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Gompertz Network and Lasso regularisation in modelling age-specific impact of COVID-19 Vaccination

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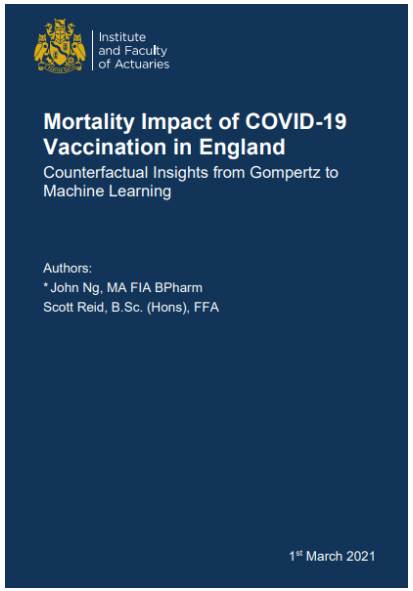
17 June 2021

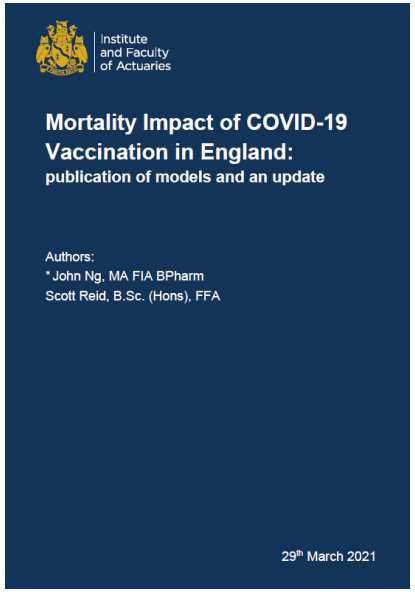
Key Questions

- What is the mortality impact of COVID-19 vaccination in England?
- How to model age-specific mortality and the “unvaccinated” counterfactual scenario?
- How do our results compare with other studies by Public Health England and Warwick University?

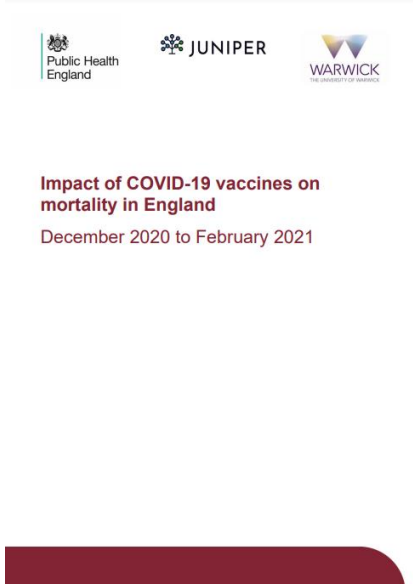
IFoA paper 1
(1 Mar)



IFoA paper 2
(29 Mar)



PHE and Warwick study
(26 Mar)



Warwick study
(18 Mar)

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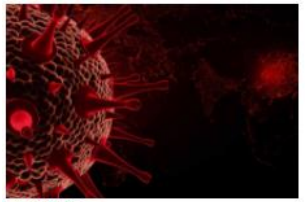
Gompertz in Literature



PANDEMICS

COVID-19 Brief: Using the Gompertz model to estimate COVID-19 risk by age

June 18, 2020 | COVID-19

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PANDEMICS

COVID-19 Mortality Rates by Age and Gender: Why Is the Disease Killing More Men than Women?

July 10, 2020 | Research and White Papers

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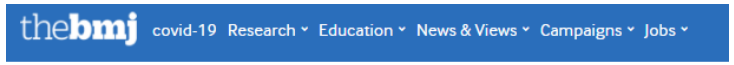

Analysis

Use of "normal" risk to improve understanding of dangers of covid-19

BMJ 2020 ; 370 doi: https://doi.org/10.1136/bmj.m3259 (Published 09 September 2020)
Cite this as: *BMJ* 2020;370:m3259

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David Spiegelhalter, chair [1]

