# Mathematics for Decisions

## Modeling and Simulation: A call to action for *COVID-19* (based on Squazzoni et al. (2020)

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# Overview

# The COVID-19 Global Challenge

- **Up to April 21**:
  - Total cases: 2,483,180
  - Total deaths: 170,501
  - Total recovered: 652,588
- Governments are taking **draconian measures** that few months ago might have caused a revolution:
  - Social distancing;
  - Intensive quarantine;
  - Lock-down;
  - Cancellation of mass gathering events;
  - Strict traffic restrictions enforced;
  - Companies shut if not essential.
- **Consequences**:
  - Dramatic loss of lives worldwide;
  - Crisis of health care systems;
  - Economic meltdown;
  - Pressure upon mental health of individuals under quarantine and lock-down measures.

# Scientists need to go out from their *comfort zone*

**Main reasons**:

1. Need for a rapid response largely incompatible with the "normal" path of scientific progress (peer review, testing and replicability to ensure the validity of scientific claims and research findings);
2. Many issues:
   - Public pressure;
   - Misplaced expectations about the role of science;
   - Misunderstanding about the certainty of scientific knowledge;
   - Confusion about public responsibility.
3. Interdisciplinary perspective: the response has environmental, ecological, political, socio-psychological and economic aspects.

# Potential of and Gaps in COVID-19 Agent-Based Models

- Predicting complex outcomes when crucial data is unreliable/unavailable and theories are undetermined;
- Repurposing models outside their original purposes by confusing original illustrative/explanatory purposes with prediction;
- Ignoring good practices of model transparency.

# The case of Imperial College

- They predicted a huge number of people would die in Britain unless severe policy measures were taken;
- It worked: isolation, household quarantine, closing of schools and universities; results endorsed by the UK government, influenced the US administration and alerted the French administration;
- BUT:
  - The model was written 13 years ago by Neil Ferguson and adapted;
  - Now code and paper are available, but not right away;
  - It does not enable the consideration of other policy options;
  - It does not use sufficient data across different contexts;
  - It does not help to understand social conditions and consequences of measures.

# COVID-19 challenges - 1) Prediction

- Displaying all sorts of non-linearities, heterogeneities and sensitivities is very challenging, independently of the scientific method used to tackle the problem;
- Small, unnoticed events may generate unforeseen, large-scale consequences (butterfly effect);
- Modelling experts strive to minimise the limitations;
- But accurate data suitable for complexity-friendly, agent-based models are not yet available (update April 23: now some data are, at https://data.europa.eu/euodp/en/data/dataset/covid-19-coronavirus-data);
- Precise estimation of the death toll at the end of the crisis is still out of scientific reach.

# COVID-19 challenges - 2) Modelling human behaviour

- Complex social dynamics related to transmission, response and compliance arise from the behaviours of individuals (not predictable, not optimal decision, etc.);
- Psychological effects of quarantine (see Brooks et al. (2020));
- Difficult modelling task and cross-disciplinary collaboration: incorporating agents' heterogeneity in tersm of cognition and behaviours;
- Models that cannot examine the social dynamics of COVID-19 contagion are missing a crucial aspect that has serious implications for any possible estimation, scenario or prediction;
- Agents are not simply virus carriers and their preferences and actions have implications at multiple levels.

# COVID-19 challenges - 3) Data calibration and validation

- Sometimes data are unavailable and during emergencies, experimental samples or tests might be impossible or unethical;
- Fine-tuning parameters of a predictive model via empirical validation tests during an event can generate confusions;
- Data with fine-grained quality needed to calibrate and validate COVID-19 models are dispersed, fragmented and rarely available in a comparable time window, scale and format, subject to biases;
- Numbers are also dependent on:
  - Actual number of cases;
  - Testing capabilities in a given region and sensitivity/specificity of tests;
  - The same definition of "*cases*";
- **Building predictive models based on the number of cases without considering how cases were defined and data collected can lead to biased estimations**;
- Possible dramatic calibration/validation consequences.

