Institution: Imperial College London

Unit of Assessment: 02 Public Health, Health Services and Primary Care

Title of case study: Modelling the COVID-19 pandemic to underpin national and international policy

Period when the underpinning research was undertaken: 2005-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Marc Baguelin	Lecturer in Infectious Disease Epidemiology	2019 - present
Samir Bhatt	Reader	2016 - present
Anne Cori	Lecturer	2010 - present
Zulma Cucunuba	MRC/Rutherford Fund Research Fellow	2017 - present
Christl Donnelly	Professor of Statistical Epidemiology	2000 - present
Ilaria Dorigatti	Lecturer / Sir Henry Dale Fellow	2011 - present
Nuno Faria	Reader in Viral Evolution	Apr 2020 - present
Neil Ferguson	Professor/Vice Dean (Academic Development)	2000 - present
Axel Gandy	Chair in Statistics	2006 - present
Katy Gaythorpe	Research Fellow	2017 - present
Azra Ghani	Chair in Infectious Disease Epidemiology	2007 - present
Nicholas Grassly	Professor of Infectious Disease & Vaccine Epidemiology	2001 - present
Timothy Hallett	Professor of Global Health	2004 - present
Katharina Hauck	Reader in Health Economics	2010 - present
Alexandra Hogan	Imperial Research Fellow	2017 - present
Shevanthi Nayagam	Clinical Fellow	2017 - present
Lucy Okell	Senior Lecturer	2009 - present
Margarita Pons-Salort	Sir Henry Dale Fellow	2014 - present
Steven Riley	Professor of Infectious Disease Dynamics	2010 - present
Helena Unwin	Imperial College Research Fellow	2018 - present
Robert Verity	MRC Research Fellow	2013 - present
Eric Volz	Senior Lecturer	2013 - present
Patrick Walker	Lecturer	2010 - present
Peter Winskill	Imperial College Research Fellow	2014 - present

Period when the claimed impact occurred: February - December 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

The COVID-19 pandemic has had global impact requiring response from all countries. The Imperial team rapidly developed epidemiological models and undertook underpinning data analysis to support the UK and global response. Key evidence in March 2020, demonstrating the need to move to a suppression strategy to avoid the NHS becoming overwhelmed, led to the first UK national lockdown whilst weekly estimates of the reproduction number R, the epidemic growth rate and medium-term projections were used to support UK government policy and NHS planning. Analysis of the novel variant in December 2020 demonstrated its increased transmissibility resulting in tightening of restrictions.

2. Underpinning research (indicative maximum 500 words)

Through the establishment of the Medical Research Council (MRC) Global Infectious Disease Analysis (GIDA) Centre in 2007, Imperial researchers developed statistical methods and

mathematical modelling to support pandemic preparedness and response. In early 2020, the team focused: (i) estimating the speed and extent of spread - showing much higher levels of infection in Wuhan than had been reported and (ii) estimating severity utilising data emerging from China, summarised as age-stratified estimates of the infection fatality ratio (IFR) (1).

To support the UK response an individual-based simulation model developed for influenza pandemic planning (2) was re-parameterised to explore policy scenarios, including home isolation of suspect cases, home quarantine of household members, social distancing and school closures. Working closely with the NHS executive, model parameter assumptions were aligned with emerging UK data to output demand on hospital beds and intensive care facilities in the UK. This demonstrated that under even the most stringent mitigation scenarios (whereby transmission is reduced but not interrupted), UK health services would quickly become overwhelmed ("Report 9" (3)). In contrast, suppression strategies, whilst enabling the epidemic to be brought quickly under control, would need to be intermittently sustained until other therapeutic options became available.

A stochastic compartmental model was developed to provide real-time estimates of the epidemic and short-term projections of hospital demand (4). This was fitted to sub-national UK data with updates provided at least weekly to the SPI-M modelling subgroup, Scientific Advisory Group for Emergencies (SAGE) and other government departments. These included estimates of the reproduction number and epidemic growth rate, and projections of number of infections, cases, hospitalisations, and deaths in different sub-populations, including care homes. Model-based analyses were also performed in support of the test- and trace strategy, quantifying the impact of PCR-testing of symptomatic cases (and self-isolation of positive cases), weekly screening of health-care workers and contact tracing on transmission.