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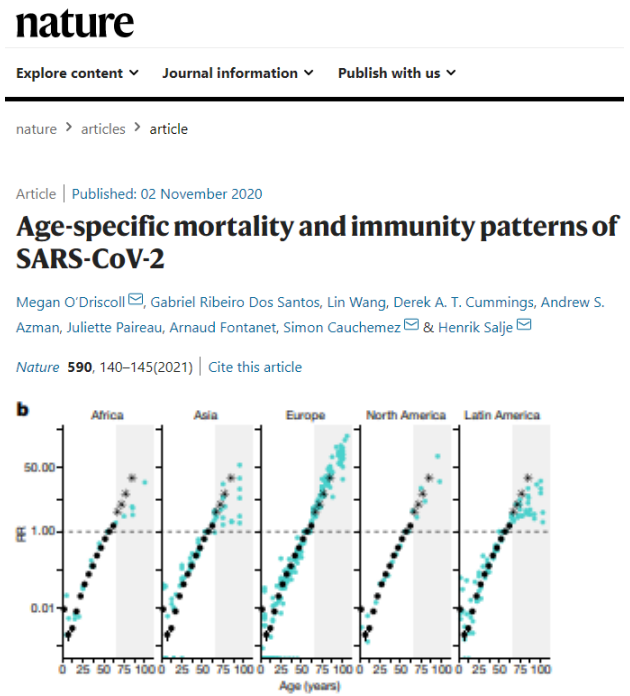
Accumulating data on deaths from covid-19 show an association with age that closely matches the "normal" risk we all face. Explaining risk in this way could help people understand and manage their response, says **David Spiegelhalter**

04. Ng J, Bakrania K, Falkous C, Russell R. Covid-19 mortality rates by age and gender: why is the disease killing more men than women?RGA 2020 Jul 10. https://rgare.com/knowledge-center/media/research/covid-19-mortality-rates-by-age-and-gender-why-is-the-disease-killing-more-men-than-women



[RGA papers; Jun 2020; John Ng et al]
COVID-19 mortality rate by age in 10 countries follow the Gompertz (log-linear) pattern, and similarly for male and female

[BMJ; Sep 2020; Sir Prof David Spiegelhalter]
COVID-19 population fatality rates display strong linearity on the logarithmic scale, and roughly proportional to all-cause mortality risks

[Nature; Nov 2020; University of Cambridge]
Analysis of deaths data from 45 countries shows consistent log-linear relationship between age and risk of death, especially for 30-65 years old.

Multiple death metrics are available in England (e.g. ONS', hospital deaths, PHE's), but all 4 of the above studies used "ONS registered deaths"

