UK COVID-19 Inquiry: Module 2 - Rule 9 Request to Dr Petra Klepac - Reference: M2/SAGE/01/PXK1

Please provide the following information:

1. **A brief overview of your qualifications, career history, professional expertise and major publications.**

Current Appointments:

Assistant Professor of Infectious Disease Modelling, Department of Infectious Disease Epidemiology, London School of Hygiene and Tropical Medicine

Long term visiting researcher, Department of Applied Mathematics and Theoretical Physics, University of Cambridge

Education/Qualifications:

Dipl. ing. (Masters equivalent) Biology - ecology, University of Zagreb, Croatia 2001

Ph.D. Biological Oceanography, Massachusetts Institute of Technology, USA 2007

Employment:

Postdoctoral Fellow, Center for Infectious Disease Dynamics, Pennsylvania State University, USA, 2007-2009

Postdoctoral Research Associate and Lecturer, Ecology and Evolutionary Biology, Princeton University, USA, 2009-2012

Research Fellow, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, 2012-2014

Long term visiting researcher, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, 2014 - present

Senior Mathematical Modeller, Public Health England, 2015-2018

Assistant Professor of Infectious Disease Modelling, Department of Infectious Disease Epidemiology, London School of Hygiene and Tropical Medicine, 2018 - present

Current Grant Funding

UKRI. *JUNIPER (Joint UNIversity Pandemic and Epidemic Research)*. £3.8M. Nov 20 – Mar 22. Co-I.

UKRI MRC. *An analytical framework for Test, Trace and Isolate in the UK: optimising and targeting deployment alongside other measures* . UK MRC. £400k. 2020-2021. Co-I.

Selected COVID-19 Publications

Davis, E., T. Lucas, A. Borlase, T. M. Pollington, S. Abbott, D. Ayabina, . . . , T.D. Hollingsworth* and P. Klepac*. 2021. Contact Tracing Is an Imperfect Tool for Controlling

Covid-19 Transmission and Relies on Population Adherence. *Nature Communications* 12:5412

Prem K, Zandvoort Kv, Klepac P, Eggo RM, Davies NG, Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, et al. 2021. Projecting contact matrices in 177 geographical regions: An update and comparison with empirical data for the COVID-19 era. PLoS Comput Biol 17(7): e1009098.

Crellen, T., Pi, L., Davis, E.L., Pollington, T.M., Lucas, T.C. D., Ayabina D., Borlase A., Toor J., Prem K., Medley G.F., Klepac P. and D. Hollingsworth T. 2021Dynamics of SARS-CoV-2 with waning immunity in the UK population *Philosophical Transactions of the Royal Society B*, 376:20200274.

Lucas, T.C., Davis, E.L., Ayabina, D., Borlase, A., Crellen, T., Pi, L., Medley, G.F., Yardley, L., Klepac, P., Gog, J. and T.Hollingsworth,., 2021. Engagement and adherence trade-offs for SARS-CoV-2 contact tracing. *Philosophical Transactions of the Royal Society B*, *376*(1829), p.20200270.

Prem, K., Liu., Y., Russell, T.W., Kucharski, A.J., ..., and Klepac, P. 2020. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. *Lancet Public Health*

Davies, N.G., Klepac, P., Liu, Y. *et al.* 2020. Age-dependent effects in the transmission and control of COVID-19 epidemics. *Nat Med* 26, 1205–1211.

Klepac, P., Kucharski, A. J., Conlan, A. J., Kissler, S., Tang, M., Fry, H., & Gog, J. R. 2020. Contacts in context: large-scale setting-specific social mixing matrices from the BBC Pandemic project. medRxiv 2020.02.16.20023754;

Jarvis I.C., Van Zandvoort K., Gimma A., Prem K., CMMID COVID-19 Working Group, Klepac P., Rubin J.G., Edmunds J.W. 2020. Quantifying the impact of physical distance measures on the transmission of COVID-19 in the UK, BMC Medicine: 18 (124)

Liu Y, Gong W, Clifford S,..., and Klepac, P. 2020. Designing a multi-layered surveillance approach to detecting SARS-CoV-2: A modelling study. *Wellcome Open Res*, **5**:218

Firth, J.A., Hellewell, J., Klepac, P. *et al.* 2020. Using a real-world network to model localized COVID-19 control strategies. *Nat Med* 26, 1616–1622.

