Age perturbations of COVID-19 pandemic excess mortality

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Data

- Sources for overall deaths:

Source	Nr Countries	2020	2021
UNPD sources	32	32	11
Eurostat	32	32	30
WHO	17	17	6
HMD / STMF	14	14	7
National sources	4	4	3
TAG	3	3	1
Totals	102	102	58

- Criteria for selecting sources/year:
  - 2020 or 2021 must be available
  - prioritize source coherence with respect to longer periods
  - preference for more detailed age-groups
- Sources for exposures: WPP 2022 (single year of age)
- Age-range: 0-100
- By sex

Model

- For each population over age x, we have two mortality patterns:
  - $\eta^b(x,t)$ for the baseline log mortality age pattern derived from 2D *CP*-splines model fit to prepandemic mortality
  - $\eta^p(x,t)$ for pandemic (2020 or 2021) observed log mortality

- We model data in 2020 (2021) as follows:

$$\eta^p(x) = \eta^b(x) + c + \delta(x)$$

  - c overall excess scaling factor
  - $\delta(x)$ age-perturbation component ($\sum \delta(x) = 0$)

- Both $\eta^b(x)$ and $\delta(x)$ are assumed to be smooth and all estimations are carried out within a Poisson framework

- The model is multiplicative at the force of mortality level:

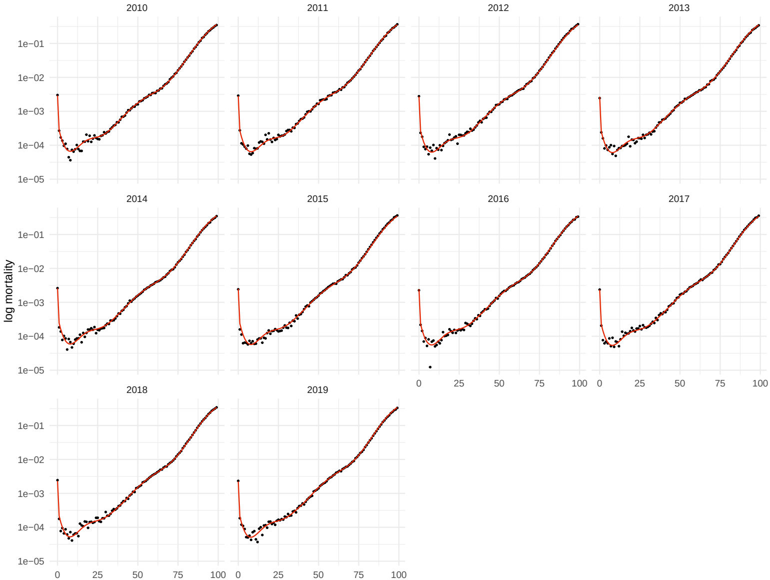
$$e^{\eta^p(x)} = \mu^p(x) \; = \; e^{\eta^b(x)}\, e^c\, e^{\delta(x)} = \mu^b(x)\, e^c\, e^{\delta(x)}$$

  - both e^c and $e^{\delta(x)}$ can be interpreted as relative risk factors

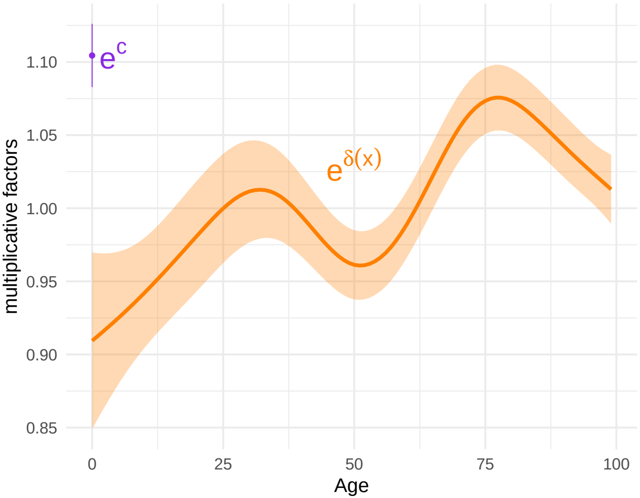
Age perturbation

- The scale-free age perturbation factor $\delta(x)$ is the main result.
- The age-free scalar e^c relates to marginal excess, as estimated by the TAG.
- Given a marginal excess estimate (count), C, and an age-pattern of baseline mortality $\mu^b(x)$ (e.g. the projection from WPP 2019) then $D^b(x) = \mu^b(x) \cdot E(x)$, and $e^c = \frac{D^b+C}{D^b}$.
- Then deaths by age, $\widehat{D(x)} = D^b(x)e^c\delta(x)$
- But...

