The Impact of Covid-19 on Higher Age Mortality

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Agenda

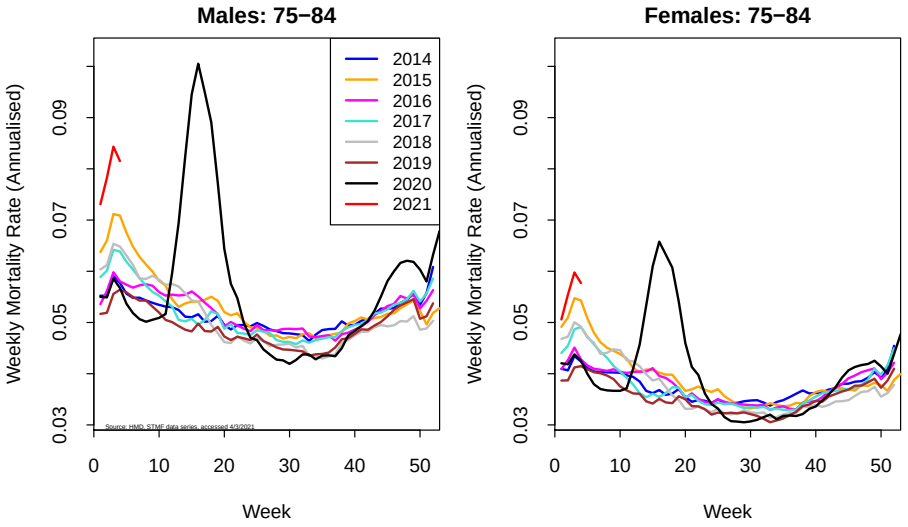
- Background and objectives
- Demographics of the Covid-19 victims
  - What is the relationship between Covid mortality and all-cause mortality?
  - What do we know about infection rates?
- Demographics of the surviving population (ADM's APPLE)
  - The Accelerated Deaths Model
  - Adjusted (Post-Pandemic)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

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

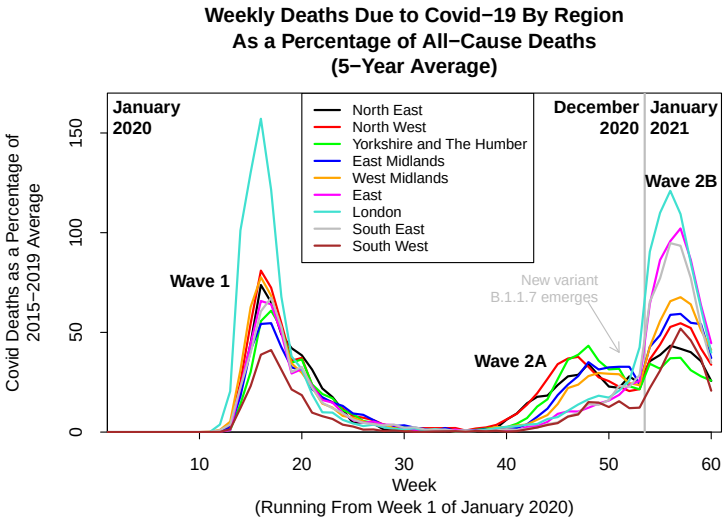
Objectives of Our Work

- 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?

2020 in Context: English Weekly Mortality Rates Since 2014

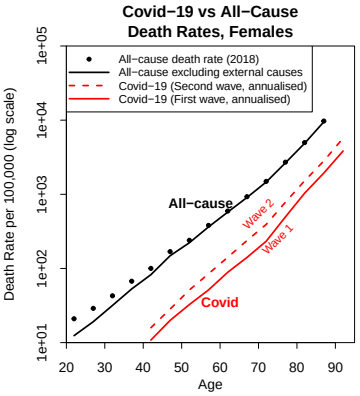


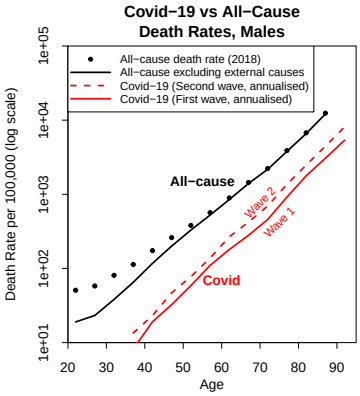
Weekly Covid-19 Death Rates: 2020 by English Region



- Considerable variation between regions
- More variation around Europe
- Wave 1:
  - London leads, but similar timing
  - Very different magnitudes
- Wave 2:
  - Wave 2A in the northern regions
  - Wave 2B more in the south
- London 3× more deaths than the South West

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





- Death rates are on a logarithmic scale
- All cause: with and without external causes
- The solid lines and the dots 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

