SPI-M-O: Medium-term projections and model descriptions

Date: 31st October 2020.

Background

1. These projections represent SPI-M-O's best assessment of the potential trajectory of the epidemic over the next six weeks, based on current trends and the data available up to 26th October. **The projections are not forecasts or predictions. They represent a scenario in which the trajectory of the epidemic continues to follow current trends and do not account for the impact of future policy or behaviour changes.**

2. The delay between infection, developing symptoms, hospitalisation and death means the projections **cannot fully reflect changes in transmission that might have occurred over the past two to three weeks**. Furthermore, this delay means any policy interventions or behavioural changes would take one to two weeks to impact the number of hospitalisations and three to four weeks to impact the number of deaths.

3. Each SPI-M-O modelling group produce their own set of projections. These individual projections are combined to form a consensus and then reviewed by SPI-M-O and agreed by the Scientific Advisory Group for Emergencies (SAGE). A description of the statistical methodology used to combine the projections can be found in the paper "Combining COVID-19 model forecast intervals".

4. Beyond two weeks, the projections become more uncertain with greater variability between individual models. This reflects the large differences that can result from fitting models to different data streams, and the influence of small deviations in estimated growth rates and current incidence. Projections in the nearer term, however, are more certain; for example, those projected to die from COVID-19 in two weeks' time are likely to already be infected.

5. The charts included in the annex show the consensus medium-term projections SPI-M-O have produced for daily hospital admissions and deaths in England. Please note **these projections are plotted on a *log scale* to better display the large range of values**. The data from before the projections start is plotted in red. Some of these data points have been revised since the projections were produced; this is particularly the case for the number of daily deaths where reporting delays can result in significant upward revisions. The subsequent number of hospital admissions and deaths once the projections begin are shown in black, allowing past projections to be compared to the outturn data.

Model descriptions

In addition to the links provided for each model, Section 9 and Appendix 2 of the paper "*Reproduction number (R) and growth rate (r) of the COVID-19 epidemic in the UK: methods of estimation, data sources, causes of heterogeneity, and use as a guide in policy formulation*" describes some of the models listed as of August 2020. Please note that models will have been further developed and refined in the weeks since this publication.

Some of the models below are deterministic, whilst others are stochastic. In deterministic models, the output is determined by the input data, conditions and parameter values. In stochastic models, there is some randomness; the same input data, conditions and parameters values may lead to different outputs each time. Stochastic models are generally run multiple times and an average of outputs taken.

Modelling Group	Published pre-print or paper on model	Description
London School of Hygiene and Tropical Medicine EpiNow2 Model	A detailed description of the model can be found in this pre-print paper. Further refinements to the model continue to be made.	A semi-mechanistic model that estimates current and future hospitalisations. The trajectory of infections that lead to hospitalisations is reconstructed using a renewal equation model and distributions of the incubation period and time to hospitalisation and positive test. The resulting trajectory is fitted to the number of new and newly confirmed cases in hospital using a negative binomial observation model with a multiplicative day-of-the-week effect. A more detailed description of the model can be found here, although refinements continue to be made.
London School of Hygiene and Tropical Medicine Transmission Model	A paper is being prepared for pre-print publication in the coming weeks.	Age-structured dynamic transmission model for the UK, four nations and seven NHS regions of England. This model uses Google mobility data to parameterize the impact of social distancing measures in each NHS region. The model is fitted to deaths, hospital admissions and bed occupancy, seroprevalence and virus prevalence in each region.
Imperial College London	Further information on the model including the source code is available	Age-structured stochastic compartmental transmission-dynamic Susceptible-Exposed-Infectious-Recovered (SEIR)-type model. The model incorporates hospital care pathways and disease transmission within care homes to reconstruct the course of the epidemic in the three devolved nations and seven NHS regions of England.

