The Impact of Covid-19 on Higher-Age Mortality

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Agenda

- Background and objectives
- Demographics of the Covid-19 victims
  - What is the relationship between Covid mortality and all-cause mortality?
  - What do we know about infection rates?
  - Rethinking future extreme scenarios
- Demographics of the surviving population (ADM's APPLE)
  - The Accelerated Deaths Model
  - Adjusted (Post-Pandemic) Life Expectancy
  - Secondary effects

Focus on English data.
But many conclusions will apply to other countries.

Objectives of Our Work

- What does the mixture of people dying from Covid-19 look like?
    - e.g. age profile, deprivation, region

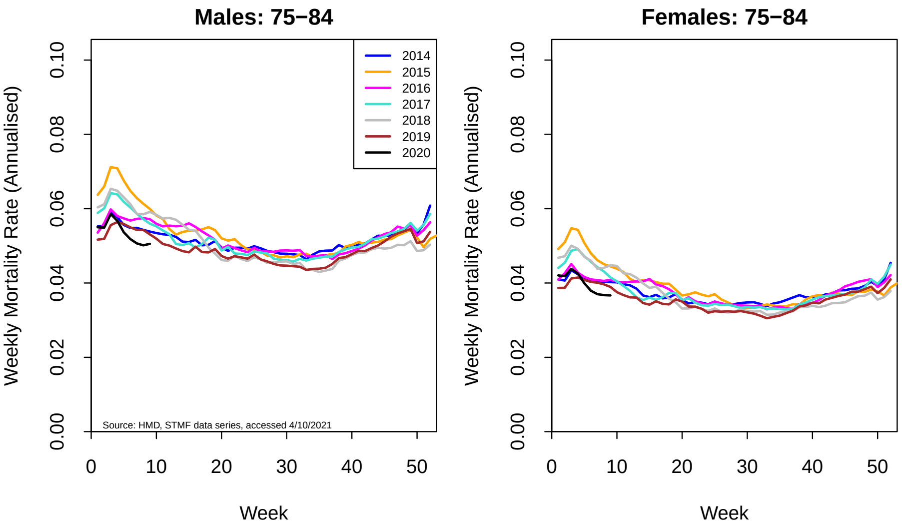
- Is the level of Covid-19 mortality inequality different from the level of all-cause mortality inequality in 'normal' years?

- Are pandemic survivors more healthy than the pre-covid average?
    - Will they have higher life expectancies?

- What might the longer-term impacts be of the pandemic?

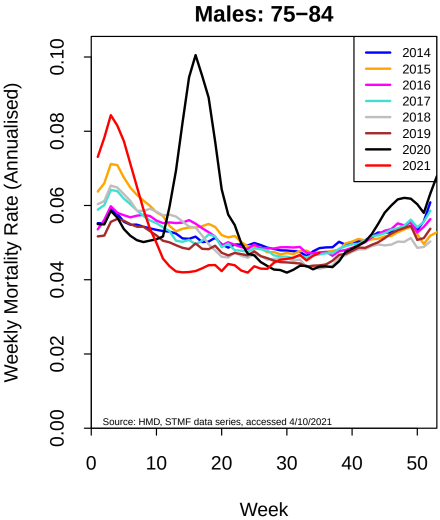
- Do we need to revise our catalogue of extreme scenarios?

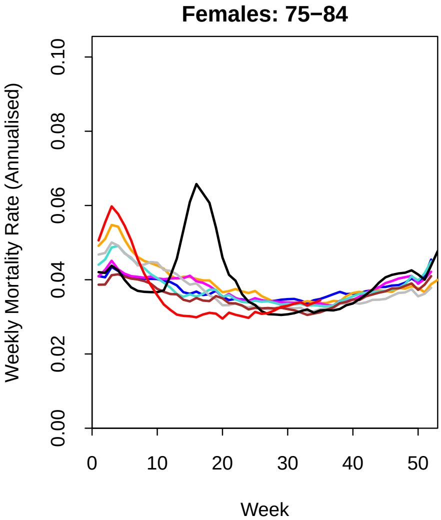
English Weekly Mortality Rates 2014 to March 2020



Source data: www.mortality.org (STMF data series, accessed 4/10/2021)