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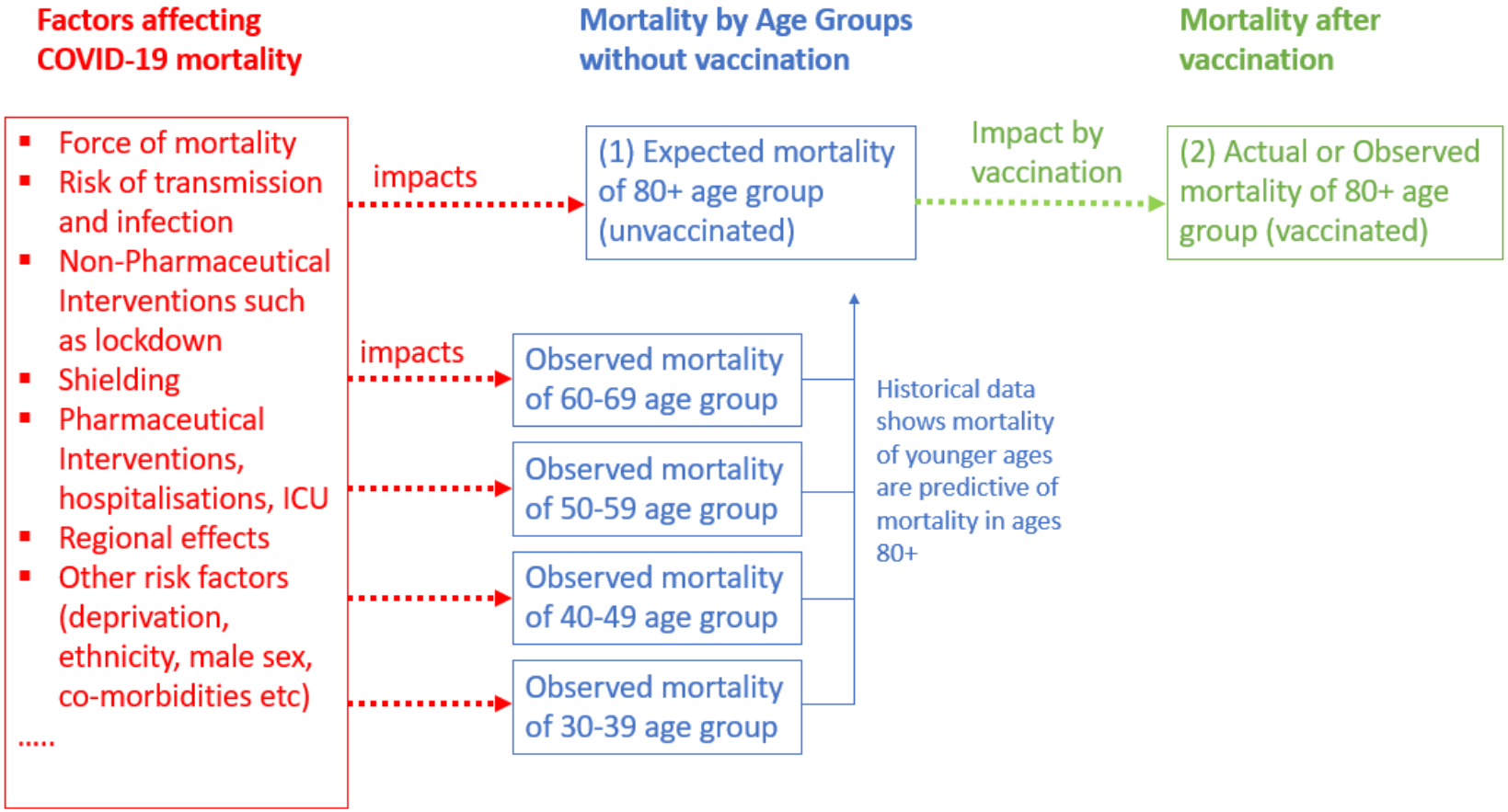
Age-structured COVID-19 Mortality Modelling



Mortality Impact
