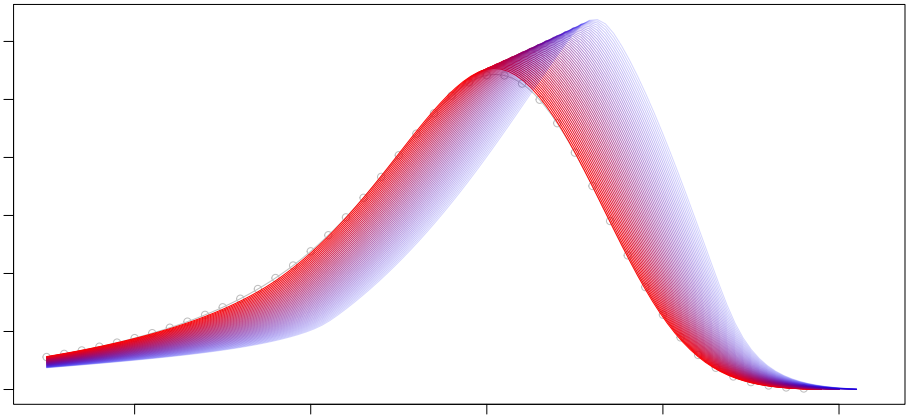


The Future of Mortality

Mortality Forecasting by Extrapolation of Deaths Curve Evolution Patterns

Matthias Börger (with Martin Genz and Jochen Ruß)

Longevity 19, Amsterdam, September 2024

Technische Hochschule Nürnberg

Motivation

Different perspectives in modeling mortality and (deterministic) forecasting:

Actuaries

- focus on mortality rates, probabilities of deaths, or mortality improvements
- statistical analysis and extrapolation of patterns in historical data
- detailed forecasts by integer ages and years

Demographers

- aggregated statistics based on distribution of deaths (age-at-death distribution)
- analysis of mortality evolution in terms of demographic scenarios, e.g. shifting mortality, compression, or rectangularization
- typically focus on certain aspects of the mortality evolution, but no granular forecasts at age/year level

Motivation

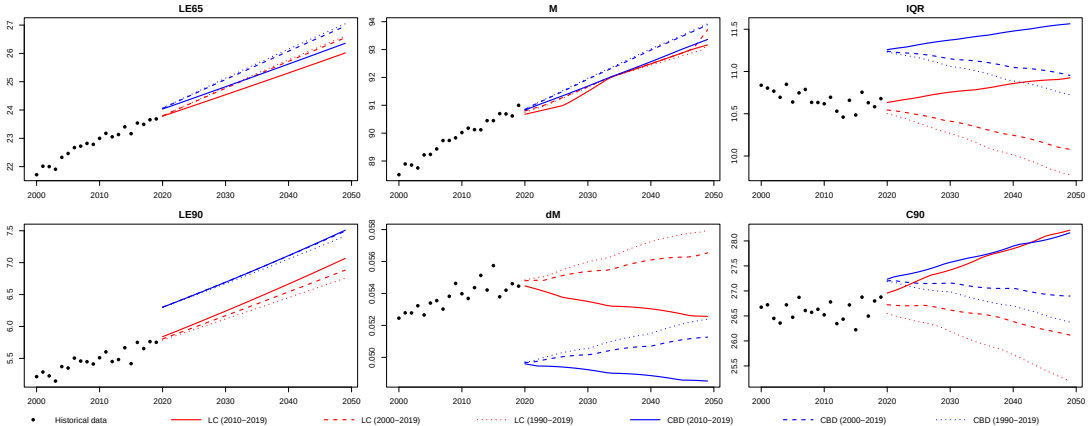
Issues in actuarial / statistical mortality modeling:

- granular modeling of unobservable quantities like mortality rates
- risk of "micro modeling" with sometimes hundreds of model parameters
- forecasting typically by extrapolation of historical trends
- choice of adequate historial data often unclear, in particular after covid
- allowance for input from other disciplines difficult
- demographic plausibility of forecasts often unclear

Motivation

Examples for demographic (im)plausibilities of purely statistical forecasts:

- Lee-Carter and Cairns-Blake-Dowd models applied to Swiss females (10, 20, 30 years of data, ages 65+)



Objectives

Key questions

- How can we derive mortality forecasts which are consistent with basic demographic trends?
- How can we incorporate expert input from other disciplines?