Modelling Group	Published pre-print or paper on model	Description
	here. Further refinements to the model continue to be made.	Infected individuals may remain asymptomatic, develop mild symptoms or influenza-like illness. Parameters such as susceptibility, mixing patterns and the probability of developing symptoms, being admitted to hospital and death are age dependent. Model parameters are fitted to epidemiological data including hospital admissions and bed occupancy, ICU admissions, deaths, Pillar 2 testing and serological data. The exact data and sources used vary across regions. Further information on the model can be found here, although refinements to the model continue to be made.
University of Warwick	A detailed description of the model as of September 2020 is available in this paper. Further refinements have continued to be made since this publication.	Age-structured compartmental ordinary differential equation (ODE) model, using a generalised Susceptible-Exposed-Infectious-Recovered (SEIR) framework to model the epidemic in the three devolved nations and seven NHS regions of England. The infectious compartment is split into symptomatic (detectable), and largely asymptomatic (undetectable) infections. Parameters such as susceptibility, mixing patterns and the probability of developing symptoms, being admitted to hospital and death are all age dependent. Model parameters are fitted to epidemiological data including hospital admissions and occupancy, ICU admissions, deaths, serological data and for some model configurations the proportion of Pillar 2 tests that are positive. The exact data and sources used vary between nations. A more detailed description of the model as of September 2020 is available here, although further refinements to the model structure and fitting procedures have continued to be made.

Modelling Group	Published pre-print or paper on model	Description
University of Manchester/Oxford/Lancaster	A paper is being prepared for pre-print publication in the coming weeks.	Deterministic Susceptible-Exposed-Infectious-Recovered (SEIR)-type model. The model is not age-structured, but employs different transition rates between compartments depending on the next state (e.g. those recovering naturally and those admitted to hospital spend different times in their infectious state). Infected cases can be asymptomatic or symptomatic; symptomatic cases recover or go to hospital; hospitalised cases recover, die or proceed to ICU; and ICU cases die or step down to hospital and then recover. The model is fitted to hospital data and is used to project the number of COVID-19 hospitalisations in the UK, four nations and seven NHS regions of England independently. The data streams used vary between nations, but include at least hospital admissions, ICU bed occupancy and hospital deaths. Parameters related to infection outside of hospitals are fixed.
University of Cambridge MRC Biostatistics Unit and Public Health England	A detailed description of the model as of August 2020 is available in this paper. Further refinements have been made since this publication.	Age- and spatially-structured deterministic Susceptible-Exposed-Infectious-Recovered (SEEIIR, with two exposed and infectious classes) transmission model, combined with disease reporting models for the seven NHS regions of England. The model includes age- and time-varying infection fatality rates, with other parameters such as susceptibility and mixing patterns also being age-dependent. The model's parameters are fitted to data including but not limited to deaths and serological data, such as antibody prevalence, as well as recent mobility data. A more detailed description of the model as of August 2020 is available here. Please note that further refinements have been made to the model since this publication.

Annex: SPI-M-O medium term projections for daily hospital admissions and deaths in England compared to outturn data.

Figure 1: Medium-term projections for daily hospitalisations in England on a *log scale*. Hospitalisations are defined as patients admitted with confirmed COVID-19 and those who test positive in hospital after admission. Blue shows the consensus projection based on current trends, not including the effects of past or future policy or behaviour changes that were yet to be reflected in the data available at the time. The dark blue shows the interquartile range and the light blue the 90% CI. The red dots indicate the data from before the projections begin, and the black dots the number of daily hospitalisations since. Please note some of the data in red has been revised since these projections were produced.