# A call to action

1. **To the community of agent-based modellers and computational social scientist**: maintaining high standards of model building and committing to best practisces of transparency and rigour for replicability;
2. **To institutional agencies**: engaging the most trusted scientific associations in setting up data infrastructures in order to make data available to the academic community while protecting stakeholders' interests.

# Best practices

1. **Using open source software and tools** (e.g., NetLogo, MASON) to build models to minimize obstacles to replication and effective access costs for reviewers and possible re-users;
2. **Adopting standard protocols** to document models to make easier for reviewers and re-users to assess model properties and building blocks, while allowing model builders to reflect on the adequacy of their models's structure and features;
3. **Using online repositories** (e.g., ComSES, GitHub) to archive fully documented models before submission of a paper to a journal to speed up assessment and replicability.

# Smaldino's NetLogo model

- Generic NetLogo SIR model of disease transmission, timely and openly accessible for the public;
- Main goal: to illustrate the possible consequences of an (unsuccessful) lock-down and of social distancing on flattening the curve of population contagion;
- Not specific to COVID-19 and no explicit implementation of mortality due to an editorial decision by the newspaper;
- Links:
  - Blog post: http://smaldino.com/wp/covid-19-modeling-the-flattening-of-the-curve/
  - NetLogo model (web version): http://modelingcommons.org/browse/one_model/6224#model_tabs_browse_info

# Seven modelling purposes by Edmonds et al. (2019)

| Purpose | Value in a crisis context | Usefulness to decision-makers | Risks |
|---|---|---|---|
| Prediction | Ability to anticipate and compare intervention scenarios (including the consequences of doing nothing). Assessment of uncertainties, and development of 'robust' policies that minimize maximum regret. Base line numbers to use in planning. | If answers to questions can be derived quickly enough, and interventions formalized accurately, it could make a valuable contribution to discussion over interventions. | Over-reliance on the model as an 'oracle', inappropriate political exposure of developers, inability of an effectiveness-focused model to forecast policy utility. Often, the quality of data to calibrate important model parameters is questionable, especially during an event. It is also not necessarily the case that decision-makers will adopt the policy the model recommends. |
| Explanation | Explanation could address questions such as how we (might have) arrived at a particular outcome, but does not guarantee that the particular causal chain that really led us there is the one simulated. | More likely of use in 'lessons learned' exercises, especially if in conjunction with several other models with a similar purpose. | Enacting measures that address *possible* causes rather than *the actual* causes risks unintended consequences in future. |
| Description | A descriptive model could be used to explore scenarios in a heavily constrained context. | Unlikely to be of value at the national scale, in part because the generalizations needed to model at that scale would be inconsistent with this modelling purpose. Could be used for local levels, however. | Elements not simulated might prove later to be relevant. Over-generalization from a model fitted to specific circumstances is also a risk. Possible confusion with prediction. |

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|---|---|---|---|
| Social Learning | Potentially valuable in resolving conflict. The main value is the process by which the model is constructed, rather than the model itself. | Resolving arguments, encouraging people to see others' points of view, observing the logical consequences of beliefs. | Modelling what people in a group believe does not guarantee relevance beyond the group, or to the empirical world. Usual risks of group-work (e.g. groupthink, dominant voices) need to be carefully managed by facilitators. |
| Illustration | Useful for communication and education of ideas to the general public. | Provides a means of communicating reasoning behind policies for dealing with the crisis that may be unpopular | Under certain conditions, the model may not behave consistently with the communicated ideas. |
| Theoretical Exposition | Unlikely to be of value. | In a crisis context, decision-makers will have little time for comparing or exploring theories. | No (necessary) connection with the real world in this purpose risks over interpretation if attempt is made to use it. |
| Analogy | Of little value other than distracting the modellers themselves from the psychological consequences of the crisis. | Not useful. | Over interpretation of findings that merit more rigorous study using, say, theoretical exposition or explanation purposes. |

Table 1: A taxonomy of modelling purposes, value, usefulness and risks during a crisis (adapted from Edmonds et al. 2019).

In my opinion, the most important ones are (in order of relevance): *Prediction*, *Social learning*, *Illustration* and *Description*.

# References


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