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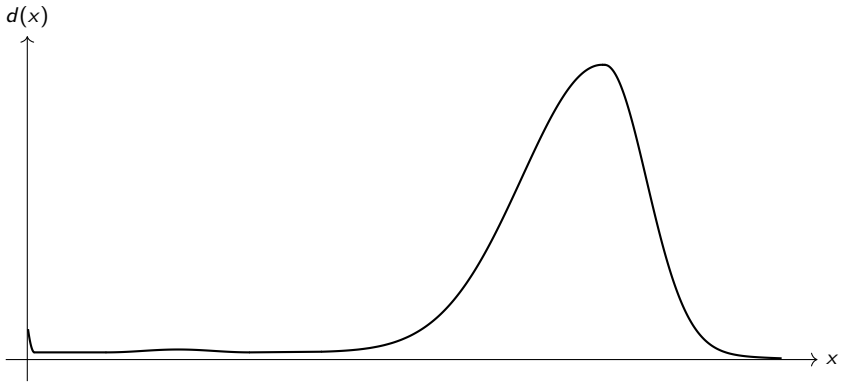
- How can we incorporate expert input from other disciplines?

Key findings

- Purely statistical mortality forecasts often exhibit demographic implausibilities even in the immediate future.
- To ensure demographic plausibility, forecasts can be based on aggregated demographic statistics with clear interpretation.
- If desired, expert opinions from other disciplines can additionally be incorporated by specifying the future evolution of these statistics.
- We provide a framework for "demography-based" mortality forecasts.

Classification of Mortality Scenarios

Stylized deaths curve and statistics in the mortality scenario classification framework of Börger et al. (2018):



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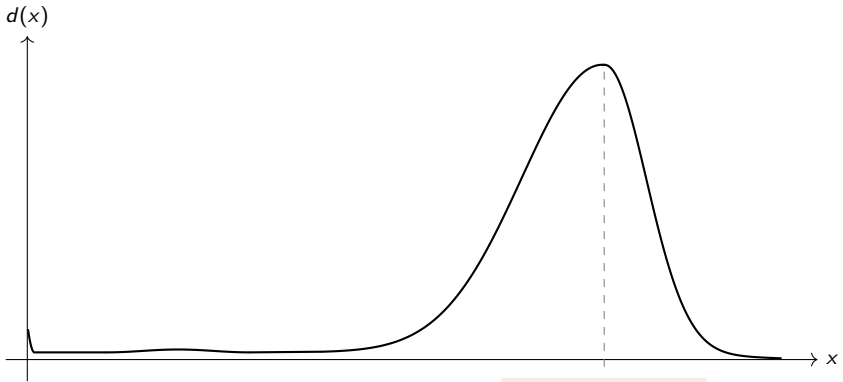

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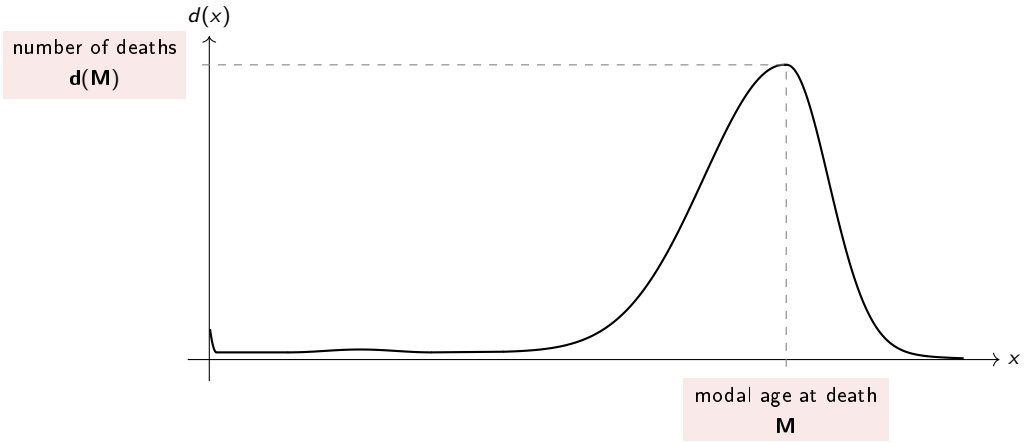

