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Roles and Challenges of Mathematical Modellers in the Era of Coronavirus Disease 2019 (COVID-19) Pandemic

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ABSTRACT
The emergence of Coronavirus Disease 2019 (COVID-19) creates huge opportunity for mathematical modellers to play a pivotal role in policy decision making towards pandemic suppression and containment. Modelling studies can serve as a tool to measure the impact of policies and identify leverage point where the policies will be most effective. Economic evaluation studies combined with epidemic modelling help gauge the economic impact of COVID-19 as well as the monetary benefit and payoff given various COVID-19 measures. The models can also project future end-game scenarios of the pandemic. The academic modellers mostly work with theory-driven research questions, while the service-oriented modellers usually deal with day-to-day operational questions and need to validate the findings against policy direction in equal importance with scientific validation. A platform to finetune diverse understandings and interests between policy-makers and modellers should be established.

Keywords: *Coronavirus disease 2019; Pandemic; Mathematical modellers; Challenges*

Contribution of modelling study in pandemic response

Since the advent of Coronavirus Disease 2019 (COVID-19), a number of mathematical modellers have used diverse techniques to assess the dynamics of disease transmission [1]. The modelling studies of COVID-19 pandemic gain much more substantial attention from the wider society (including, government, media and general population) than for any previous pandemic. This may be attributed to the dramatic impact of COVID-19 on almost all walks of life, and the world had little knowledge on the disease at the very beginning of the pandemic. At the same time, it means that the world is in dire need of research in all angles of COVID-19. This is the first time since the H1N1 influenza pandemic in 2009 when there is an unprecedented advancement in global communication and technical support in modelling studies on emerging diseases [2]. Novel model frameworks, improved computational techniques, public data sharing, improved code availability, better visualisation methods and integration of models across scientific paradigms are observed in the current scientific arena.

Policy-makers involve modellers in various steps of the policy process, though some models face considerable criticism and their limitations require serious acknowledgement [3,4]. A clear example can be noticed in the case of China where border-closure policy was strongly influenced by the modelling. Imai et al and De Salazar et al suggest that, during the early phase of the pandemic, the incidence rates were significantly under-reported both in and outside China [5] . China then imposed an internal travel lockdown on Wuhan in late January 2020 and many countries enacted the same mobility restrictions in the following months [6]. The modelling studies on COVID-19 appear in numerous forms. A systematic review on 242 peer-review articles related to COVID-19 demonstrate that about 46% of the papers used compartmental models, and 32% used time-series and growth models [1]. Few used novel analysis techniques, such as artificial intelligence (7%), Bayesian approach (5%) and agent-based models (1%) [1].

With respect to model application, the model projections based on viral infectiousness help demonstrate the pandemic potential, which can be used as a guidance for healthcare resource planning [7,8]. The models may serve as a tool to assess the impact of policies and address optimization problems like which policy is effective in which sub-population by what approaches.

The economic evaluation studies combined with epidemic modelling help gauge the economic consequences of COVID-19 and the monetary benefit (or payoff) for each measure. Ultimately, the models can project future end-game scenarios and address certain key policy questions, for instance, whether, how, and when suppression can be achieved [9,10].

Platform where modellers interact with policy-makers

The interaction between policy-makers and modellers is highly dynamic. At one end, some mathematical modellers who are not part of the state authorities start a direct communication with the wider public through academic publications or media campaign. Once their findings are 'bought-in' by the public then they become a key input for policy decision.

The majority of these 'academic modellers' work in educational institutes which, literally, are not always part of the bureaucracy. Often, these modellers worked with theory-driven research questions via a relatively 'clean' secondary dataset. A scientific validation is the foremost concern of the analyses. A prominent example of academic modellers is a team by Imperial College London, which heralded the widespread of disease across UK and US if a suppression strategy to hammer reproduction number down to below one was not pursued [8].

Some renowned academic institutes commissioned groups of modelling experts to address a vast range of questions, and sometimes these questions lie beyond a single country concern. Another obvious example is 'The Lancet COVID-19 Commission' [11] and 'COVID-19 International Modelling Consortium [CoMo Consortium] by University of Oxford and Cornell University' [12]. The function of these initiatives is greatly diverse, from descriptive monitoring of the global progress to addressing complicated multi-faceted issues (such as genomic epidemiology, health-systems preparedness and political economy of the pandemic) [12].

At the other end, there are mathematical modellers who are part of the bureaucracy, namely, 'service-oriented modeller'. Oftentimes, the state authorities, like the Ministry of Public Health, or even the Cabinet itself, set up groups of experienced technocrats and official public health specialists to work on mathematical models to respond to the pandemic.

Some key differences between service-oriented modellers and academic modellers are presented in Table 1. While academic modellers are mostly engaged with theory-driven questions, service-oriented modellers are basically influenced by policy directions and field implementation in practicality. Additionally, service-oriented modellers may have more advantages than academic modellers in terms of data accessibility in a timelier manner despite the fact that these data are not often well organised and sometimes subject to measurement error. However, the distinction between academic modellers and service-oriented modellers is just a fine line and some modellers play a dual role from time to time.

Challenges of how modelling studies can be injected in policy decision making

The inconvenient truths faced by all modellers are 'no model is perfect' and 'no model can address all policy questions.' In addition, not all the time, policy-makers make a decision based on evidence generated by the models. This situation happens partly because

Table 1 Key differences between academic modellers and service-oriented modellers

Characteristics	Academic modellers	Service-oriented modellers
Institution of modellers	- Mostly academic institutes (universities or research entities)	- Mostly government authorities (such as the Cabinet and the Ministry of Public Health)
Data involved	- Clean and structured but less timely - Accessed via public domains	- Timely but not well organized and often with higher inaccuracy - Accessed via internal database of the authorities
Model questions	Theory driven	Operation driven or policy driven
Model validation	Focusing on more complete scientific validation, based on external reliable data and less relying on expert opinion	Focusing on policy validation based on expert opinion and available data while keeping acceptable scientific rigour
Finding dissemination	-Research reports or academic journal -Direct communication with media	-Internal reports of the authorities -Direct communication with high-level officials or policy-makers

there are numerous contextual environments affecting policy decision, which cannot be captured by conventional mathematical parameters. The challenge herewith is how the modellers translate those influences into mathematical parameters and plug them into the model. This approach makes the model more comprehensive but the modellers need to spend a payoff with enhanced computational burden and risk of losing interpretation power.

Another key challenge is the policy question is not always well set from the outset, but policy-makers demand for mathematical models to initiate the policy direction. Such a situation contradicts conventional approach of the modellers where the work is usually commenced only once the research question is well-established.

Therefore, it is crucial to have a platform or process to finetune diverse understanding and interest of between policy-makers and the modellers. This process should be able to translate and tailor policy-makers' need while accounting for model feasibility; and the scientists (or the modellers) may contribute to the process by providing input or proposing better-specified objectives or modified interventions (raised previously by policy-makers) to the platform. To do so, a method for harnessing the collective knowledge of all concerned parties beyond policy-makers' and modellers' sphere is demanded [13]. This era, when the COVID-19 pandemic is still ongoing, is an opportune period to establish the aforementioned work platform; and if it is successful, the world will be better prepared for any emerging diseases or future unexpected health threats.

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