

Cause-specific mortality improvements and excess deaths

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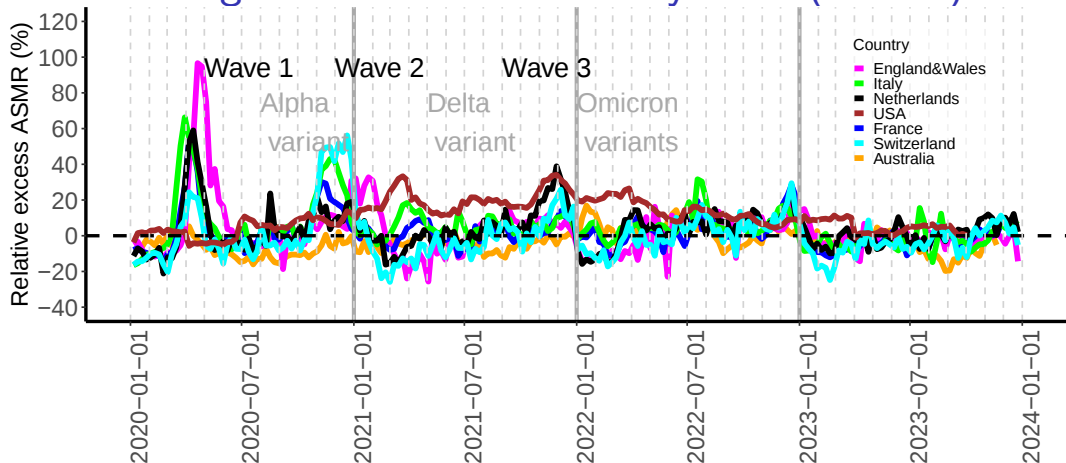
Exploring trends in mortality improvements:
COVID-19, excess mortality, future outlook – Swiss Re

L20, Singapore, 9 September 2025

Outline

- Motivation
- Data
- Empirical analysis and smoothing
 - ... Excess mortality
 - ... Mortality improvements
- Discussion

Motivation: Age-standardised mortality rates (ASMR)

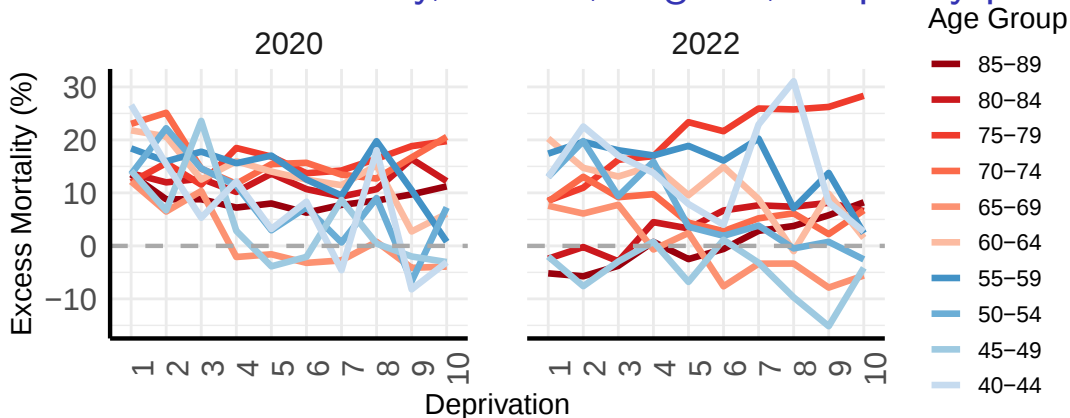


- Relative excess ASMRs, women, ages 0–85+, compared to 2015–2019

...European Standard Population (ESP) 2013; WHO Standard Population (2000-2025) for the USA