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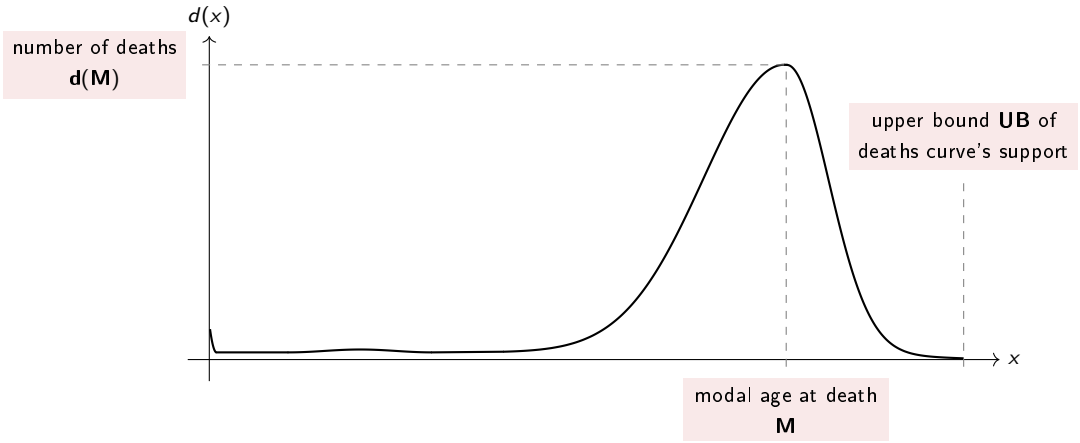

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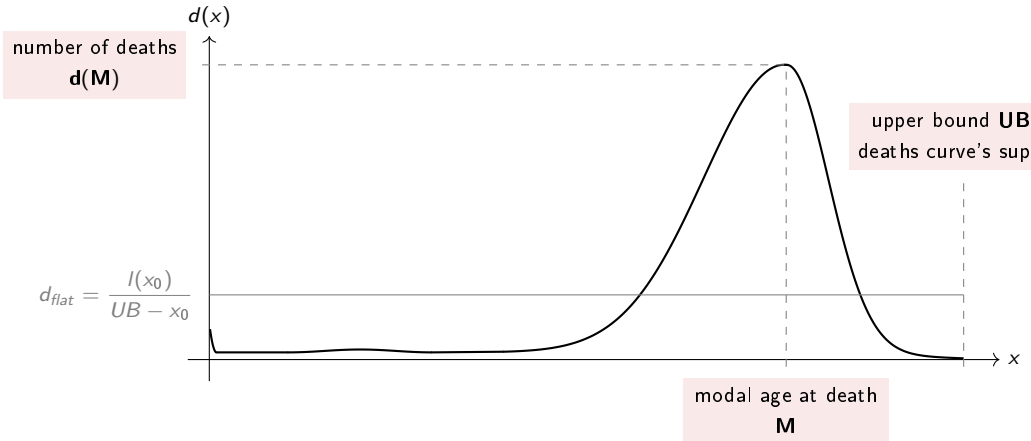