2020-21 in Context: English Weekly Mortality Rates Since 2014



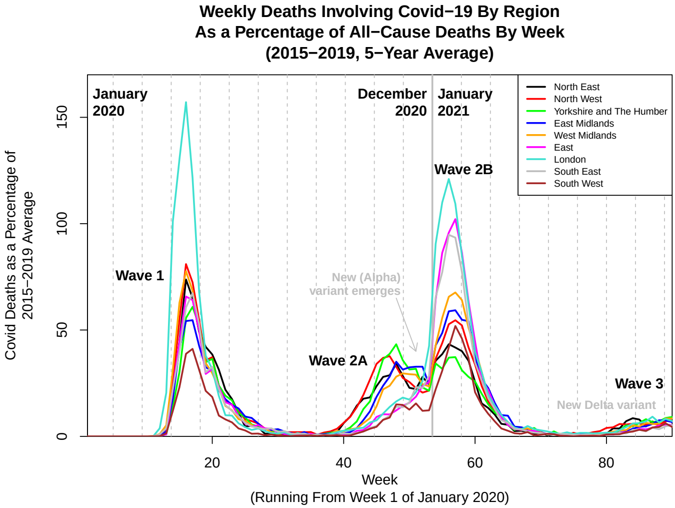


Variation By Region

North East
North West
Yorkshire & Humber
East Midlands
West Midlands
East of England
London
South East
South West

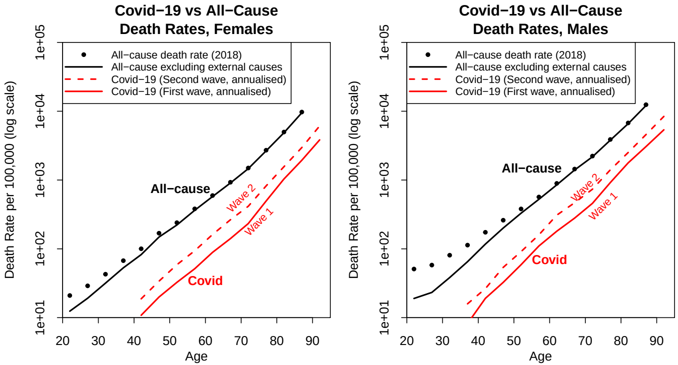
Not in dataset:
Scotland, Wales,
Northern Ireland

Weekly Covid-19 Death Rates: 2020/21 by English Region



- Considerable variation between regions
- More variation around Europe
- Wave 1:
  - London leads, but similar timing
  - Very different magnitudes
- Wave 2:
  - Wave 2A more focused in the northern regions
  - Wave 2B stronger in the south
- London Covid death rates 170% higher than the South West

Covid-19 Death Rates, Waves 1 and 2 (up to January 2021)



(Adapted from a David Spiegelhalter blog)

- Death rates are on a logarithmic scale
- All cause: with and without external causes
- Waves 1, 2 and 2018-all-cause are almost parallel!
- Waves 1 & 2: very similar age profile
- Conclusion: Covid death rates by age are approximately proportional to all-cause mortality (excluding external causes).

Provisional Takeaway

The comparison with all-cause death rates suggests the following way to look at Covid-19 mortality for age x:

$$\text{Covid Mortality Rate}(x) = \text{all-cause mortality rate}(x) \times \text{infection rate}(x) \times \text{relative frailty}(x)$$

- "Relative Frailty" measures the probability of death from Covid-19 (if infected) *relative to* the annual probability of death from all causes.
- The graphic suggests that $\text{infection rate}(x) \times \text{relative frailty}(x)$ varies only slowly with age

Generalising the *proportional to all-cause mortality* concept

Individuals aged x, have varying levels of 'frailty':

- Data $\Rightarrow$ variation by sub-group (e.g. mortality varies considerably by deprivation/wealth/affluence/education); the result of variation in
  - individual risk factors (e.g. smoking, poor diet, exercise, ...)
  - individual state of health

General observation about Covid-19: if infected

- Older people are more at risk
- People who have more co-morbidities *than the average for their age group* are more at risk

Generalising this concept by group

Group i

$$\text{Covid Mortality Rate}(i,x) = \text{All-cause mortality rate}(i,x) \times \text{infection rate}(i,x) \times \text{relative frailty}(i,x)$$

where group i might be characterised by e.g.