= Actual/Expected
= (2)/(1)

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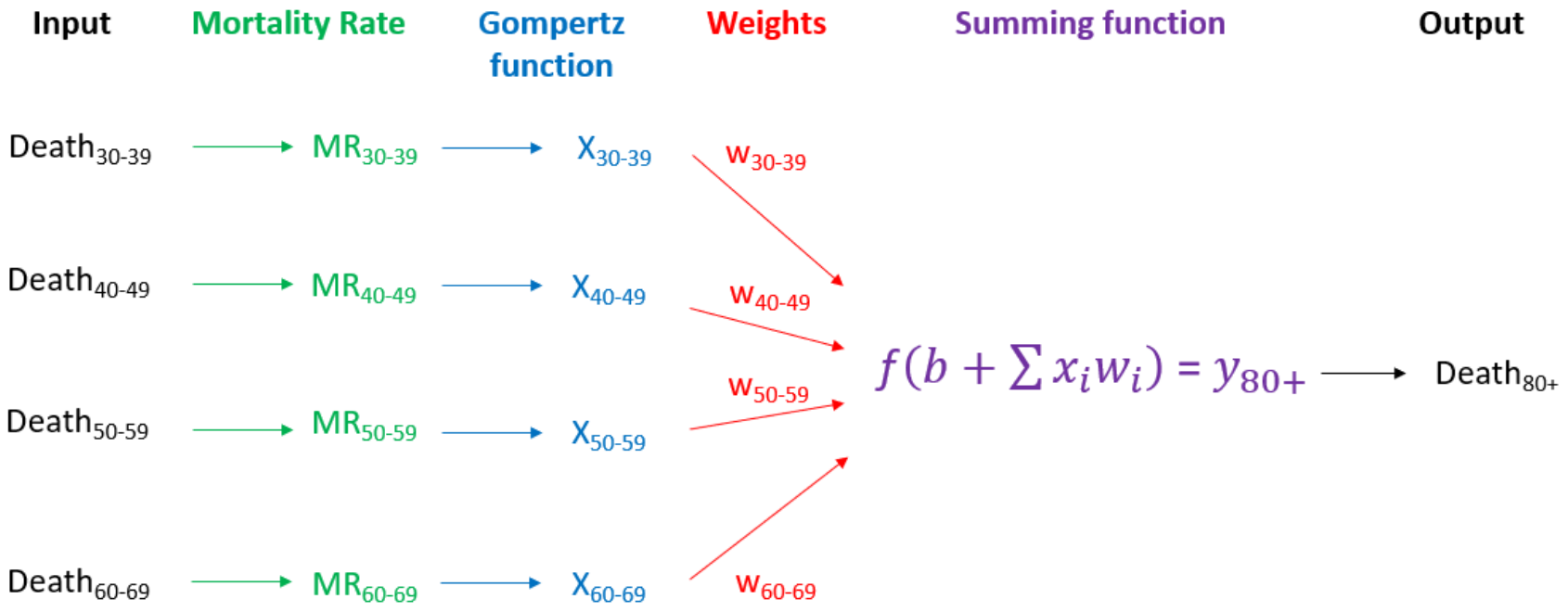
Gompertz Network Model