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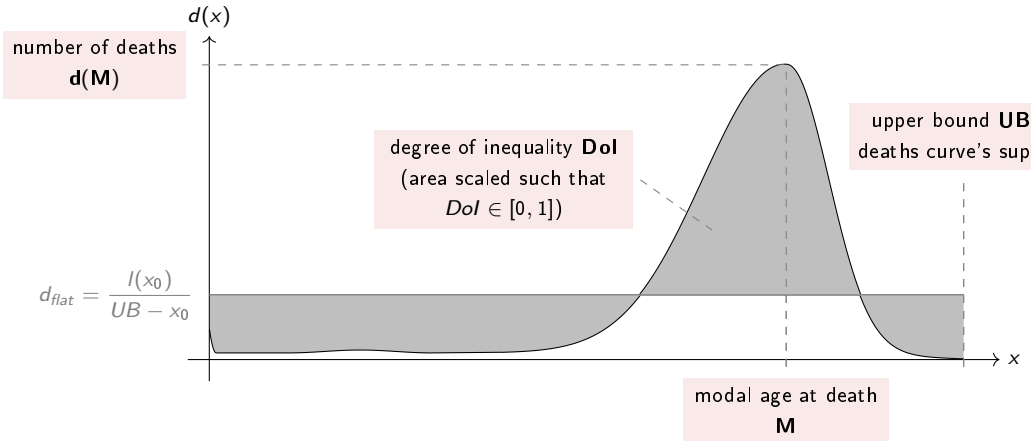
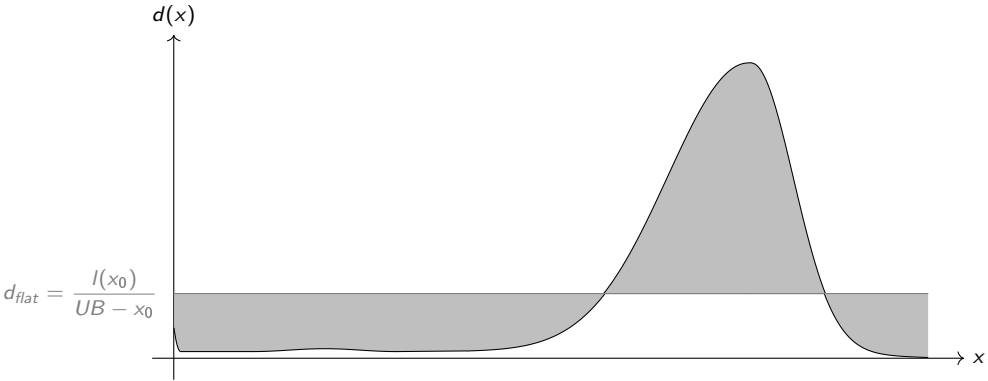


Classification of Mortality Scenarios

Demographic interpretation of deaths curve statistics:



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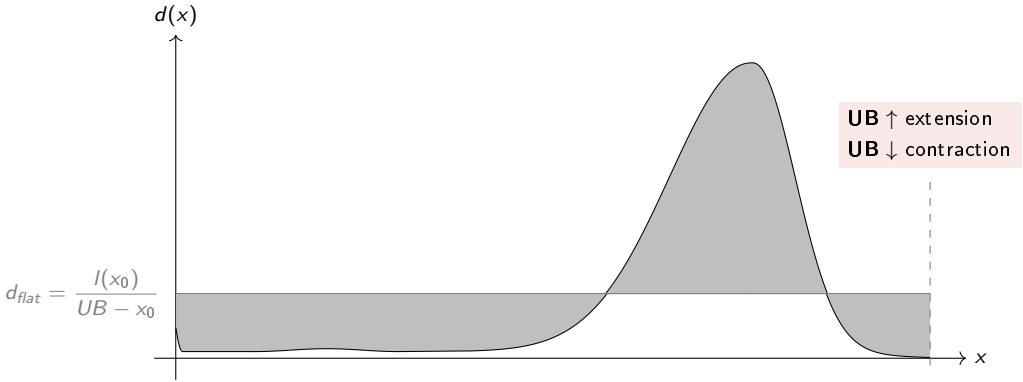

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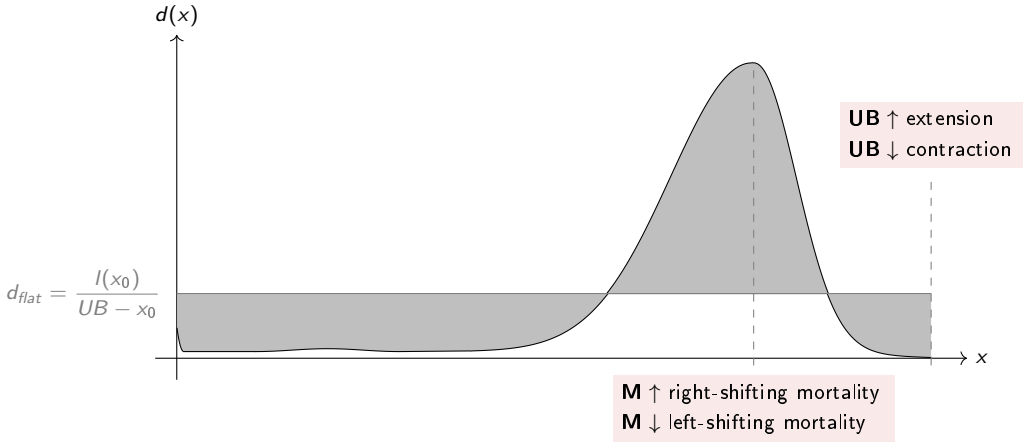