- neighbourhood deprivation
- region; urban/rural etc.
- ethnic group

Hypothesis:
relative frailty(i,x) does not vary much by age or sub-group
i.e. differences in Covid-19 mortality between groups are largely due to differences in all-cause mortality and in infection rates

Infection Rates

$$\text{Covid Mortality Rate}(i,x) = \text{All-cause mortality rate}(i,x) \times \text{infection rate}(i,x) \times \text{relative frailty}(i,x)$$

Infection-rate data & covid mortality rates & all-cause death rates $\Rightarrow$ relative frailty

Infection rates: early evidence

- Regional variation:
  death rates during the first wave $\Rightarrow$ e.g. London has experienced much higher infection rates
- Antigen testing: how many are *currently infected*

Cumulative Infection Rates

Covid-19 Antibody testing

- Imperial College REACT study, August 2020
- Sample size c. 100,000
- England: 6.0% overall carrying antibodies (Wave 1)
- Adjusted odds ratios:
  - Males, Females: similar infection rates
  - Deprivation quintiles: similar (Most deprived $1.1\times$; reference Least depr.)

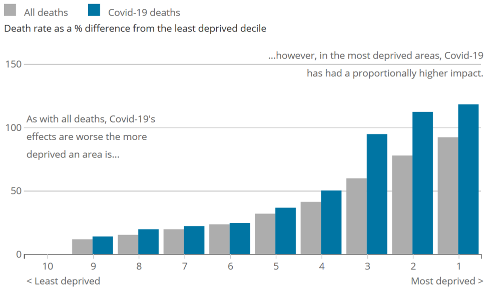
  - Ages 18-24 $1.4\times$ (reference age group 35-44)
  - London $2.4\times$; S.W. England $0.8\times$ (reference S.E. England)
  - Ethnic: Black $2\times$, Asian $1.4\times$ (reference White)
  - Patient-facing healthcare worker $2.1\times$ (reference "other occupation")
  - Client-facing care home worker $3.1\times$ (reference "other occupation")
  - Household size "7+" persons $1.6\times$ (reference Size $=1$ person)

Mortality Rates

$$\text{Covid Mortality Rate}(i,x) = \text{All-cause mortality rate}(i,x) \times \text{infection rate}(i,x) \\ \times \text{relative frailty}(i,x)$$

- $i = 1, \ldots, 10$: deprivation deciles
- infection rate$(i,x) \approx$ constant

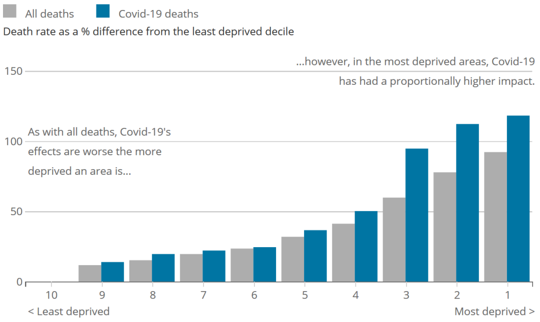
ASMRs by deprivation decile (UK: Office for National Statistics Data)



Source: Office for National Statistics – Deaths involving COVID-19

- ASMR = Age Standardised Mortality Rate
  - = weighted average of single age death rates
  - weights are based on a "standard" population
- Here we look at ASMRs by decile *relative to decile 10*
- Compare Covid-19 ASMRs (blue) against All-Cause ASMRs (grey)

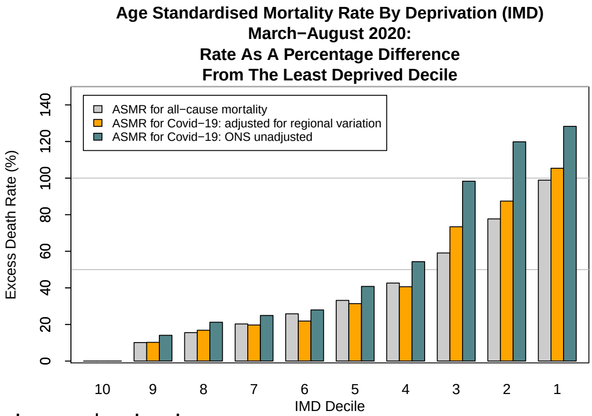
Age Standardised Mortality Rates (ASMR) by deprivation decile



Source: Office for National Statistics – Deaths involving COVID-19

- Apparently, the most deprived deciles have been disproportionately affected
- But, e.g., London has had much higher infection rates
- And London has higher levels of deprivation
- So this might distort the comparison of ASMRs