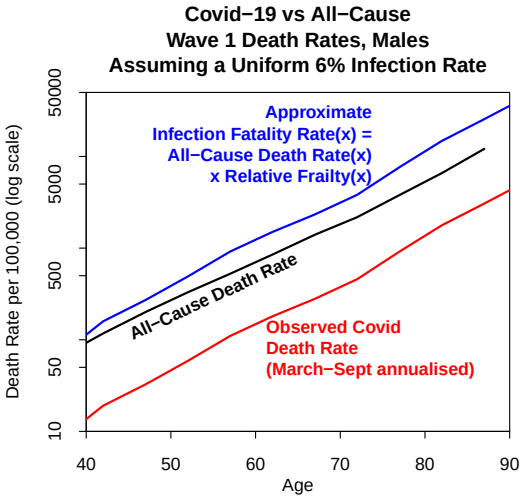
Spiegelhalter's graphic suggests the following way to look at Covid-19 mortality for age x:

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

- "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 infection rate(x) $\times$ relative frailty(x) varies only slowly with age

- All-cause mortality rate(x) $\times$ relative frailty(x)
  = "Infection Fatality Rate"(x) (IFR)
  = Probability of death given an individual aged x has become infected

Approximate Infection Fatality Rates By Age (IFR)



- Wave 1 Data $\Rightarrow$
  $\sim$ 6% infected *on average*
- Assume 6% at all ages: scale up to 100%
  $\Rightarrow$ shift from **Red** to **Blue** line.
- Implication: in Wave 1, the IFR was about 1$\times$ to 2$\times$ the annual all-cause death rate
- IFR will be gradually falling as treatments improve
- This is just the starting point for a more detailed analysis of the infection rate and relative frailty separately.

Generalising this concept

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

- Evidence: variation by sub-group (e.g. mortality varies considerably by deprivation)
- Individual risk factors (e.g. smoking, poor diet, exercise, ...)
- Individual state of health

It was also observed early in the pandemic that

- people dying from Covid-19 tend to have *underlying conditions* (co-morbidities)

More precisely:

- Older people are more at risk (if infected)
- 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

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

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*

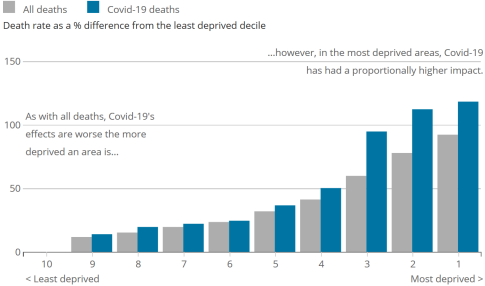
Cumulative Infection Rates

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

Mortality Rates: All-Cause compared with Covid-19

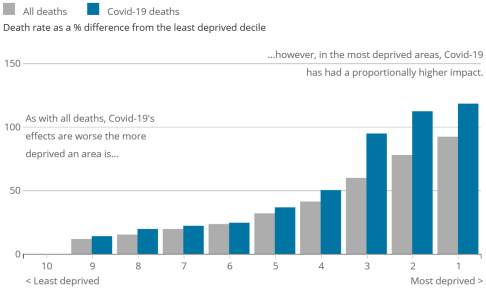
ASMRs by deprivation decile (UK: Office for National Statistics Data)



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)

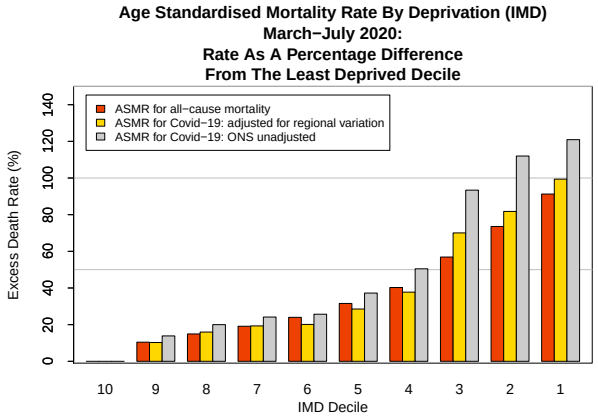
ASMRs by deprivation decile (ONS Data)



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

- Apparently deprived groups 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



- Grey bars: no adjustment for regional variation
- **Gold 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

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

$$i = \text{deprivation decile}$$

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

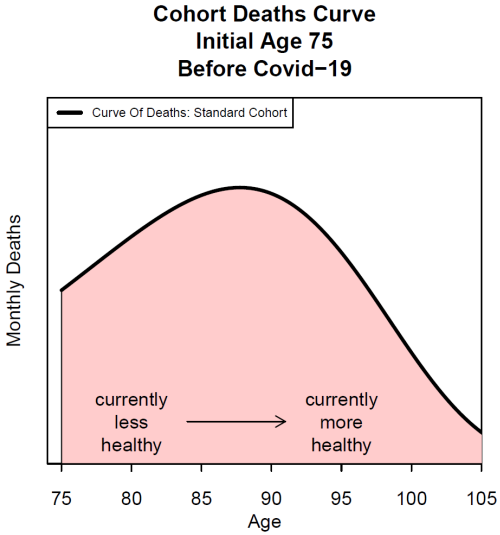
What, therefore, do we infer?