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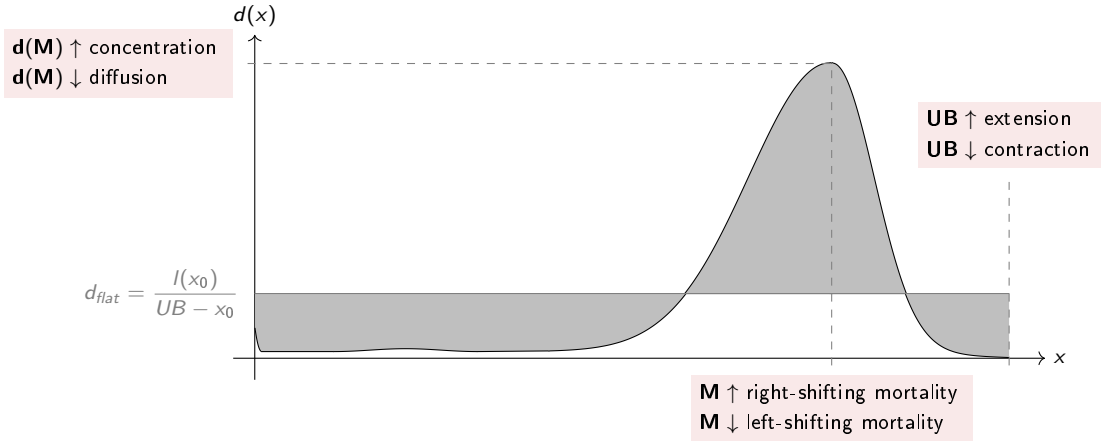

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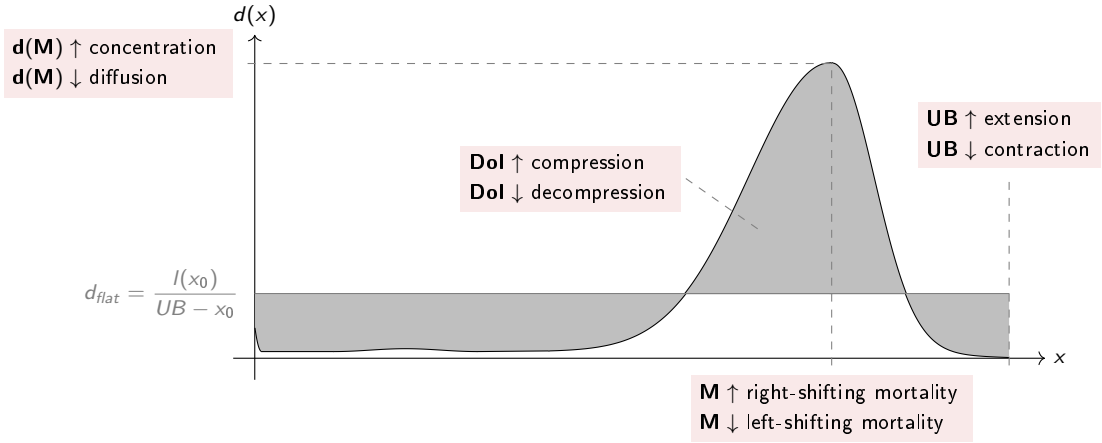

Mortality Forecasting

General forecasting approach

1. Provide forecasts for demographic statistics, e.g. by expert opinion or extrapolation of most recent trends.
2. Alter the most recent deaths curve as little as possible from year to year such that it becomes consistent with the statistics' forecasts.
3. Check the resulting mortality forecasts for plausibility and derive any desired quantities, e.g. probabilities of death.

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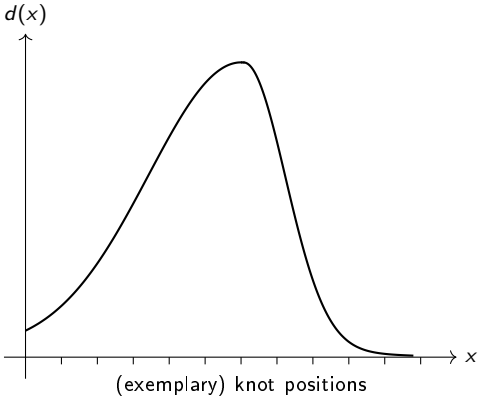
In the paper, we present two possible implementations of this forecasting approach.

