UK covid-19 predictions

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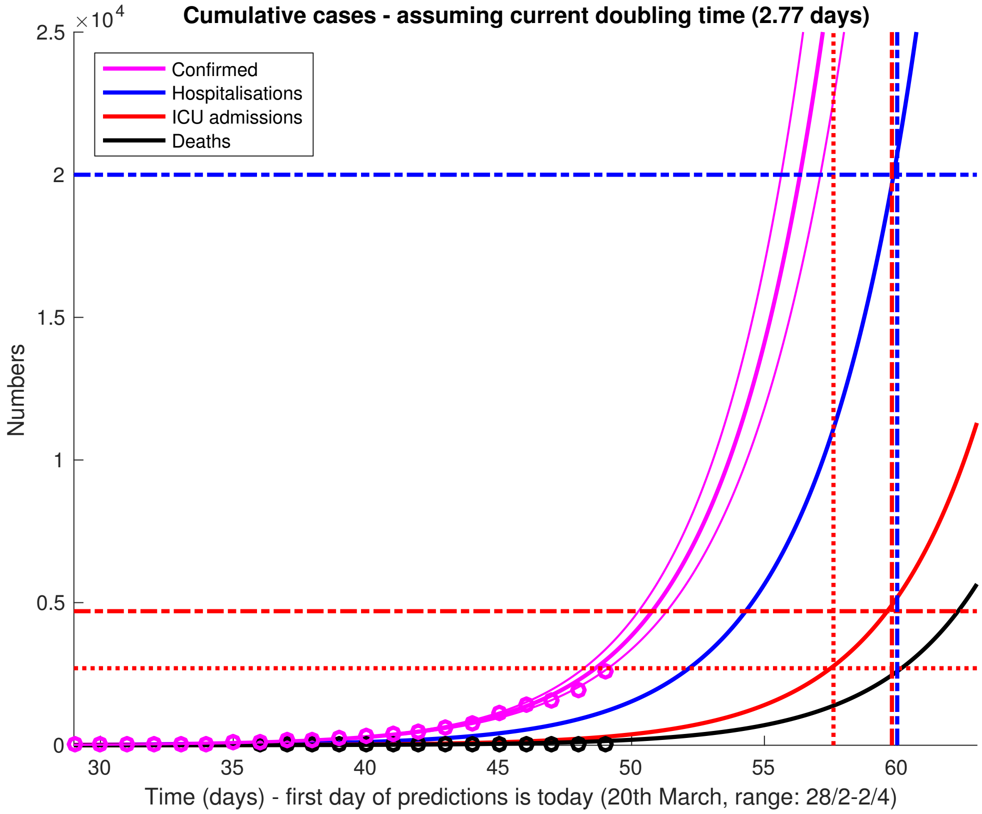
- Doubling time in the UK and most EU countries appears to be **consistently < 3 days**
- At current rate of growth, **NHS** predicted to be **overwhelmed in 10 days**
- Without the suggested surge in ICU bed capacity (from 4000 to 7000, with 2/3 of beds assumed available for COVID-19 patients), NHS overwhelmed in 7-8 days
- Effect of current measures not yet visible. Effects of school closure won't appear before 7d
- **We are only 2 weeks behind Italy,** which however locked down infected cities and closed schools in North Italy some 10 days "before" us (in relative time), but did not promote social distancing. With all measures in place, the visible effect now in Italy is still only a cut in growth rate by half (i.e. doubling time from < 3 to ~5.5-6 days, similar to what used in Imperial College in Report 9 as baseline assumption for no interventions)
- Estimated **R_0 ~ 4.5**



<u>Fig. 1</u>: Predictions under currently estimated growth rate (r ~ 0.25/day, doubling time of < 3 days). Simple exponential growth fit to cumulative confirmed cases (see Fig. 2).
<u>Pink</u>: Cumulative confirmed cases, with thin lines giving 95% confidence interval.
<u>Blue</u>: Cumulative hospitalisation, obtained by multiplying cumulative cases by 40% (as observed in Italian data: observed range [0.35-0.5]). Horizontal dash-dotted line indicates hospital bed capacity for COVID-19 patients suggested by SPI-M. Vertical line shows time this threshold is reached.
<u>Red</u>: Cumulative ICU admissions, obtained by multiplying cumulative cases by 10% (as suggested by Italian sources and visible in Italian data: observed range [0.06-0.1]). Horizontal dash-dotted line indicates ICU capacity for COVID-19 patients suggested by SPI-M after surge in total ICU beds from 4000 to 7000. Horizontal dotted line indicates total ICU capacity before surge.
<u>Black</u>: Deaths, obtained by multiplying cumulative cases by 5% (Italian sources and data).