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

The Accelerated Deaths Model (ADM)

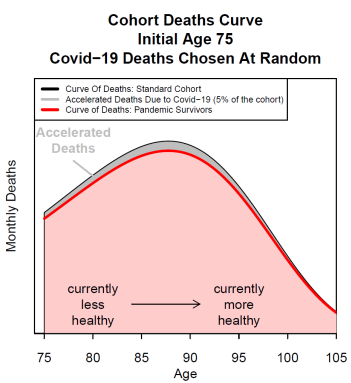
- Accelerated death $\Rightarrow$
  someone who would have died in the future from other causes
  dies earlier from Covid-19.
- For a given total number of deaths:
  we model the impact on *the surviving population*
- The model is not for predicting the ultimate size of the pandemic.
- The model is focused on the demographics of the surviving population.

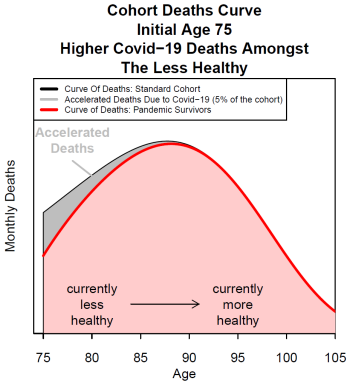
Pre-Covid: Cohort Curve of Deaths



- 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
  (e.g. total in the first pandemic wave)

The Accelerated Deaths Model (cont.)

- Simple starting point:

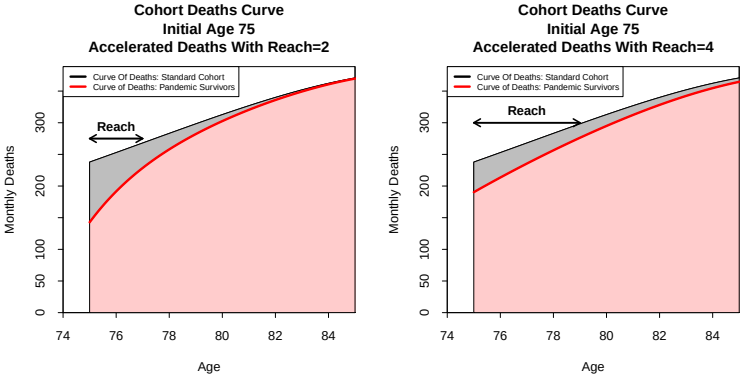
$$\pi(t,x) = \alpha(x)R(x)\exp[-t/\rho(x)]$$

- $\alpha(x)$ = "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 $d(t,x)$

$$R(x) = d(0,x) \Big/ \sum_t d(t,x)\exp[-t/\rho(x)]$$

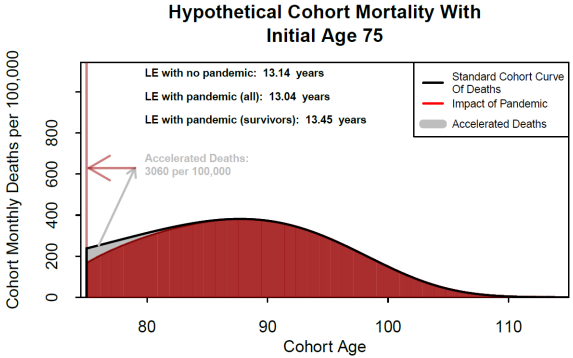
- $R(x)$ definition:
  $d(0,x) \Rightarrow$ incorporates short-term average cohort "frailty"
  $\Rightarrow \alpha(x)$ = infection rate $\times$ relative frailty

Model Features: Amplitude and Reach (an extreme scenario)



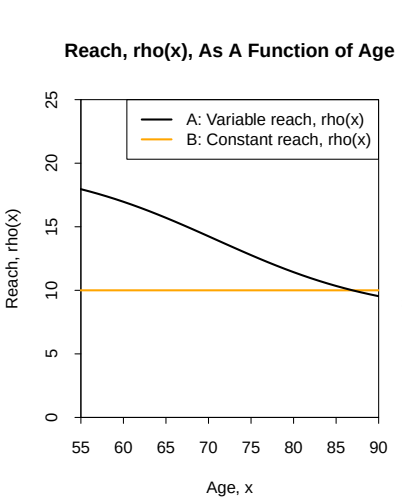
- "Amplitude" affects the proportion out of the cohort who die
- "Reach" connects to expected *years of life lost* per person who dies early from Covid-19
- "Reach" and the shape of the grey region also relates to the variation in frailty within an age group
- *More variation* in frailty $\Rightarrow$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