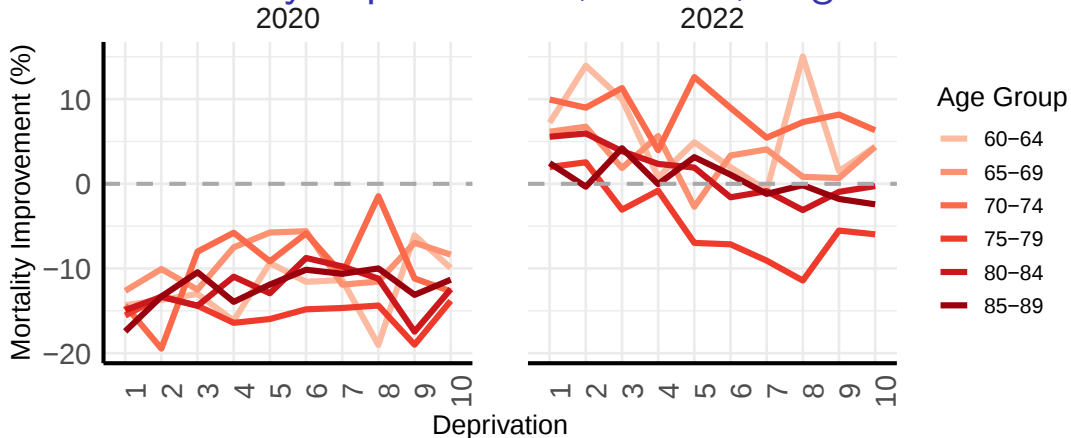
- Ongoing impact of COVID-19: elevated mortality rates?

All-cause excess mortality, women, England, inequality profile



- Excess mortality relative to the average deaths in 2015–2019
- Significant inequality between the most (1) and least deprived (10)
- 2020 → 2022: mortality deficits at certain age groups
 - ... adverse trend at ages 75+

All-cause mortality improvements, women, England



- Greater slowdown in more deprived groups
... especially evident in 2020
- 2020 ← 2022: deterioration in mortality improvements

Why do we look at cause of death data?

- What is the underlying cause of elevated post-pandemic rates?
- How to approach to different socio-economic groups?
- Which causes of death have high levels of inequality?
- How to predict and adjust mortality improvements?

To gain insights into:

- mortality modelling assumptions in life insurance and pension
- contributions to public policy discussions

Data: Cause of death groupings

1 Ischaemic heart	2 CVD and stroke	3 Other circulatory
4 Cancer: bowel	5 Cancer: liver	6 Cancer: lung
7 Cancer: breast	8 Cancer: prostate	9 Cancer: other
10 Cancer: other digestive	11 Influenza and pneumonia	12 Chronic lower respiratory
13 Other respiratory	14 COVID-19	15 Gastric and ulcer
16 Chronic liver	17 Other digestive	18 Traffic accidents
19 Self-harm and violence	20 Other external	21 AIDS and tuberculosis
22 Diabetes and obesity	23 Alcohol and drug abuse	24 Alzheimer's
25 Dementia	26 Rest of causes	

ICD-10 definitions $\Rightarrow$ available on granular level

7 broad Cause of Death (CoD) groups

Modelling reality: < 26 causes, e.g. males $\Rightarrow$ no ovarian cancer

Cause of death data in England

Death Registrations:

- 26 CoD groups
- Single year of age 20-110
- Single years 2001–2022
- Neighbourhoods: by Index of Multiple Deprivation (IMD):
 - ... 1= most deprived, 10= least deprived
 - Change in IMD $\Rightarrow$ E.g. IMD 2004 (2001 to 2003) and IMD 2019 (2016 to 2020)

Population Estimates:

- Single year of age 20 to 90+
- Single years 2001-2020
- Neighbourhoods: by IMD 2015

How to decompose all-cause excess mortality by cause?