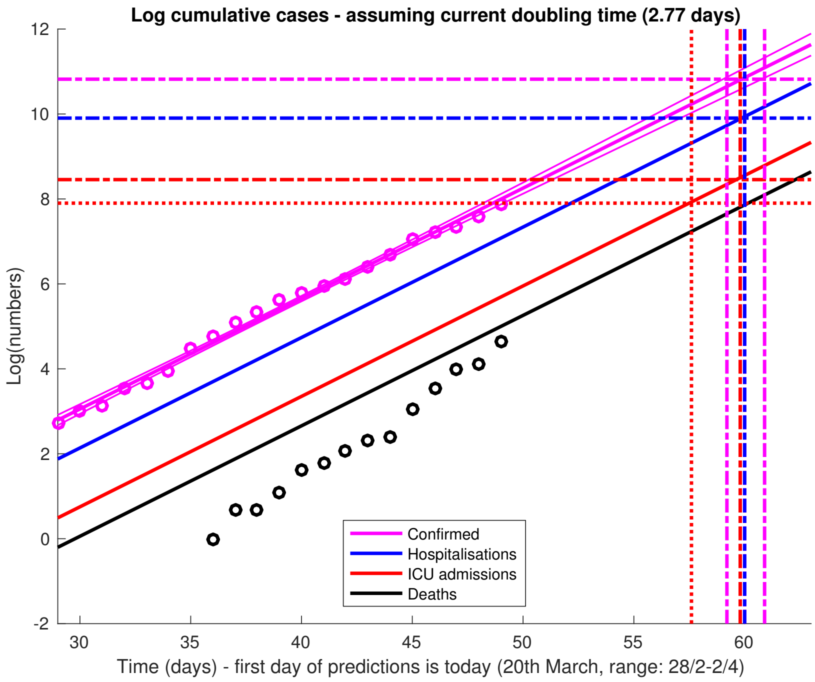
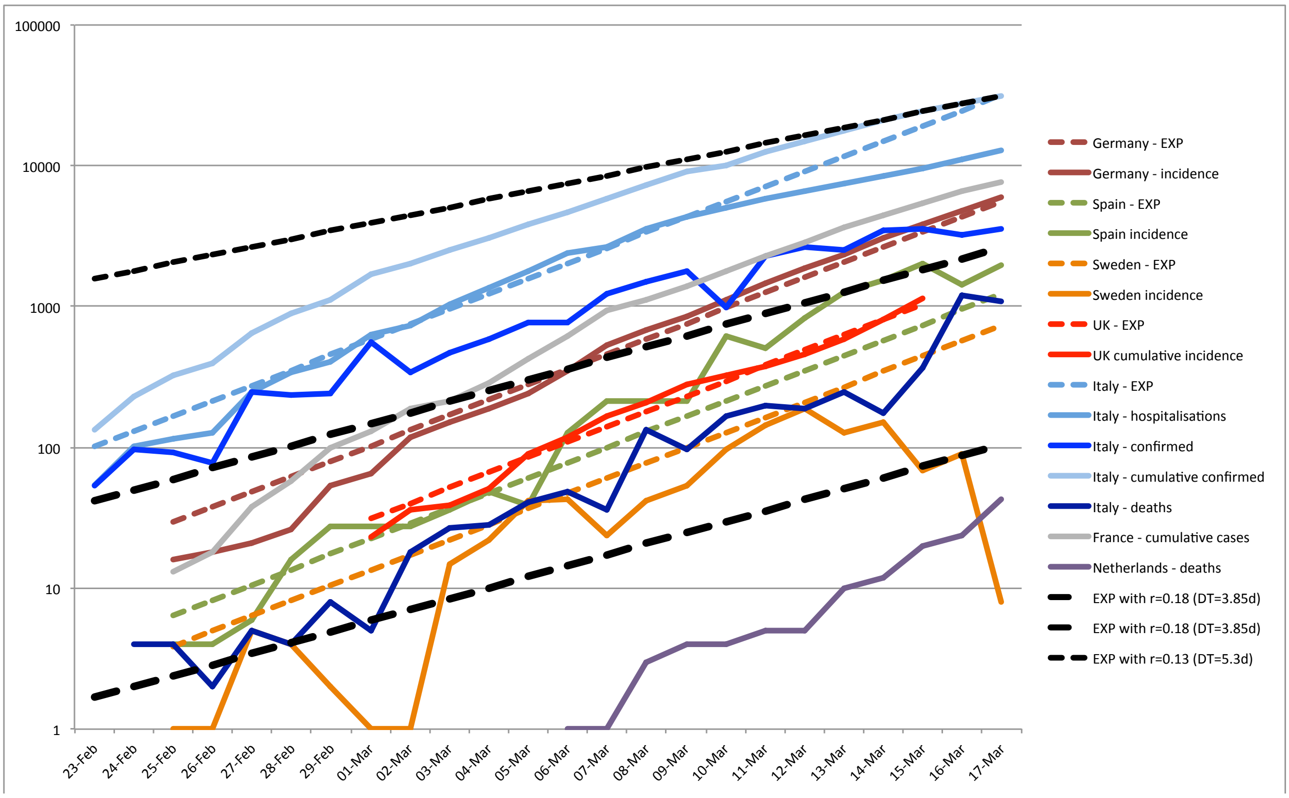