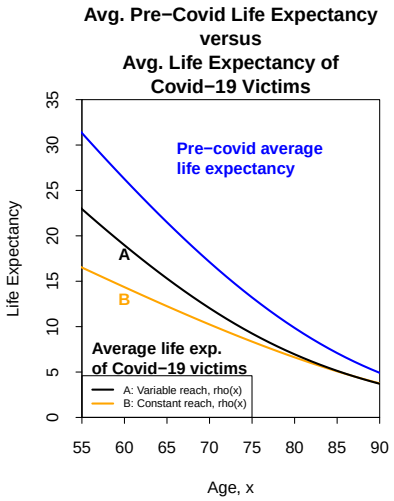
Are the survivors much healthier on average?



- The red region is the revised curve of deaths for survivors
  $\Rightarrow$ In actuarial terms, a *selection effect*, with lower mortality reverting to original cohort forecasts.
- Warning: This is a much exaggerated scenario for illustration.

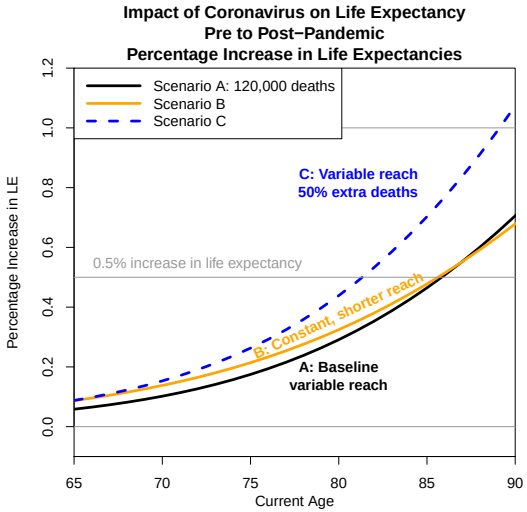
Calibrating the reach parameter, $\rho(x)$





- The shape of $\rho(x)$ depends on variability in underlying frailty
- Work in progress
- Scenario A: (experimental) reach: ~ 20 (young) to ~ 10 (old)
- Scenario B: (extreme) reach $= 10$ constant
- B is simple but not very plausible

Adjusted (Post-Pandemic) Life Expectancy



- 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

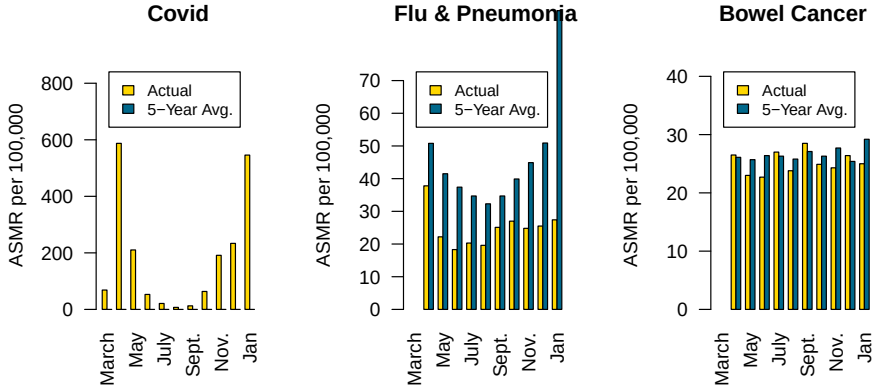
What are the other effects beyond this model?

- 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 2021 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. $\Rightarrow$ less exposure to pneumonia pathogens $\Rightarrow$ fewer deaths
- Health data $\Rightarrow$ *incidence* of many infectious diseases is well below normal

Conclusions 1

- Data are consistent with observations that people with co-morbidities are more likely to die if they get infected with Covid-19
- There is a strong relationship between Covid-19 death rates and all-cause mortality
  - by age
  - by deprivation
  - potentially other groups
- If infected, key sub-groups are not disproportiately affected by Covid-19 *relative to all-cause mortality*.
- But certain sub-groups are much more likely to get infected.
  $\Rightarrow$ we observe higher Covid-19 death rates

Conclusions 2

- Data analysis led to development of the accelerated deaths model.
  - Pandemic survivors will be healthier, on average, than the pre-pandemic population.
  - BUT, ... with the current scale of deaths and in the absence of secondary effects:
  - the impact on the collective life-expectancy of survivors will be small.
- Secondary effects could have a significant additional impact on life expectancies
  - but it will take some years to assess these impacts.
- Interpreting cause of death data for 2020 and 2021 will be challenging.

Updated paper available soon.

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