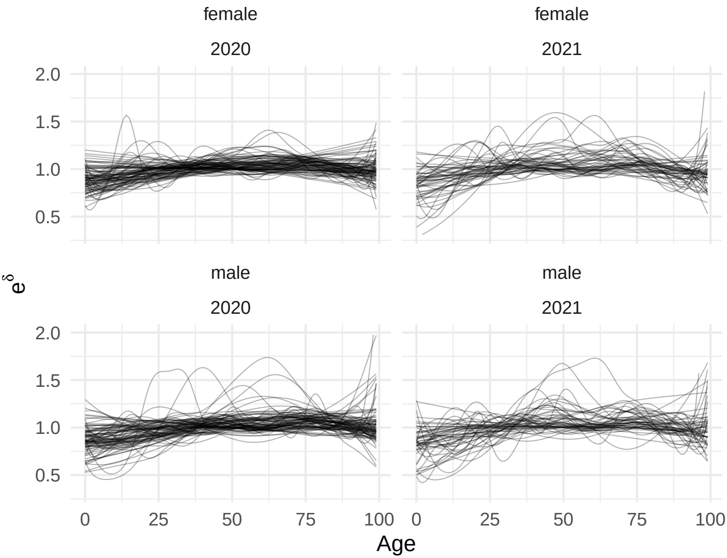
Example: Spain baseline fit



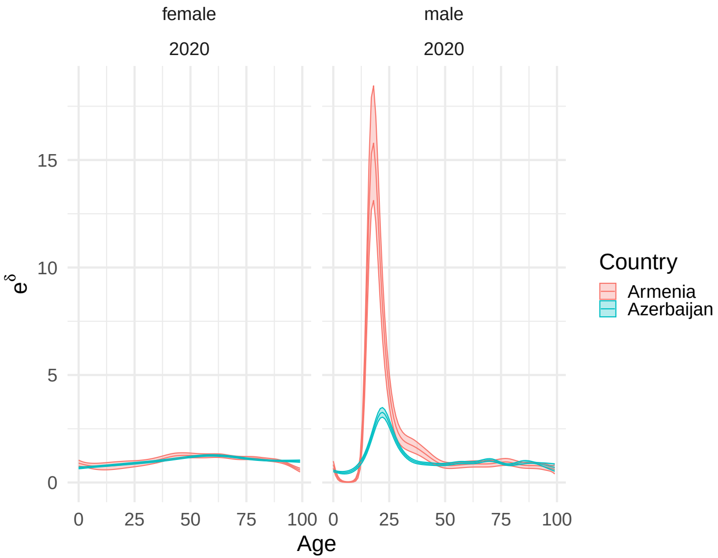
Example: Spain 2020 excess components



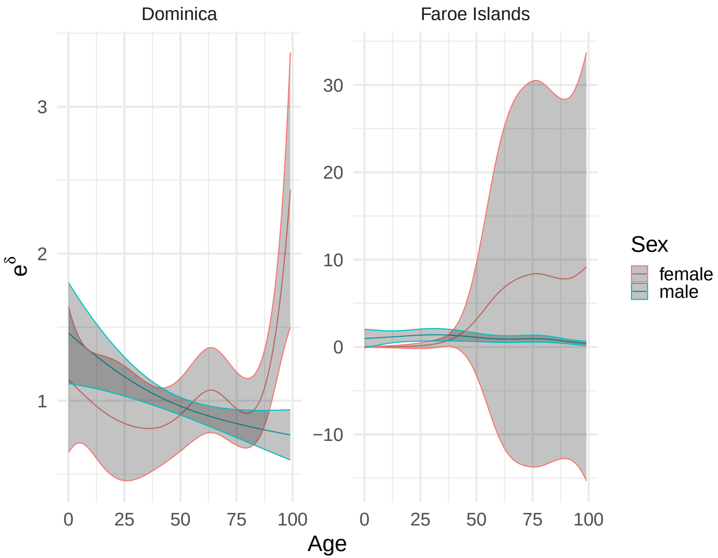
Age perturbation components (multiplicative scale)



Exclusions: Conflict-related perturbations

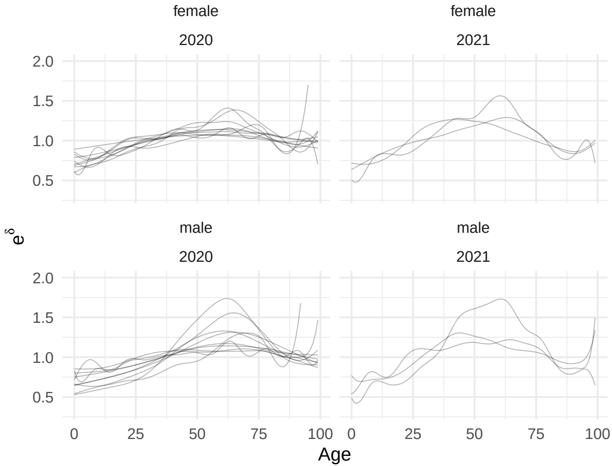


Exclusions: Low signal (there are more)



Example: Latin America concave pattern

This is the only geographically homogeneous cluster we know of



(Helpful for Honduras, Venezuela, El Salvador, and Bolivia?)

Remaining steps for age perturbation analysis

- Fine tune smoothing constraints
- Sensitivity analysis on the linearity of the time-trends
- Identify further anomalies
- Cluster / describe $\delta(x)$ patterns