Fig. 2: Same as Fig. 1, but on a log-scale.
Linear regression performed on cumulative confirmed cases (pink). Threshold on confirmed cases (pink horizontal dash-dotted line) added to explore how confidence interval in predictions change times NHS is overrun (pink vertical lines).
UK death data not fitted, but they don't influence predictions and are approaching those predicted using a simple multiplicative factor.

Further considerations:

- This is a simple exponential growth model, so it is highly dependent on the growth rate / doubling time. However, doubling times in Italy, France, Germany, Spain, Netherlands, etc. are all of ~3 days – see Fig. 3
- Data for last 2 days might show some effect of control policies put in place last week, but they might also just be random fluctuations.
- Even if effect is going to be visible, it's possible it's mild, as we don't know compliance, etc.
- Fast growth rates on confirmed cases (new daily or cumulative) might be slightly altered by errors in reporting, wrong definitions, delays, etc., but:
  - Hospitalisation and deaths are growing at the same rate (see Fig. 3);
  - The fast growth and high numbers will make all those small corrections irrelevant.
  - Any multiplicative correction, e.g. even due to a large fraction (10x) more cases than those reported, will be dwarfed but a faster exponential growth.
- The model assumes no control, but:
  - School closure will only have an effect visible a week from now;
  - Past control policies will become visible only in the next few days, but we cannot afford to wait until we see them before acting.
- This model should be used as a counterfactual, to estimate impact of control policies simulated with other models.
- Achieving controlled build up of herd immunity with these values of R_0 and of speed of spread is almost impossible, especially if we need to wait for 1-2 weeks before seeing the effects of anything we do.
- There remains the previously identified problem of what to do when spread restarts after lifting control, but the trade-off between current and future mortality is almost impossible to quantify at present.
- See this **open letter from Italy** to the scientific community**:** https://docs.google.com/document/d/1E5AOOKQrFrhNtl5au1N5FCBqKmJiRtwwUjXIBT2vMSc/edit?fbclid=IwAR3_zvJFOFfNtQ2Eu4kBnvm-Nm4ksQj0ROEkRyoay4w_jklOZNzG3OgTTlc



<u>Fig. 3</u>: Growth rates in different EU countries.
A mixed bag of numbers of confirmed cases per day (incidence), cumulative confirmed cases, hospitalisations and deaths, all showing similar growth. Only exceptions are:

- *Sweden, which seem to have controlled it or has not reported well in the past week;*
- *Italy, with growth in new confirmed and cumulative confirmed cases slowing down from beginning of March (quarantining infected towns from 22-23 Feb) and growth in hospitalisations slowing down around a week later. Deaths do not appear to be slowing down yet.*
- *Deaths in Netherlands and new cases in Spain growing even faster than the rest.*

<u>Coloured dashed lines</u> are pure exponential growth with r = 0.25/day (doubling time of 2.77 days, same as for UK) and a suitably chosen intercept (not fitted).
<u>Black thick dashed lines</u> show growth at r = 0.18/day (doubling time of 3.85 days).
<u>Black thin dotted line</u> shows growth at r = 0.13/day (doubling time of 5.33 days). Notice how that is roughly the growth in cases (new and cumulative) and hospitalisations in Italy now.

Why so different from previous predictions?