Smoothed rates for all-cause, $P(a, t)$, and cause-specific, $P^c(a, t)$, excess mortality:

- Penalised B-splines for a given gender and deprivation
... 10 knots for age and 5 knots for year
- Ages, a : 21 to 100; Years, t : 2001 and 2022
- Indicator variable: $I_{t=t'} = 1$ if $t = t'$, 0 otherwise

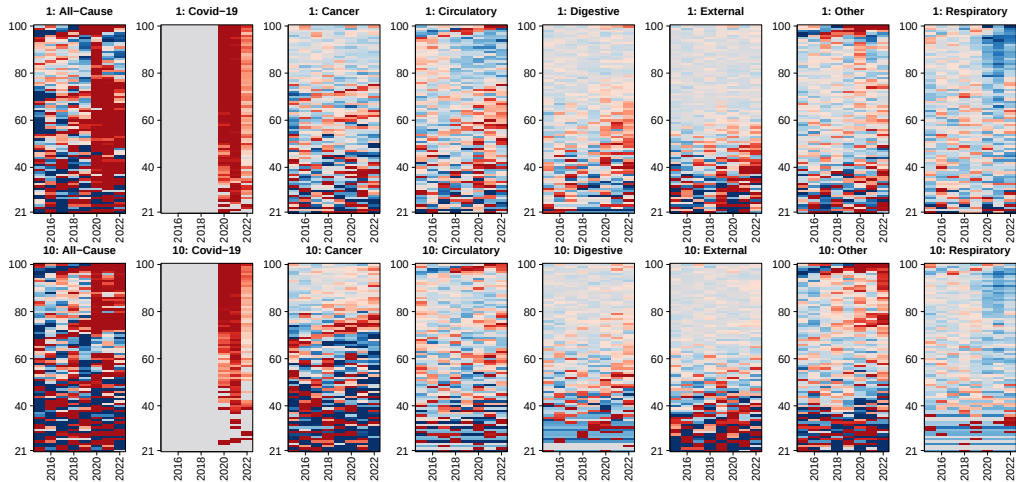
$$P_{a,t} = g(a, t) + \beta_{2020}I_{t=2020} + \beta_{2021}I_{t=2021} + \beta_{2022}I_{t=2022} + \epsilon_{a,t}$$

$$P_{a,t}^c = g^c(a, t) + \beta_{2020}^c I_{t=2020} + \beta_{2021}^c I_{t=2021} + \beta_{2022}^c I_{t=2022} + \epsilon_{a,t}^c$$

Decomposition by CoD, c :

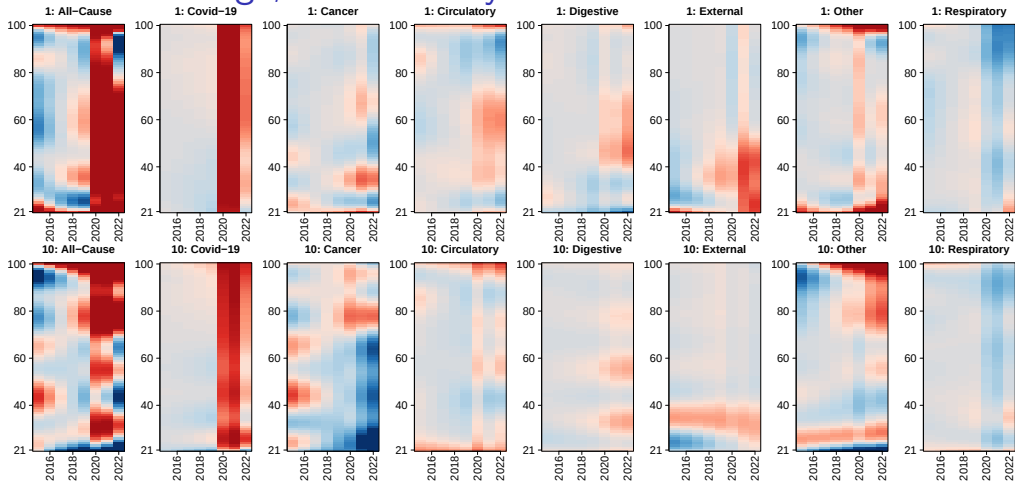
- $\hat{g}(a, t) = \sum_c \hat{g}^c(a, t)$
- $\hat{\beta}_{t'} = \sum_c \hat{\beta}_{t'}^c, \quad t' \in \{2020, 2021, 2022\}$