ASMRs by deprivation: Adjusted for Regional Variation



- Simple GLM: region + deprivation
- Blue bars: no adjustment for regional variation
- **Orange bars: ASMRs with the effect of regional variation filtered out**
- Covid-19 ASMRs by decile are now approximately proportional to all-cause ASMRs

Summarising the previous slides

$$i = \text{deprivation decile}, \ x = \text{age}$$

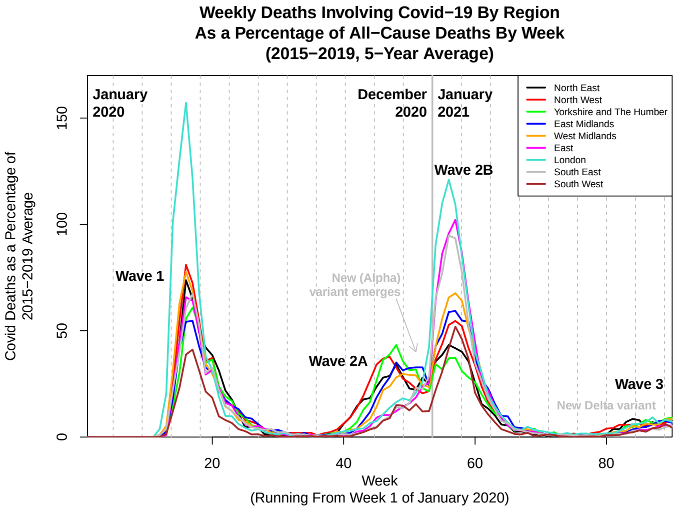
$$\text{Covid Mortality Rate}(i,x) = \text{All-cause mortality rate}(i,x) \times \text{infection rate}(i,x) \times \text{relative frailty}(i,x)$$

- Imperial College antibody data $\Rightarrow$ infection rate(i,x)
  different deprivation groups have similar infection rates *during the first wave*
- ASMRs: infection rate(i,x) $\times$ relative frailty(i,x)
  Covid mortality by deprivation is approximately proportional to all-cause mortality by deprivation

What, therefore, do we infer?

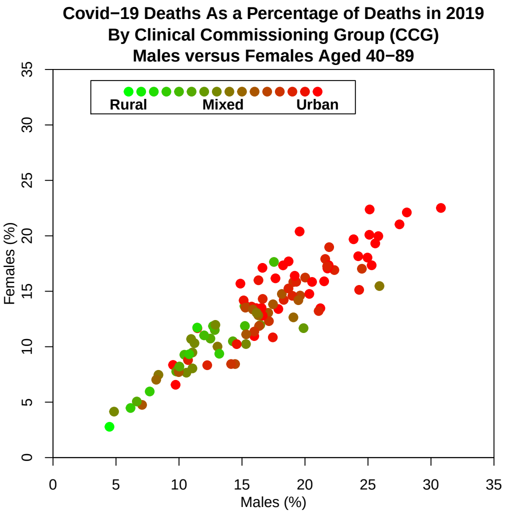
- Relative frailty(i,x) is fairly constant across deprivation groups

Recap: Regional and sub-regional variation



- Considerable variation between regions
- London Covid death rates 170% higher than the South West

Covid Deaths in 2020 as a Percentage of All Deaths in 2019 By CCG



- CCG: Clinical Commissioning Group
  = health administrative area
  average population $\sim 500,000$
- 106 CCGs across England
- Compare Covid-19 deaths in 2020 with deaths from all causes in 2019
- Covid-19 deaths: 5% to 30% of 2019 deaths
- Strong correlation between males and females
- Rural CCGs have much lower Covid death rates than urban

Discussion point 1: How does this influence the design of mortality catastrophe bonds?

"Traditionally":

- cat bonds are index-linked to national mortality
- principal at risk if national mortality is $> x\%$ higher than base mortality
- assumption that national mortality variation is highly correlated with bond issuer portfolio mortality (amounts $\times$ lives)

Covid-19 pandemic:

- Considerable variation by region/CCG and subgroups $\Rightarrow$
- Impact of Covid-19 on an insurer depends on regional and other characteristics of their portfolio
- So the correlation might not be as high as anticipated *in an extreme year*

So do mortality cat bonds need to be redesigned?

Discussion point 2: Covid-19 versus other potential pandemics

Covid-19

- Waves 1 and 2: death rates approx. proportional to all-cause death rates
- Relative frailty(i, x) by group and age does not vary much

Is this the result of

- The novelty of Covid-19 (i.e. no prior exposure to anything similar)?
- So underlying individual frailty determines outcomes.

