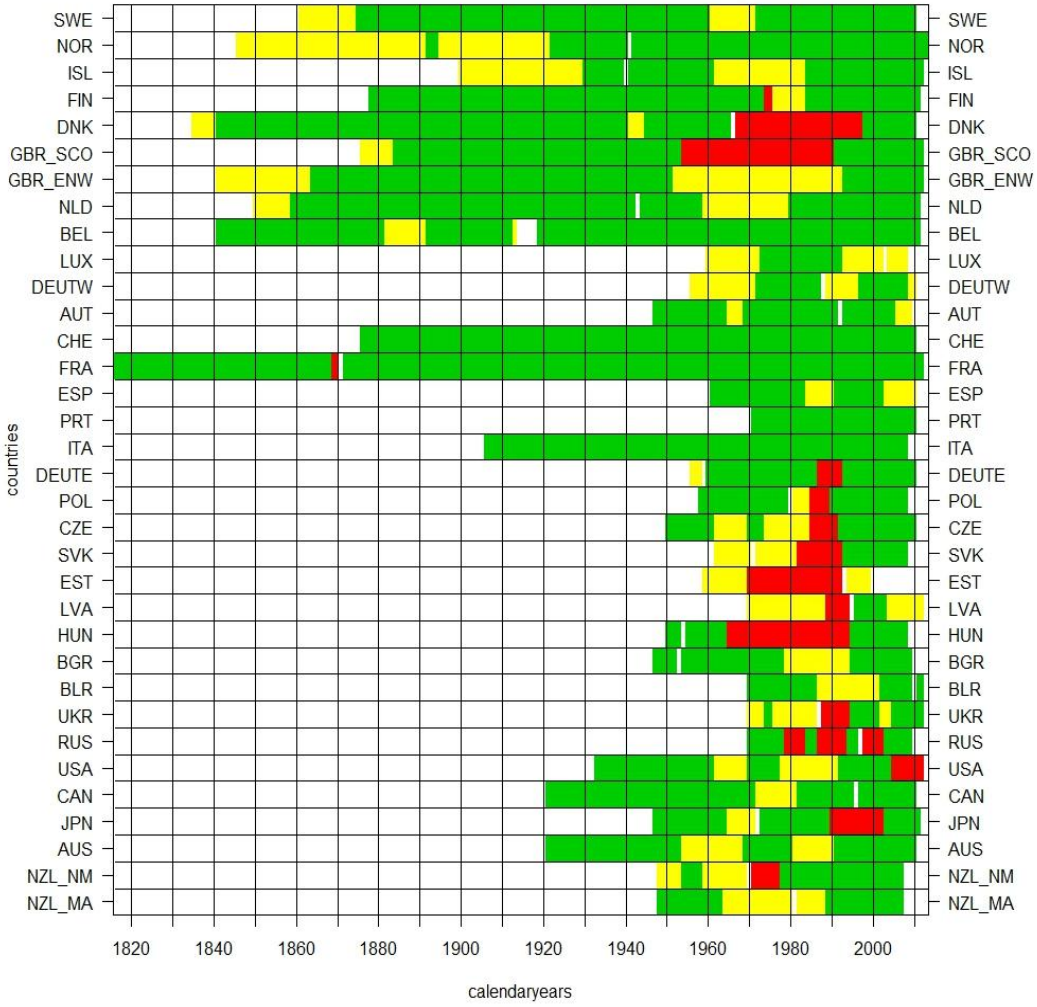
neutral

compression

- There seems to be **compression** for most countries in the last decades.
  - Exception: Some East European countries around 1990 and single "outliers".

Results

Females, starting age 0, d(M)



diffusion

neutral

concentration

- **Concentration** also seems to be a **global effect** in the last two decades, but there are some **exceptions**:
  - Almost all East European countries experience diffusion around 1990.
  - The North European countries have a relative long period of diffusion or neutral starting in the 1950s / 60s. Exception: Norway
  - There was diffusion in Japan in the 1990s and in the USA in the late 2000s.

Results
Conclusion

Is clustering a reasonable idea?

- We can detect "**vertical patterns**".
  - There are common trend changes for some countries, e.g.
    - East European countries around 1970 and 1990, or
    - Central European countries in the 1960s / 70s.
- But there are some countries which do not experience the same trend changes as their neighboring countries. For example:
  - The mortality evolution for females in Belgium shows different trend breaks, than that for females in the Netherlands or Luxembourg.
  - Norway does not experience diffusion in the 1950s/60s.

Thus, **clustering is a reasonable idea** but it **must be handled with care**.

Summary and Outlook (1)

What have we seen?

- We introduced a framework, which we use for the classification of changes in mortality evolution patterns.
- Calculation of these four statistics give us results partly with rather strong variance.
- With help of the method of Muggeo (2003) and Börger et al. (2015) and a statistical test, we can formalize the terms “increasing”, “neutral”, and “decreasing” in mathematical terms.
- We plot these trends for every population over the time axis. With these plots we can compare mortality evolutions of every country to each other.
- For females with the starting age 0, we analyzed these results and have seen...
  - ... that there are “vertical patterns”, which show common trend changes between countries,
  - ... that there are some “outliers” within a cluster of neighboring countries.

Summary and Outlook (2)

Outlook: What are the next steps?

- We have to do **further research**:
  - Analysis of more populations, especially men
  - Analysis of different starting ages, e.g. starting age 60.
- These results could for example help in the **application of multi-population models**.
  - Is it reasonable to model the mortality of small populations (e.g. Luxembourg) depending on the mortality of bigger populations (e.g. West Germany)?

Thank you for your attention!

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Literature

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Muggeo, V. M. (2003). Estimating regression models with unknown break-points. *Statistics in medicine*, 22(19): 3055-3071