Raw excess mortality, women, most v. least deprived (deciles)



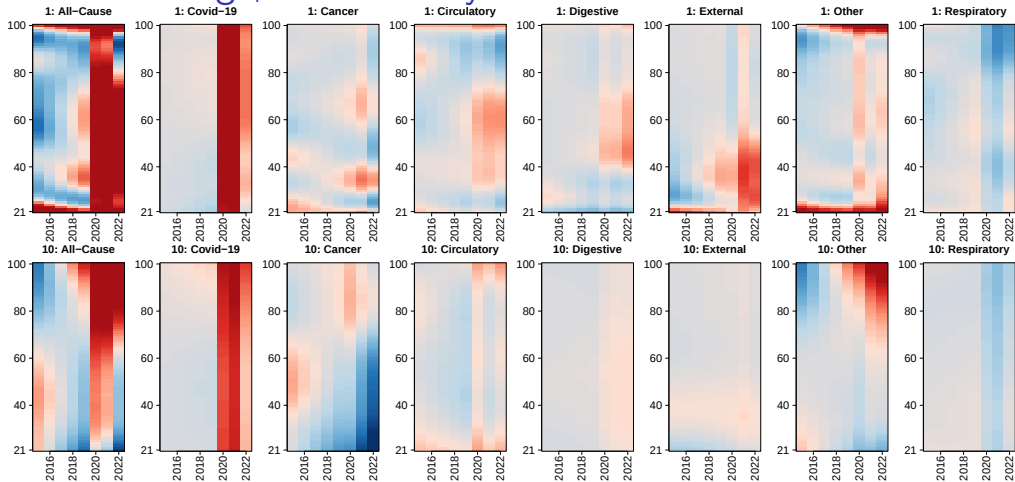
Smoothed excess mortality, women, most v. least deprived:

10 knots for age, 5 knots for year

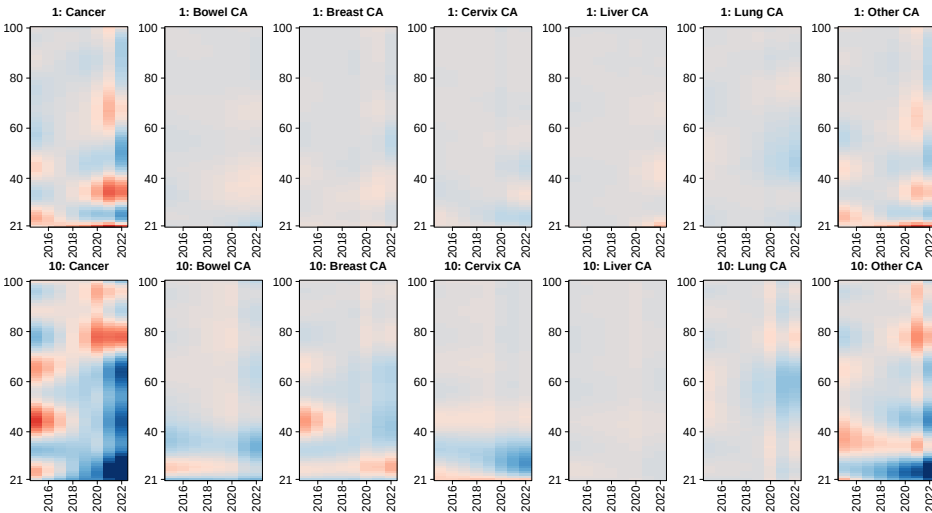


Smoothed excess mortality, women, most v. least deprived:

5 knots for age, 5 knots for year

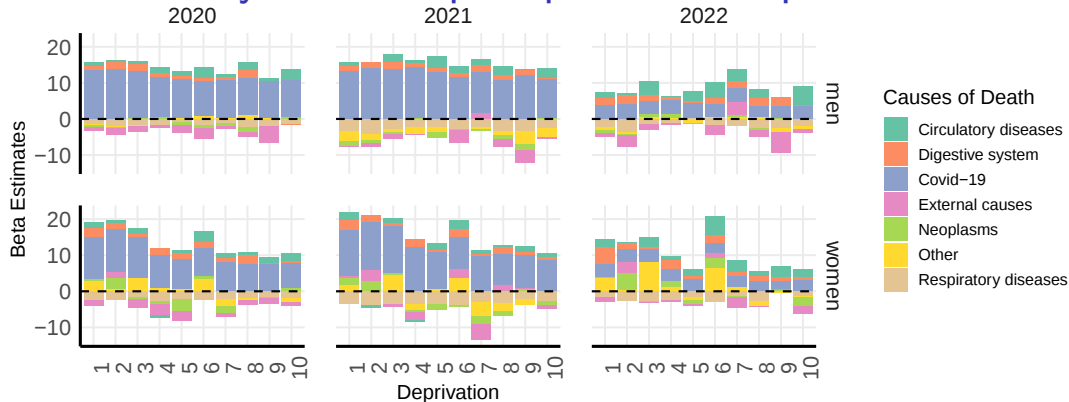


Cancer excess mortality, women, most v. least deprived



- Return to 10 knots for age and 5 for year
- Early-onset cancers: A bigger concern in the most deprived?
- Cancer in older ages: More prominent in the least deprived?

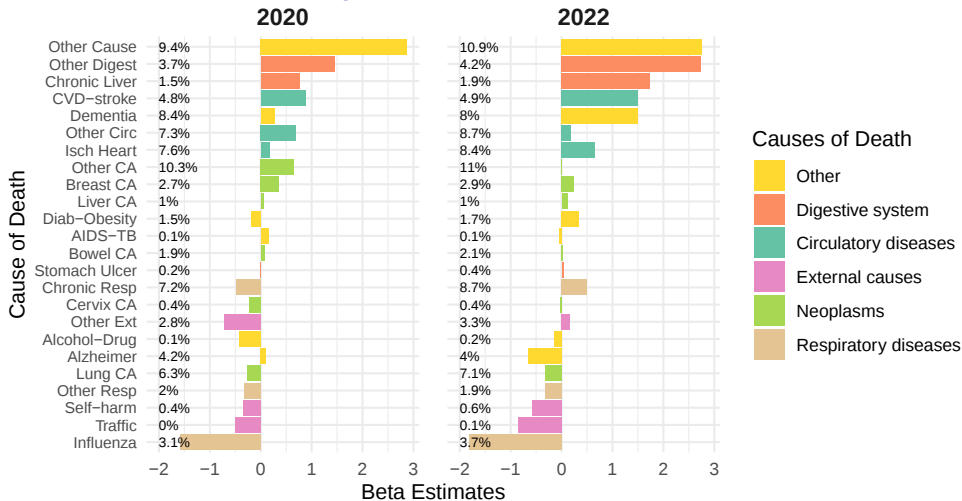
Excess mortality: women, post-pandemic impact



- Clear deprivation patterns for women:
...excess mortality in most deprived (1) v. least deprived (10)
- COVID-19 impact largely homogeneous
- Excess mortality in circulatory disease; neutral in cancer

