**Overview of COVID-19 Work**

**Preliminary COVID-19 Analysis**

* **Modelling the effect of impact of sequential non-pharmaceutical interventions to control a COVID-19 outbreak (11/03/20)**
  + Used a SIR mathematical model to explore the impact of two time-limited, sequential reductions to COVID-19 transmission on the epidemic curve.
  + We identified that the modelled NPIs would greatly mitigate the maximum peak prevalence of the epidemic curve, but also greatly extend the length of the epidemic from <1 year to >2 years.
  + Analysis carried out for SPI-M, sent to SAGE.
* **Exploring the impact of immunity on COVID-19 “wave” dynamics (19/03/20)** 
  + Used variations of the SIR model structure to explore the transmission dynamics of COVID-19 resulting from the introduction of a single package of NPIs with different assumptions regarding the presence of immunizing infection (SIR, SIRS and SIS models).
  + We identified that the presence of immunity would have very little impact of the dynamics of the initial COVID-19 epidemic wave, but with subsequent epidemic waves (2nd, 3rd) showing substantial differences across SIR, SIS and SIRS models.
  + Therefore the presence of long-term immunising infection would only have an impact as the COVID-19 progresses in the later stages of the outbreak.
  + Analysis carried out for SPI-M , sent to SAGE.
* **Exploring the impact of varying the duration of non-pharmaceutical interventions on epidemic peak timing (19/03/20 – 21/03/20)**
  + A SIR model was use to explore the impact of varying NPI duration on the size and the timing of a 2nd (post-intervention) COVID-19 epidemic peak, relative to the initial 1st epidemic peak.
  + We identified that by increasing the NPI duration by intervals of 14 days, epidemic peak can be delayed by 14-16 days.
  + This delay was constant as intervals of 14 days were added to the NPI duration.
  + Increases in the NPI duration also had mitigating effects on the size of the epidemic peak. However a saturation effect was observed, with increases in NPI duration of >42 days having little effect on mitigating the epidemic peak.
  + We highlighted that increasing the duration of an NPI can be used to delay the peak of a simulated COVID-19 epidemic and “buy-time” for the build-up of health capacity.
  + Analysis carried out for SPI-M, sent to SAGE.
* **Impact of varying the efficacy of non-pharmaceutical on COVID-19 transmission dynamics (31/03/20)**
  + Used a SIR model to explore how differential adherence to introduced NPIs can impact the epidemic peak and attack rate of a simulated COVID-19 outbreak.
  + This simple analysis highlighted that lower NPI efficacy will have a reduced effect at mitigating the peak prevalence and attack rate of a COVID-19 outbreak.
  + Analysis carried out for SPI-M.

**Large Projects**

* **Segmentation and shielding of the most vulnerable members of the population as elements of an exit strategy from COVID-19 lockdown (01/04/20 – 20/05/20)**
  + A SIR mathematical model was used to explore the concept of “enhanced shielding” to protect vulnerable segments of the population and their closest contacts, termed shielders, while ramping down restrictions for the non-vulnerable segments of the population.
  + We identified a range of strategies that allow for the relaxation of restrictions in the non-vulnerable segments of the population, while maintaining or strengthening interventions in the shielder/vulnerable segments, this was explored in the context of preventing a excessive peak of COVID-19 prevalence in any of the population segments.
  + Epigroup formalised this work in April/May 2020 and a manuscript was accepted (awaiting publication) in the “Modelling evidence supporting the COVID-19 response in the UK” issue of the *Philosophical Transactions of the Royal Society B*.
* **Optimising time-limited non-pharmaceutical interventions for COVID-19 outbreak control (27/02/20 – 09/03/20, 12/06/20 - 29/08/20)**
  + A SIR mathematical model was used to explore the feasibility of optimising five time-limited non-pharmaceutical intervention scenarios to minimise the peak prevalence and the attack rate of a simulated COVID-19 outbreak.
  + Optimised NPI interventions were found to be highly effective at minimising the human health outcomes of COVID-19, but were found to be fragile and very sensitive to implementation error.
  + We identified the use of less-effective, but more robust “sub-optimal” NPIs, which are able to reduce peak prevalence and attack rate over a wider, more achievable parameter space.
  + This work provided an illustrative example of the concept of NPI optimisation across a wide range of different NPI scenarios.
  + This work was done on an ad-hoc basis in March during the initial stages of the UK COVID-19 outbreak for SPI-M and was later sent to SAGE.
  + Epigroup formalised this work in July/August 2020 and a manuscript was submitted (under review) to the “Modelling evidence supporting the COVID-19 response in the UK” issue of the *Philosophical Transactions of the Royal Society B*.

**Later Modelling Requests**

* **Trigger day timing of non-pharmaceutical intervention timing and the impact on COVID-19 transmission dynamics (22/06/20 – 24/06/20).**
  + Used a SIR model to modify the timing of a NPI introduction by ±7 days to identify the effect on the size of the resulting COVID-19 epidemic curve.
  + The impact of even a small delay in the introduction of an intervention has profound implications, with a large increase in the epidemic peak.
  + Analysis carried out in preparation for Epigroup representation at the UK Parliament Select Committee.
* **Effect of the importation of cases on Scottish COVID-19 transmission dynamics (18/09/20)**
  + Explored the impact of the importation of cases into Scotland (5 or 25 cases per day) using a basic SIR mathematical model.
  + The impact of importation was explored in the context of varying the magnitude of local transmission (R0).
  + We identified the number of COVID-19 cases attributable to importation compared to a baseline without importation.
  + The highest number of cases attributable to importation was identified where local transmission was lower and the number of imported cases was higher.
  + Analysis carried out for the Scottish Government COVID-19 Advisory Group.
* **Modelling the impact of non-pharmaceutical interventions to reverse the growth in COVID-19 incidence in Scotland. (01/10/20 – 05/10/20)**
  + Used a SIR model to explore the time taken for modelled NPIs to reverse the increase in COVID-19 incidence back towards a threshold of 150 cases/day.
  + We identified that a stronger and earlier introduction of NPIs reduces the time needed to return COVID-19 incidence below the 150 cases/day threshold and reduce the overall number of deaths and cases during the outbreak.
  + This was explored in the context of a second Scottish COVID-19 epidemic wave.
  + Analysis carried out for the Scottish Government COVID-19 Advisory Group.
* **Illustrative model-based analysis of vaccination and release strategies (Scotland) (26/12/20 – 05/01/21)**
  + Used a SIRV model to explore different scenarios for the phased removal of NPI restrictions as vaccination is rolled out.
  + The SIRV model stratified infected individuals based on vaccination status and with three subpopulations being modelled to represent different vaccination priority groups.
  + This analysis was parameterised for a Scottish population at the beginning of the UK vaccination campaign (November 2020).
  + Sensitivity analyses were conducted exploring the senstivity of the model results to alterations to vaccine efficacy, coverage, presence of waning immunity (natural/vaccine-induced), reduced mixing etc.
  + Release of restrictions for the entire population immediately after the vaccination of the highest priority groups resulted in a major resurgent epidemic across the majority of explored senstivity analyses.
  + A phased release of NPIs (release of NPIs following the vaccination of the respective priority group) and full release after vaccination of the medium priority vaccination group did not result in a resurgent epidemic across the majority of senstivity analyses.
  + Low vaccine coverage, efficacy and the presence of waning vaccine-induced immunity compromises the efficacy of NPI release strategies resulting in large resurgent epidemics following NPI release.
  + Analysis carried out for SPI-M.