Internationally, country-level estimates were provided in March for the potential scale and impact of different strategies globally using a compartmental SEIR model. This model was subsequently extended to understand how epidemiological differences (including demography and mixing patterns) and differences in healthcare supply and quality could lead to different outcomes (and hence appropriate responses) in low- and middle-income countries (LMIC) compared to high-income countries (5). From May, the model was fitted at least weekly to data from all LMIC with country summary outputs provided on an open-access dashboard.

The team developed renewal equation models to determine the impact of specific non-pharmaceutical interventions (NPIs) (6). Estimates of their effectiveness in Europe and the US were provided on open-access dashboards. The framework was subsequently expanded to track the UK epidemic at the local authority area, with a public dashboard developed to provide short-term projections of the incidence per population head and the reproductive number R.

Towards the end of 2020 rapid research was undertaken to evaluate the significance of a new variant of SARS-Cov-2 that had emerged in the UK, with phylodynamic analysis coupled with epidemiological analysis demonstrating significantly increased transmissibility of the new variant of concern.

3. References to the research (indicative maximum of six references)

(1) Verity, R., Okell, L.C., Dorigatti, I., Winskill, P., Whittaker, C., Imai, N., Cuomo-Dannenburg, G., Thompson, H., Walker, P.G.T., et al. (2020) Estimates of the severity of coronavirus disease 2019: a model-based analysis. *Lancet Infect Dis*; 20(6): 669-677. DOI.

(2) Ferguson, N.M., Cummings, D.A.T., Fraser, C., Cajka, J.C., Cooley, P.C., Burke, D.S. (2006). Strategies for mitigating an influenza pandemic. *Nature;* 442(7101): 448-452. DOI.

(3) Ferguson, N.M., Laydon, D., Nedjati Gilani, G., Imai, N., Ainslie, K., Baguelin, M. et al. (2020) Report 9 - Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. DOI.

(4) Knock, E. Whittles, L., Lees, J., Perez Guzman, P., Verity, R., Fitzjohn, R. Gaythorpe, K. et al. (2020). Report 41 - The 2020 SARS-CoV-2 epidemic in England: key epidemiological drivers and impact of interventions. DOI.

(5) Walker, P.G.T., Whittaker, C., Watson. O.J., Baguelin, M., Winskill, P., Hamlet, A., Djafaara, B.A., Cucunuba, Z., Olivera Mesa, D., et al. (2020). The impact of COVID-19 and strategies for mitigation and suppression in low- and middle-income countries. *Science*; 369(6502): 413-422. DOI.

(6) Flaxman, S., Mishra, S., Gandy, A., Unwin, H.J.T., Mellan, T.A, Coupland, H., Whittaker, C., et al. (2020) Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe. *Nature;* 584: 257-261. DOI.

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4. Details of the impact (indicative maximum 750 words)

UK early response (January - April 2020)

Long-term investment by the MRC in the GIDA Centre at Imperial meant that as the pandemic emerged, staff were in place to rapidly respond, with over 50 staff and students mobilised in the first 6 months of the pandemic. The early work of the Imperial team was cited in the UK coronavirus action plan published on 3 March [**A**]. A summary of scientific evidence supporting the response to coronavirus published on 26 June [**B**] includes a unique section on "Imperial College Reports", including the first 8 online reports and reference (1 above) which provided the most robust estimates of the IFR. During February 2020, several Imperial College reports submitted to SAGE (meetings 9, 10, 12 and 13 [**C**]) directly informed SAGE advice to government. These include evidence of the potential impact of a range of NPIs - including banning of large gatherings, school closures and isolation of the elderly.