Contrast with, e.g., 1918 Spanish Flu

- Relative frailty(i, x) was much higher for younger ages
- Reason: older age groups had prior exposure to other variants of influenza

Discussion point 2: Covid-19 versus other potential pandemics (cont.)

- A future Covid pandemic:
  some age groups potentially have higher levels of immunity to future new and dangerous variants

Generating future scenarios:

- Differentiate between novel viruses *versus* viruses with prior exposure meaning different levels of immunity/protection by age $\times$ region $\times$ subgroup
- Pandemic simulations need to allow for significant variation between
  - regions; urban/rural; socio-economic subgroups
  - age groups for viruses with prior exposure
  - age groups due to variation in social behaviour

The Impact of Covid-19 on Future Mortality

Preceeding discussion:

People of the same age who are more "frail" are more likely to die if they become infected with Covid-19.

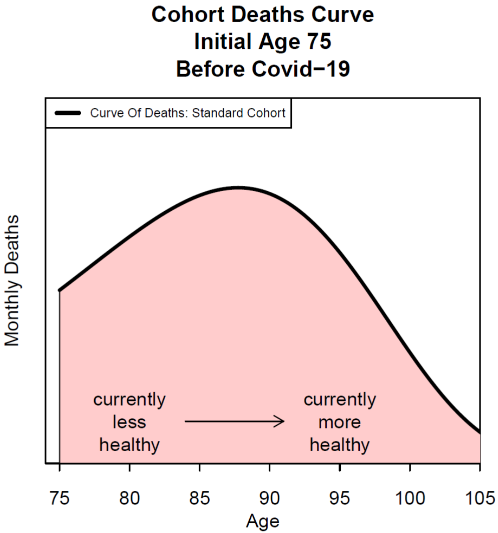
$\Rightarrow$ impact on the mortality of the surviving population.

The Accelerated Deaths Model (ADM)

- Accelerated death $\Rightarrow$
  someone who would have died in the future from other causes
  dies earlier from Covid-19.
- For a given total number of deaths:
  we model the impact on *the surviving population*

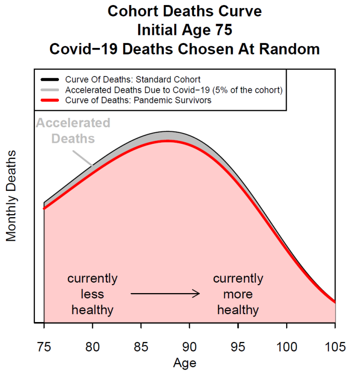
- The model is not for predicting the ultimate size of the pandemic.
- The model is focused on the demographics of the surviving population.

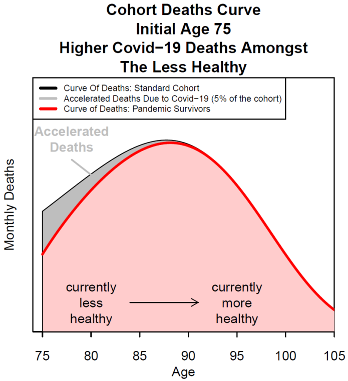
Pre-Covid: Cohort Curve of Deaths



- For a cohort currently aged 75: what will be the ages at death?
- Less healthy now $\Rightarrow$ more likely to die earlier

Impact of Covid-19 on the Curve of Deaths





- A (left): Covid victims randomly chosen from the cohort
- B (right): Covid deaths more prevalent amongst the less healthy

Scenario B is consistent with the empirical evidence that those with co-morbidities are more likely to die if they get infected

The Accelerated Deaths Model

Example: Consider a cohort currently aged x (e.g. 75)

- Initial cohort size: 100,000
- $d(t, x)$ = pre-Covid curve of deaths, $t = 0, 1, 2, \ldots$
- Out of the $d(t, x)$
  a proportion $\pi(t, x)$ die from Covid
- Out of the original $d(t, x)$ "scheduled" to die at t
  $\pi(t, x)d(t, x)$ die in the short term due to Covid

The Accelerated Deaths Model (cont.)