- spline representation of most recent deaths curve
- year to year modification of knot positions and spline weights such that demographic statistics are met
- in what follows, focus on pension ages, i.e. $x_0 = 65$, and the technically more simple implementation
- additional statistic $d(x_0)$ to fix "base mortality" at left boundary of deaths curve's support

Mortality Forecasting

The forecasting algorithm consists of four steps:



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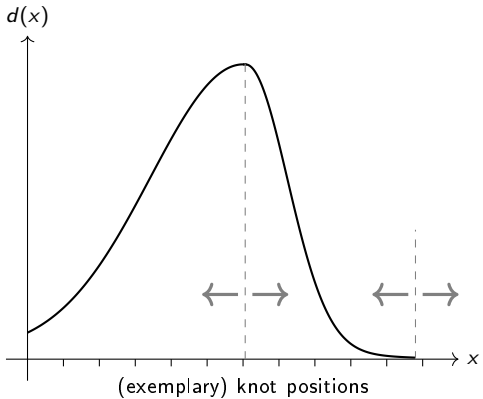

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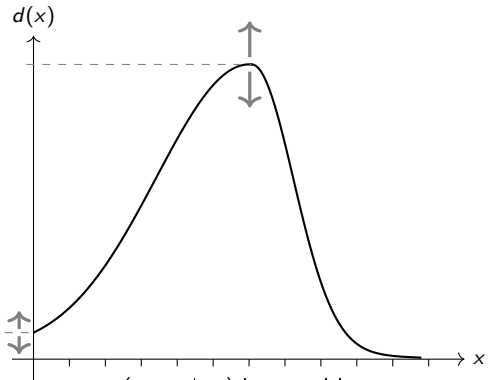

(exemplary) knot positions

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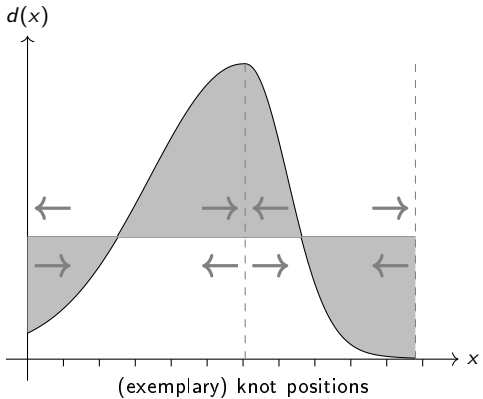

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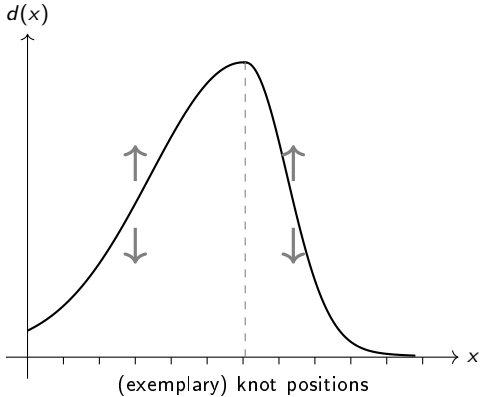

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4. Adjust spline coefficients outside x_0, M, and UB such that

$$\sum_{x=x_0}^{\lfloor UB \rfloor} d(x) = l_{x_0}.$$

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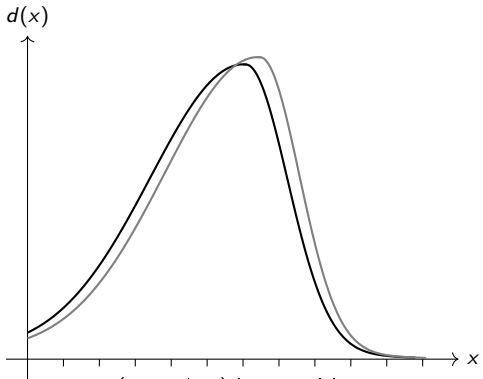