Whilst multiple UK teams contributed to the modelling evidence underpinning the UK lockdown that occurred in March 2020, "Report 9" (ref 3 above) was clearly one of the most globally influential, with the highest ever global score for impact in the Altmetric database (63,840 mentions as of 31 December 2020). The policy report summarised scenarios for NPIs developed in close collaboration with SAGE and the Government Office for Science. The results contained in this report were shared with SAGE, the government Chief Scientific Advisor, Chief Medical Officer, the NHS executive and Downing Street in the days preceding the first announcement from the UK government of a move to a suppression strategy on 16 March 2020 [**D**] that subsequently led to the first UK lockdown on 23 March 2020. The widespread global media coverage of Report 9 generated considerable global impact as evidenced by a 35% drop in global mobility from 17 March determined using Google mobility data (https://www.google.com/covid19/mobility/).

UK response (May 2020 - December 2020)

From May 2020 the UK government has published weekly estimates of the reproduction number, R, and associated growth rates [**E**], of which the Imperial team is one of several contributing modelling groups. These estimates, provided as part of a SPI-M-O "consensus statement", are shared across government departments, the NHS and local resilience forums and are used widely for planning purposes and to support local and national responses, thereby directly impacting the course of the UK epidemic.

The Imperial team have additionally provided medium-term projections to support government departments in the form of "Reasonable Worst-Case (RWC)" projections [**F**]. Similar RWC outputs were developed for an independent report produced by the Academy of Medical Sciences highlighting the need to prepare for a challenging winter period [**G**]. As testing capacity increased

in the UK and NHS Test and Trace was established, Imperial research directly informed the policy on mass testing [**H**].

In December 2020, phylodynamic analysis provided the first estimates of increased transmissibility of the new Variant of Concern 202012/01 (VOC) of up to 70%, the figure cited by the Prime Minister in his statement on 19th December [**I**] that led to the decision to put more regions of the UK into Tier 4 restriction, and eventually the 3rd UK national lockdown.

International response

During the early phase of the pandemic, the Imperial College team worked closely with World Health Organisation (WHO) as an official modelling collaborating centre, providing estimates of the transmissibility and severity of SARS-CoV-2 during January and February 2020. In March 2020, in response to a direct request from WHO, global estimates of the potential scale of the epidemic across all countries were developed ("*Report 12*" subsequently published as academic reference (6)) that were shared across several United Nation organisations, the World Bank, the International Monetary Fund and the Global Fund to inform early resource planning. An open-access dashboard accessed over 73,000 times as 31 December 2020, was developed and a user interface to the model software (www.covidsim.org) used by WHO to support country planning. The global fits from this model were used to underpin WHO estimates of financial need in low- and middle-income countries [**I**].

Public Engagement

The Imperial College team produced 42 open-access reports in 2020, with summaries translated into 7 languages. Major reports were accompanied by videos shared on social media and YouTube. Two reports were reproduced for the Science Journal for Teens. The team undertook extensive media engagement with major channels nationally and internationally, with >1,000 media appearances across 49 countries.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[**A**] UK Government Coronavirus Action Plan, 3 March 2020. Archived here.

[**B**] Summary of scientific evidence supporting the UK government response to coronavirus, 26 June 2020. Archived here.

[**C**] Reports from Imperial College considered at SAGE meetings: Meeting 9, 20th February 2020 (archived here); Meeting 10, 25 February 2020 (archived here); Meeting 12, 3rd March 2020 (archived here); Meeting 13, 5th March 2020 (archived here).

[**D**] Key government and SAGE documents informing the move to a suppression strategy: Meeting 16, 16th March (archived here); Meeting 17, 18th March (archived here).

[**E**] UK government weekly estimates of R and the growth rate of the COVID-19 pandemic released via SAGE. Process and confirmation of Imperial College membership of the SPI-M subcommittee providing estimates. Archived here.

[**F**] Medium-term projections of the UK COVID-19 epidemic released by UK government, 31 October 2020. Archived here.

[**G**] Academy of Medical Sciences, Preparing for a Challenging Winter, 14th July 2020 commissioned by the Chief Scientific Advisor. Archived here.

[**H**] Prime Minister's statement on coronavirus, 19th December 2020. Archived here.

[I] WHO projected healthcare resource needs for an effective response to COVID-19 in low and middle-income countries, Lancet Global Health, September 2020 (co-authored paper).

[J] Announcement by New York Governor's Office of Research Partnership with Imperial College London, May 18 2020. Archived here.