- WHO estimates of R_0 around 2-2.5.
- I have a theory (to be verified):
  - Most estimates of R_0 coming from early observations from Wuhan
  - Growth rate in Wuhan very biased due to huge flow of people (including infectives) to other parts of China for Chinese New Year. So:

    r_observed = r_true - outflow

  - My early estimates from Wuhan showed r = 0.18, but Wuhan not a “closed system”
  - If including all of China (a “closed system”), estimates are more like r = 0.22-0.24 (work in progress).
- To do: analyse various estimates of R_0 (range 2-6+) in the literature to see where they come from.
- **However, it doesn’t matter why – the overwhelming EU (and UK) evidence is doubling time < 3 days.**

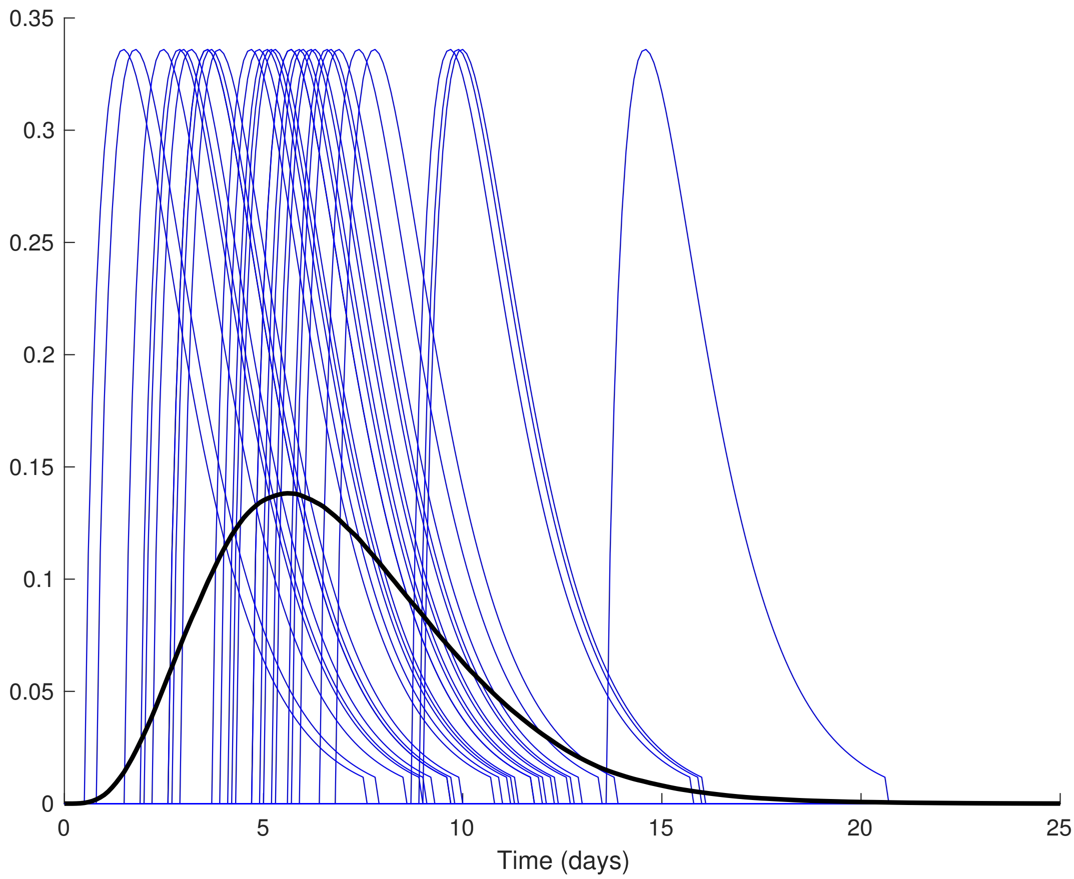
Estimation of R_0

- The urgency for action is mostly due to the fast pace of this pandemic, which comes straight from data. Data is limited and potential biases are unclear, but trends appear consistent across countries and over multiple weeks.
- Estimates of R_0 unavoidably introduce assumptions, so less direct, but relevant for control.
- Assuming:
    - A Gamma-distributed latent period with mean of 4.83 days and standard deviation of 2.78 days (estimates from Manchester)
    - A Gamma-shaped infectivity profile, with mean 2.2 days and standard deviation of 1.64 days, truncated after 7 days (suggested for consistency across models used when discussing impact of school closure – no current evidence for or against this)
    - All individuals equally infectious

  I get the following estimates of R0:

r	doubling time	R0
0.13	5.33	2.30
0.18	3.85	3.07
0.25	2.77	4.47

- 30 realisations of this infectivity profile and the mean of 10 000 realisations (then used to estimate R_0 from the Lotka-Euler equation) look like this:



- Adding a huge variation in infectivity between different individuals (Gamma distributed total infectiousness with mean 1 and sd = 1/sqrt(k), with k = 0.25), gives virtually the same result for R_0.