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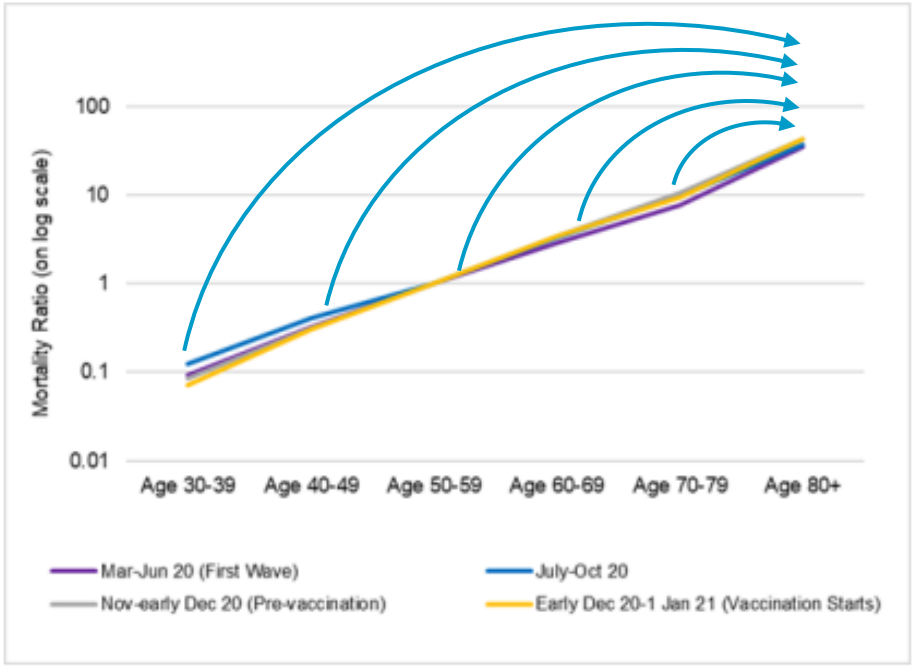
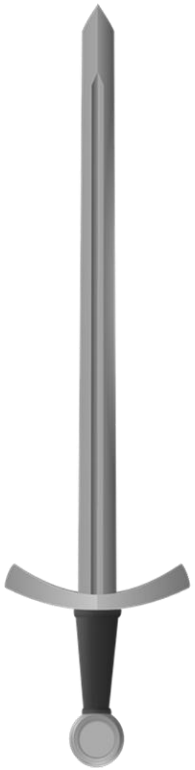
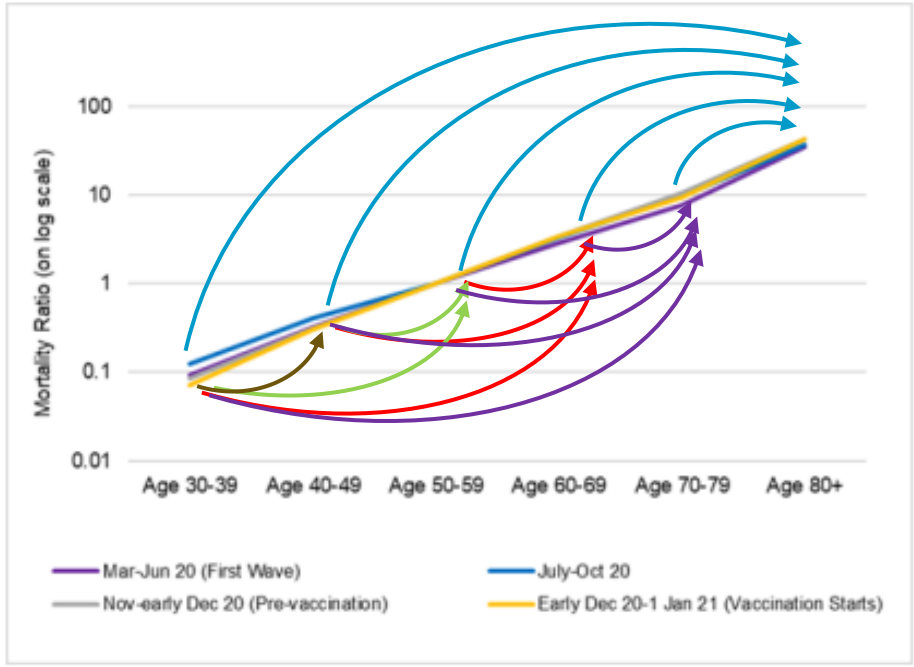
Problem: Age-dependency is a double-edge sword!