- Simple starting point:

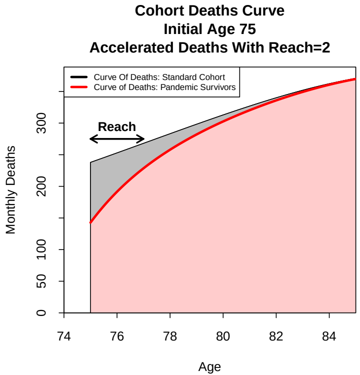
$$\pi(t,x) = \alpha(x)R(x)\exp[-t/\rho(x)]$$

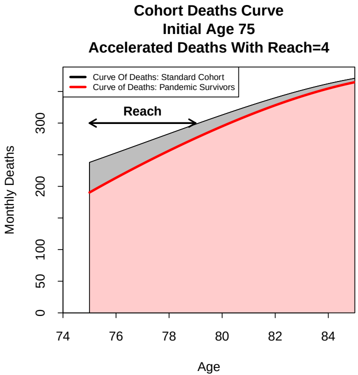
- $\alpha(x)$ = "amplitude" $\Rightarrow$
  this determines the proportion of the entire cohort who die from Covid
- $\rho(x)$ = "reach" $\Rightarrow$
  links to the years-of-life-lost (YLL) by those who die from Covid
- $R(x)$ = normalising const. depending on $\rho(x)$ and the shape of $d(t,x)$

$$R(x) = d(0,x) \Big/ \int_0^\infty d(t,x)\exp[-t/\rho(x)]dt$$

- $R(x)$ definition:
  $\Rightarrow \alpha(x)$ = infection rate $\times$ relative frailty

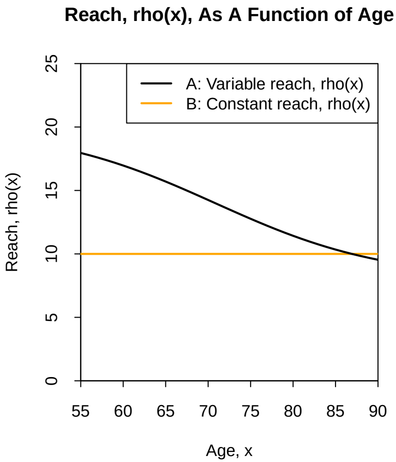
Model Features: Interpreting the Reach

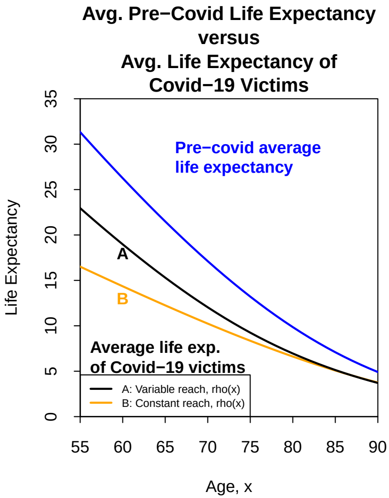




- "Amplitude" affects the proportion out of the cohort who die (area of grey region)
- "Reach" connects to expected *years of life lost* per person who dies early from Covid-19
- "Reach" and the shape of the grey region also relates to the variation in frailty within an age group
- *More variation* in frailty within a cohort $\Rightarrow$ *lower* reach

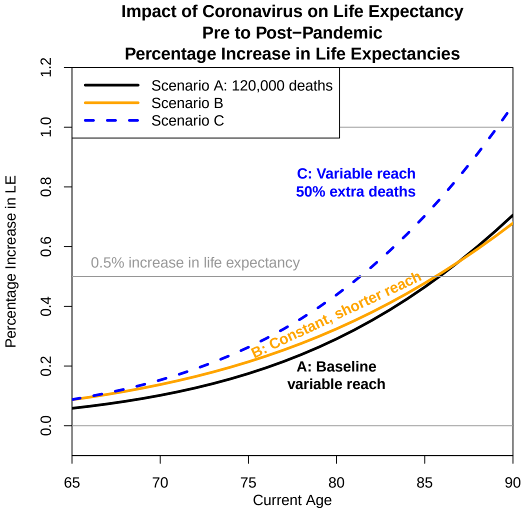
Calibrating the reach parameter, $\rho(x)$





- The shape of $\rho(x)$ depends on variability in underlying frailty
- Scenario A: (experimental) reach: $\sim$ 18 (young) to $\sim$ 10 (old)
- Scenario B: (extreme) reach $= 10$ constant
- B is simple but not very plausible

Adjusted (Post-Pandemic) Life Expectancy (APPLE)