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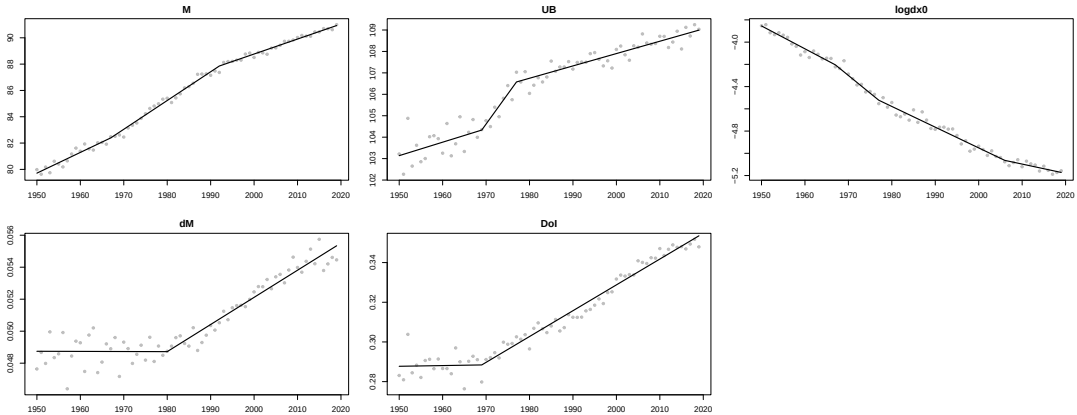
Repeat all steps iteratively until the target values for all statistics are met simultaneously.

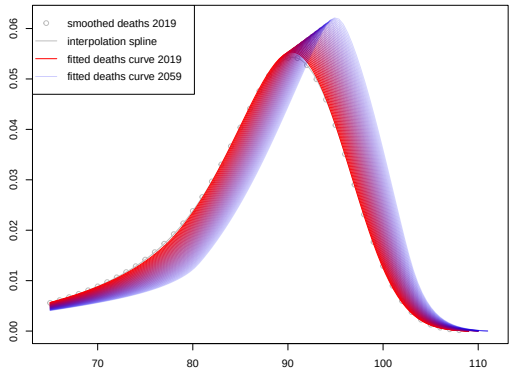
Example: Swiss Females

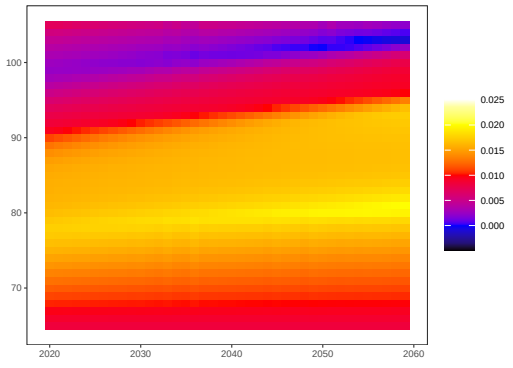
We illustrate the forecasting approach by extrapolating historical trends up to 2019:



Example: Swiss Females

Forecast deaths curves and mortality improvements from 2019 to 2059:

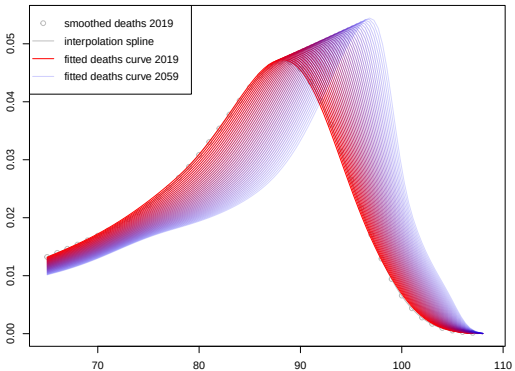


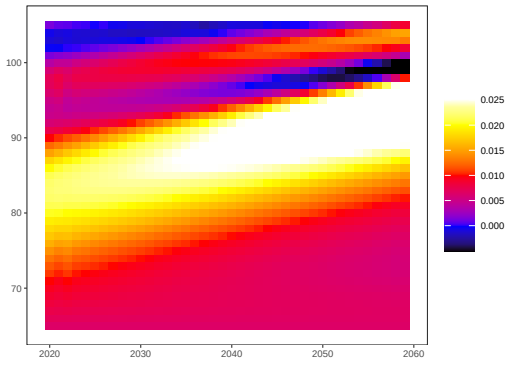


- model forecasts often observed shift of strong mortality improvements toward older ages
- solely age dependent improvements imply risk of underestimating future improvements at older ages