Good for modelling:
Age-dependency





Not Good for modelling:
Multi-collinearity



Solution: Lasso regularisation to handle multi-collinearity and variable selection

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Actual vs Expected Results for Registered Deaths

- Actual/Expected for ONS Registered Deaths based on Gompertz Network Model
- Additional results on hospital deaths and PHE occurred deaths presented in the paper

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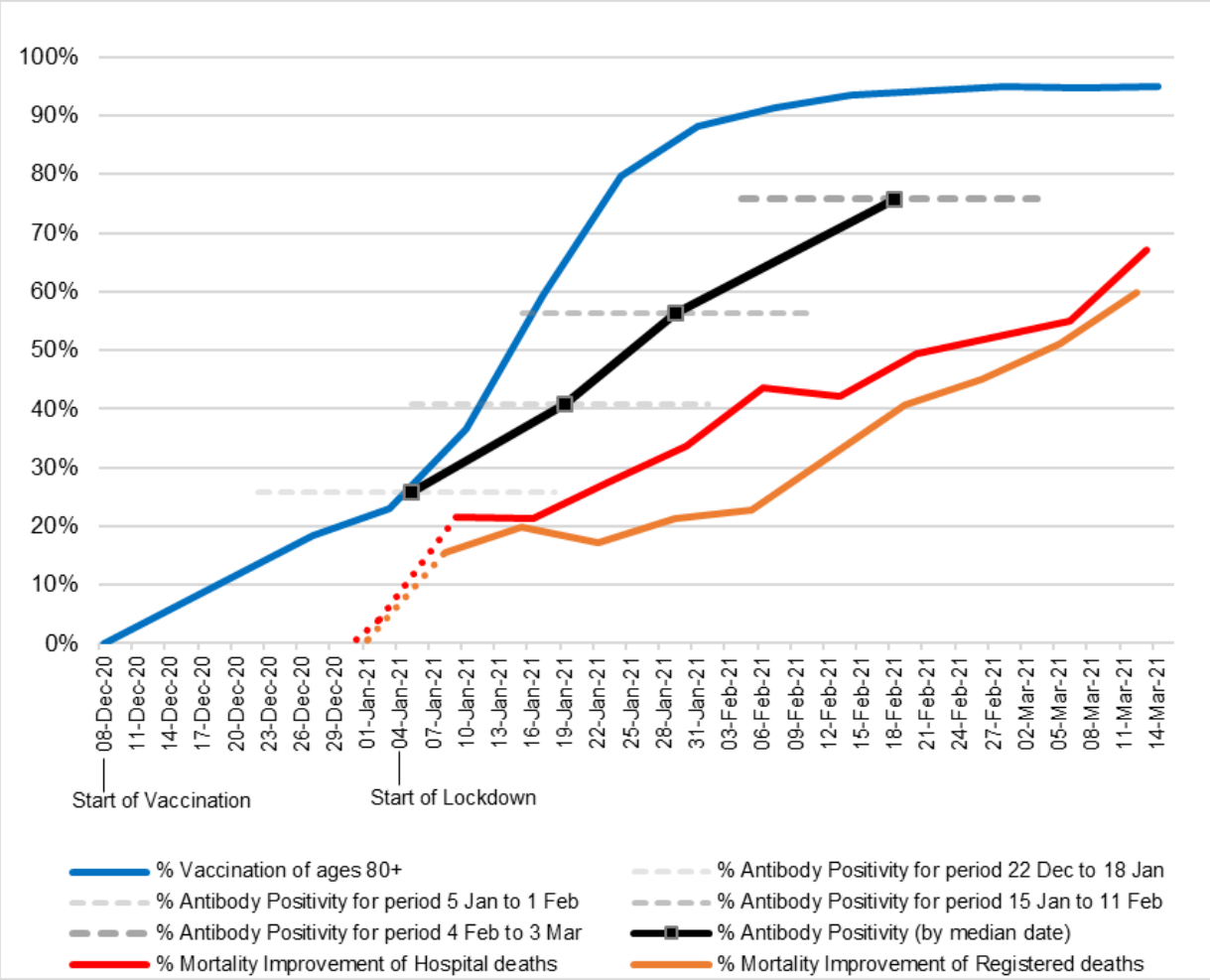
Vaccination Rates, Antibody Positivity and Mortality Improvement in ages 80+



- High degree of association between the slopes for *vaccination rates*, *antibody positivity* and *mortality improvement*. This likely depicts the real-world impact of their logical sequence.
- Mortality improvement of ages 80+ (derived from Actual-vs-Expected analysis) increases with time and achieved c. 60% by mid-March

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Comparison against PHE and Warwick studies

	PHE model	Warwick Model	IFoA Model
Approach	Daily mortality impact = vaccine effectiveness against mortality x vaccine coverage	Dynamic age-structured model and run simulations	Expected deaths of ages 80+ is predicted from observed mortality of younger age groups
Vaccine effectiveness against death	81%	82%	Independent
Vaccine doses to date	Dependent	Dependent	Independent
Time lag to death	31 days	Dependent	Independent
Deaths prevented	6100 by end of Feb; 6700 if vaccine effectiveness is 85%	6592 by end of Feb	Ages 80+: 8000 from mid-Jan to end of Feb; 10,300 by mid-Mar

Key difference: IFoA paper's approach is empirical and not dependent on vaccine-related assumptions

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Conclusions and Learnings

- Vaccines are already preventing a lot of deaths in England, where initially rolled out in first doses and from two brands, namely Pfizer and AstraZeneca
- This likely implies a high real-world vaccine effectiveness against death in the older ages
- All three approaches (IFoA, PHE, Warwick) yielded broadly consistent results
- If the vaccines continue to have very high effectiveness against death in all age groups, (re)insurers could apply sensitivity testing on simpler assumption of vaccine supply and uptake to overlay unvaccinated mortality projections, to estimate COVID-19 related mortality outlook
- In absence of granular data, while acknowledging this imperfectness, finding a ‘constant’ or ‘invariant measure’ can help to indirectly control the latent and less-dominant effects
- Actuarial Science (Actual vs Expected) and Data Science (supervised machine learning) could be used in new areas such as modelling the pandemic and impact of interventions
- See paper for detailed methodology, data sources and limitations. Models and codes are available for open access on GitHub. Questions and feedbacks are welcomed.

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