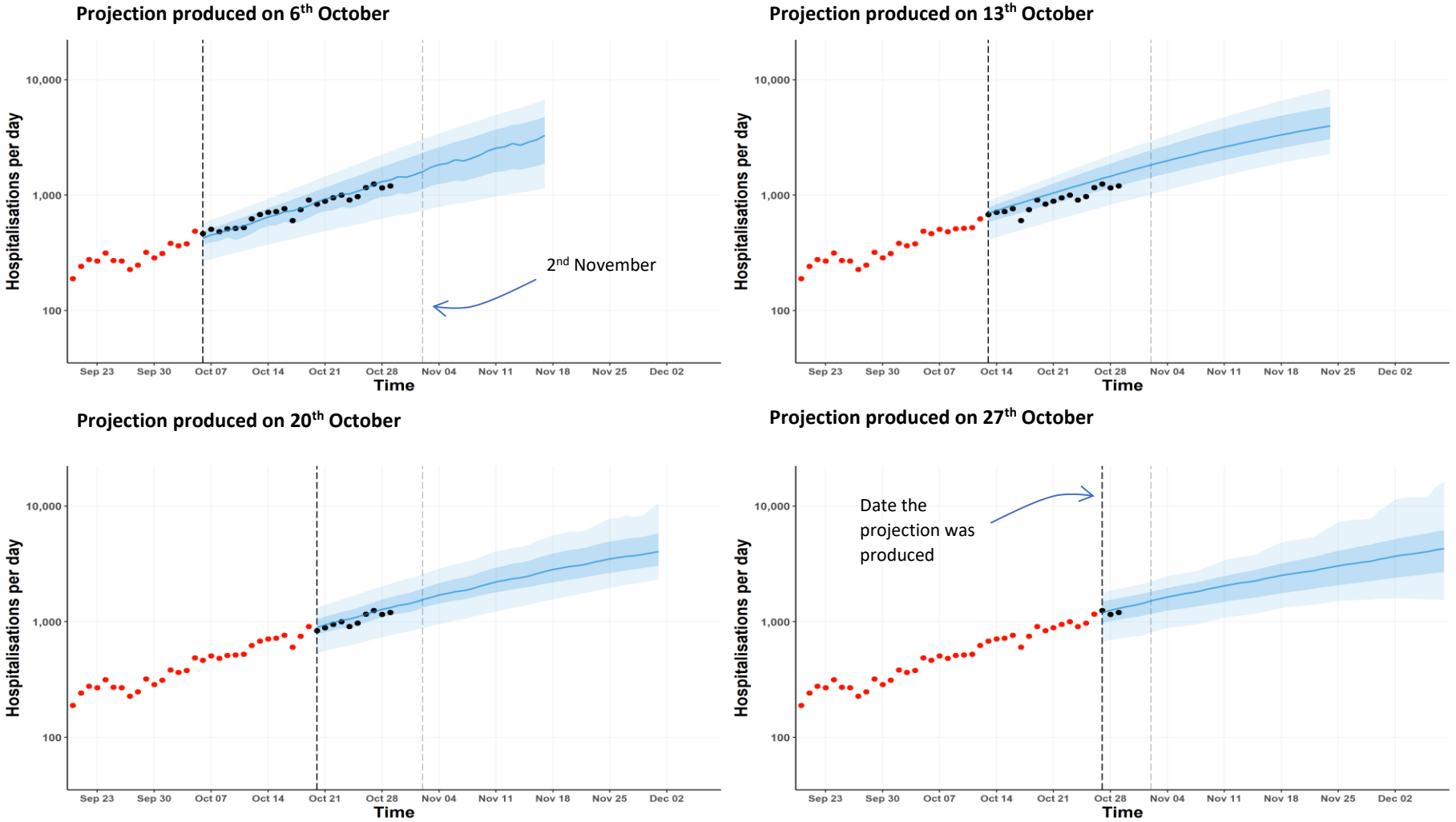

Figure 2: Medium-term projections for daily deaths by date of death in England on a *log scale*. Deaths are defined as people who have tested positive for COVID-19 and died within 28 days of their first positive test. Blue shows the consensus projection based on current trends, not including the effects of past or future policy or behaviour changes that were yet to be reflected in the data available at the time. The dark blue shows the interquartile range and the light blue the 90% CI. The red dots indicate the data from before the projections begin, the black dots the number of daily deaths. Please note some of the data in red has been revised since these projections were produced. A previously published version of this document incorrectly plotted data points for all deaths following a positive test, instead of deaths with 28 days. The projections themselves are not affected and neither are the data presented at the press conference.