- More realistic scenarios in terms of total Covid-19 deaths
- LE(pre-covid) $\rightarrow$ LE(survivors)
- What is the percentage Increase?
- Scenarios:
  - A: 120,000 deaths + variable reach
  - B: 120,000 deaths + constant reach
  - C: 180,000 deaths + variable reach
- Age 65: APPLE of healthier survivors is less than 0.1% higher than pre-Covid cohort life expectancy
- Impact assumes no secondary effects e.g. no long-term impairments $\Rightarrow$ further data and modelling

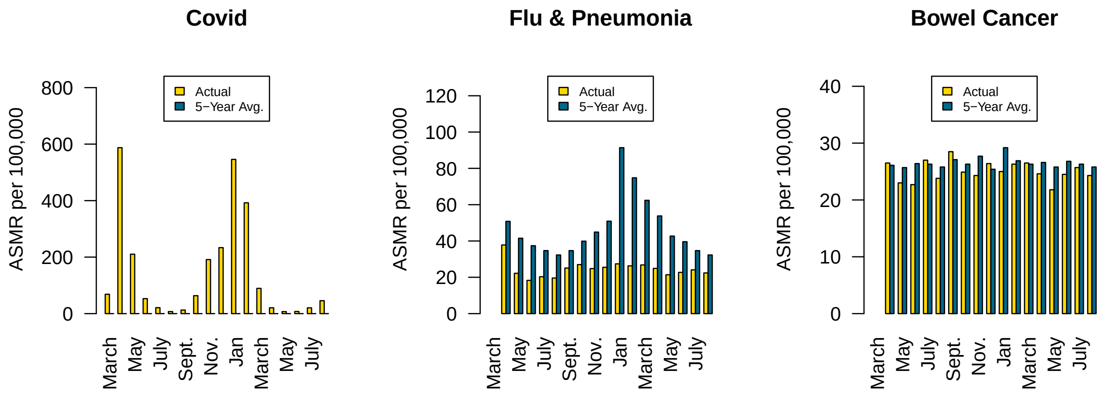
What are the other secondary effects beyond this model?

- Non-Covid illnesses (e.g. late cancer diagnosis or delayed treatment)
- More extreme forms of "Long Covid"
  Covid survivors might have long-term health impairments
- Lasting impact of innovation during the pandemic
- Behavioural changes (positive and negative)
- Impact of increased long-term unemployment
- Economic impact on future health spending and research

Some secondary effects might be observable in 2020/21 cause of death data

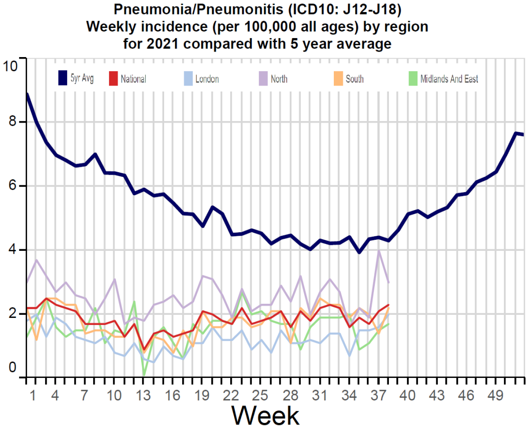
- Higher cancer death rates in 2021
- Potentially lower death rates in 2021 from e.g. respiratory diseases
  (due to accelerated death from Covid-19 in 2020)

Some secondary effects can already be observed in 2020/21 data



- Pneumonia deaths, e.g. August 2020: 60% of 5-year average
- Home working, hygeine etc. ⇒ less exposure to pneumonia pathogens ⇒ fewer deaths
- Health data ⇒ *incidence* of many infectious diseases is well below normal

Reduction in pneumonia deaths matches reductions in reported cases



- Source: Communicable and respiratory disease report for England, Week 38, 2021
- Royal College of General Practitioners

Conclusions and Lessons Learned

1. Strong relationship between covid mortality(i, x) and all-cause mortality(i, x)
   - contrasts with Spanish Flu: younger affected much more; some prior immunity
   - Covid-19: novel $\Rightarrow$ no prior immunity
2. Significant variation by region and urban-rural $\Rightarrow$ much more than a normal year
   - implications for mortality catastrophe bonds as a hedge for portfolios with regional concentrations
3. In the absence of "secondary effects", the impact of the pandemic on the life expectancy of survivors is likely to be small
4. We will need time to understand the nature and magnitude of secondary effects

Thank you

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