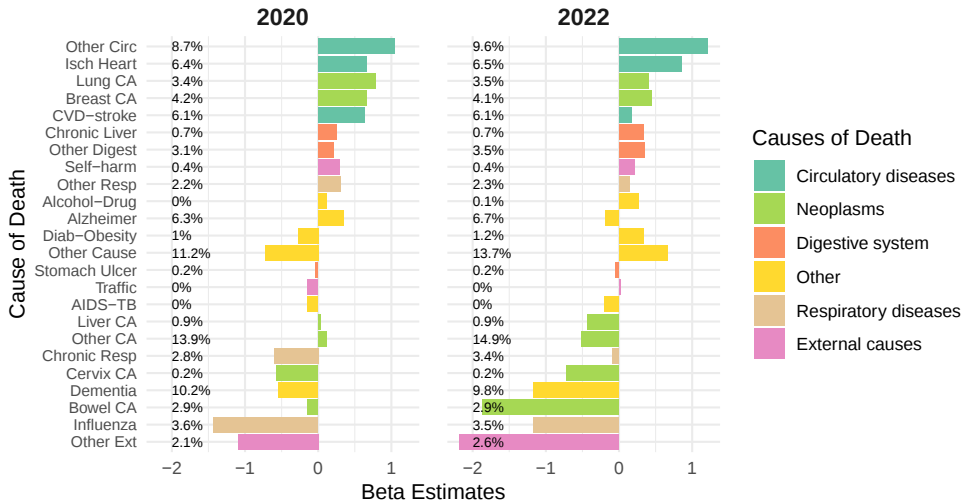
Excess mortality: decompose the estimates in different ways

Women, most deprived



- % of total deaths by cause
- Deficits in respiratory diseases and external causes
- Chronic liver is socio-economically patterned

Excess mortality: women, least deprived



- Excess mortality persists
- More excesses in cancer than in the most deprived

How to decompose mortality improvements by cause?

Improvement rates, $i_{a,t}$, at age a and year t :

$$\begin{aligned} i_{a,t} &= -\frac{\partial \log \mu_{a,t}}{\partial t} \\ &= -\frac{\partial \log d_{a,t}}{\partial t} + \frac{\partial \log E_{a,t}}{\partial t} \\ &\approx 2 \frac{d_{a,t-1} - d_{a,t}}{d_{a,t-1} + d_{a,t}} + 2 \frac{E_{a,t} - E_{a,t-1}}{E_{a,t-1} + E_{a,t}} \\ &= 2 \frac{\sum_c (d_{a,t-1}^c - d_{a,t}^c)}{d_{a,t-1} + d_{a,t}} + 2 \frac{E_{a,t} - E_{a,t-1}}{E_{a,t-1} + E_{a,t}} \end{aligned}$$

Can we access more data?

$$i_{a,t} \approx \sum_c i_{a,t}^c + i_{a,t}^E$$

- $i_{a,t}^c$: improvement due to CoD, c
- $i_{a,t}^E$: improvement due to population changes

Can we **ignore** the contribution of **population change** to improvements in 2021 and 2022?

Note: Population data needed to estimate $i_{a,t}^E$ available up to 2020

How to decompose mortality improvements by cause?

Smoothed improvement rates using an age-period (APi) model:

$$i_{a,t} = \alpha_a + \kappa_t$$

With constraint

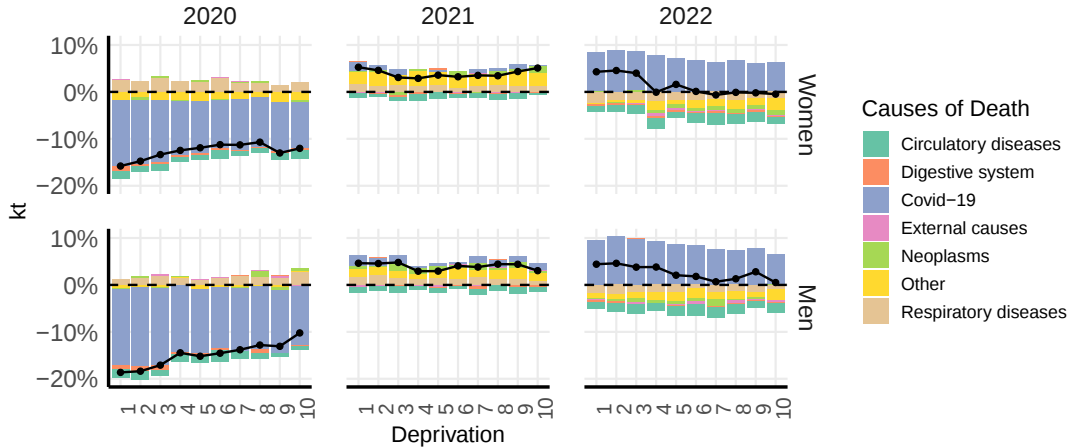
- $\sum_{t=2002}^{2019} \kappa_t = 0$

Decomposition by CoD, c:

- $\hat{\alpha}_a = \sum_{c=1}^p \hat{\alpha}_a^c + \hat{\alpha}_a^E$
- $\hat{\kappa}_t = \sum_{c=1}^p \hat{\kappa}_t^c + \hat{\kappa}_t^E$

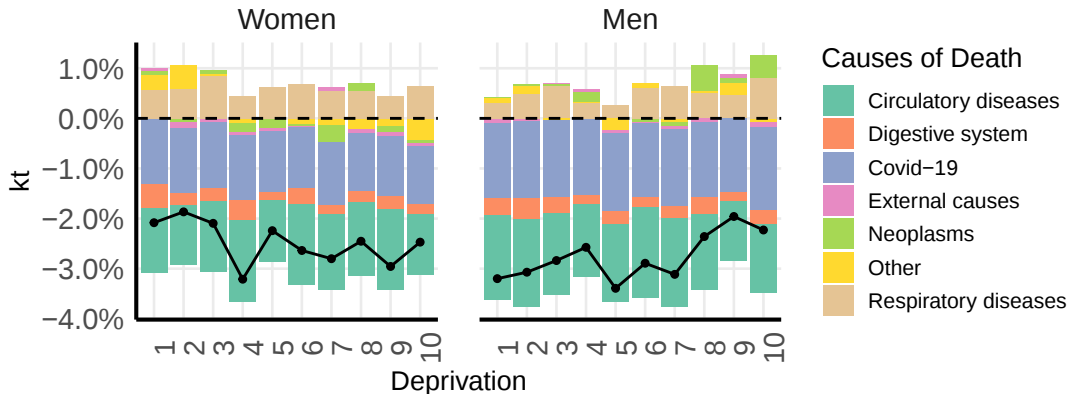
Focus on capturing excesses/deficits: $\kappa_{2020}^c, \kappa_{2021}^c, \kappa_{2022}^c$

Mortality improvements: post-pandemic inequality profile



- Greater mortality deterioration in most deprived (1) in 2020
- A slowdown in mortality gains in least deprived (10) in 2022

Mortality improvements: average post-pandemic impact



- More inequality in men compared to women?
- Ongoing COVID-impact?
- Circulatory disease: still an issue

Average post-pandemic impact: women, detailed causes



- Greater cancer gains in the most deprived?
- Deeper analysis of "other" causes?

How will excess mortality affect mortality improvements?

- Mortality improvements v. Excess mortality
 - ... similar definitions with different reference points
 - ... mortality improvement: change compared to a single year
 - ... excess mortality: change compared to average number of years
- Can we re-formulate mortality improvements?

Discussion points

- Disparities by deprivation level persist
 - ... greater excess deaths and weaker recovery in some groups
- A fuller understanding of mortality dynamics
 - ... accounting for both **persistent trends** and **sudden disruptions**
- How to incorporate **both** into standard models, e.g. CMI_2021?
 - ... structural change analysis?
- How to adjust future projections?

Thank you!

Questions?

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