Example: French Males

Forecast deaths curves and improvements from 2019 to 2059 based on extrapolations of historical trends:

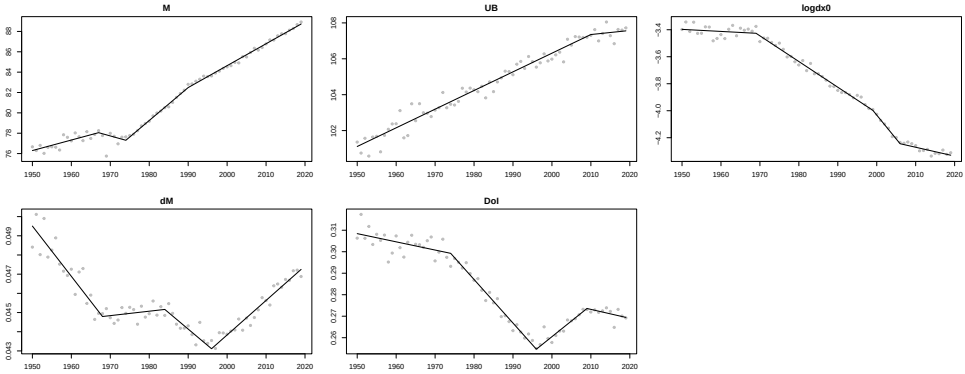




- forecasts appear plausible for about 20 years, but become odd afterwards

Example: French Males

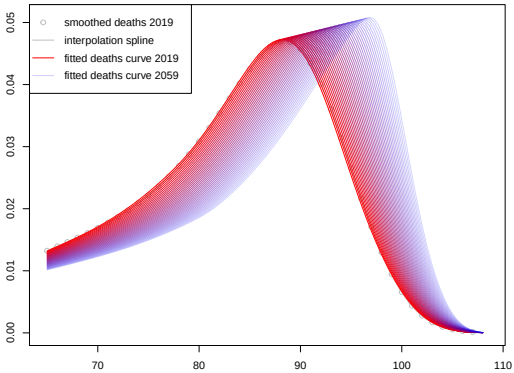
Historical trends in demographic statistics underlying the forecast:

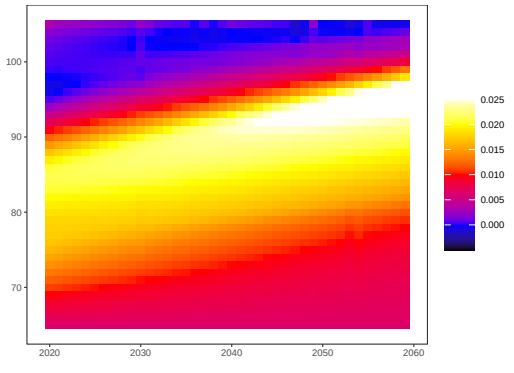


- simultaneous increase in $d(M)$ and decrease in DoI are rather unlikely in the long run
- illustration of possible expert input: only 50% increase in $d(M)$ and constant DoI

Example: French Males

Altered forecasts of $d(M)$ and DoI imply plausible forecasts also in the long run:





- expert opinion is necessary to plausify purely statistical extrapolations
- forecasts can also be entirely build on expert opinion to anticipate structural changes in mortality

Conclusion

- Purely statistical mortality forecasts often exhibit demographic implausibilities even in the immediate future.
- The assumption of solely age dependent mortality improvments implies the risk of underestimating future improvements at older ages.
- Possibly more realistic forecasts can be build on aggregated demographic statistics with clear interpretation.
- This also allows to incorporate expert opinions from other disciplines on the general mortality evolution.
- The shapes of projected deaths curves as well as the relations of the considered statistics indicate whether forecasts are demographically plausible in the long run.
- We provide a framework for this forecasting approach based on five demographic statistics.

Literature

Börger, M., Genz, M., Ruß, J., 2018. Extension, Compression, and Beyond – A Unique Classification System for Mortality Evolution Patterns. Demography 55(4): 1343–1361.

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