Kucharski, A.J., Klepac, P. et al 2020 Effectiveness of isolation, testing, contact tracing, and physical distancing on reducing transmission of SARS-CoV-2 in different settings: a mathematical modelling study. *Lancet Infectious Disease* 10:1151-1160.

Quilty, B. J., Diamond, C., Liu, Y., Gibbs, H.; ... Klepac, P.; Eggo, RM; Jit, M; (2020) The effect of travel restrictions on the geographical spread of COVID-19 between large cities in China: a modelling study. *BMC medicine*, 18 (1). 259-.

Clifford, S. J., Klepac, P., Zandvoort, K. Van, Quilty, B. J., COVID-19 working group, Eggo, R. M., & Flasche, S. (2020). Interventions targeting air travellers early in the pandemic may delay local outbreaks of SARS-CoV-2. *MedRxiv*, 2020.02.12.20022426.

Selected other publications

Klepac, P., Kucharski, A. J., Conlan, A. J., Kissler, S., Tang, M., Fry, H., & Gog, J. R. (2020). Contacts in context: large-scale setting-specific social mixing matrices from the BBC Pandemic project. *MedRxiv*, 2020.02.16.20023754.

Kissler, S. M., Klepac, P., Tang, M., Conlan, A. J. K., & Gog, J. R. (2018). Sparking "The BBC Four Pandemic": Leveraging citizen science and mobile phones to model the spread of disease. *BioRxiv*, 479154. https://doi.org/10.1101/479154

Klepac, P., Kissler, S., & Gog, J. (2018). Contagion! The BBC Four Pandemic – The model behind the documentary. *Epidemics*, 24, 49–59.

Klepac, P., Megiddo, I., Grenfell, B. and Laxminarayan, R. 2016. Self-enforcing regional vaccination agreements. *Journal of the Royal Society Interface* **13:** 20150907.

Funk, S., Bansal, S., Bauch, C. T., Eames, K. T. D., Edmunds, W. J., Galvani and P., Klepac, P. (2015). Challenges in modeling the dynamics of behavior towards infectious diseases. *Epidemics* **10**: 21-25

Klepac, P., Laxminarayan, R. and Grenfell, B. T. (2011). Synthesizing epidemiological and economic optima for control of immunizing infections. *PNAS* **108:** 14366–14370.

Klepac, P., & Caswell, H. (2011). The stage-structured epidemic: Linking disease and demography with a multi-state matrix approach model. *Theor Ecol*, *4*(3), 301–319.

2. **A list of the groups (i.e. SAGE and/or any of its sub-groups) in which you have been a participant, and the relevant time periods.**

   SPI-M-O;

   Children's Task and finish working group;

   SAGE working group on international vaccination.

   Please note that I have been on maternity leave from June 2nd 2020, to June 2021.

3. **An overview of your involvement with those groups between January 2020 and February 2022, including:**

   1. When and how you came to be a participant;

      Invited on March 10th 2020 by Prof Graham Medley to stand in as a part of BBC pandemic modelling group for Prof Julia Gog when she was away. Have attended weekly since then until my maternity leave (which started on June 2nd 2020). Confirmed regular attendee of SPI-M-O on 23.3.2020 (sent declaration of interests and confidentiality form).

   2. The number of meetings you attended, and your contributions to those meetings;

      From March to June 2020 I have attended about 20 different SPI-M-O and subgroup meetings, participating with analysing social contact data and projecting how modifying social contacts can reduce reproduction number, effects of school transmission and school closures, impacts of reopening schools on transmissioin .

   3. Your role in providing research, information and advice.

Performing original research using BBC pandemic social contact and movement data and POLYMOD data, providing advice based on assessment of evidence at a time, participating in consensus statements and reports.

4. A summary of any documents to which you contributed for the purpose of advising SAGE and/or its related subgroups on the Covid-19 pandemic. Please include links to those documents where possible.

    1. *Email to SPI-M dated 28.2. on the potential variation in time of peak between different places, especially major urban centres, based on the BBC pandemic modelling paper suggesting 5 week difference in our observed timing of simulated flu outbreak between London and Glasgow/Edingburgh (https://www.sciencedirect.com/science/article/pii/S1755436518300306) .*
    2. *BBC dataset - https://www.medrxiv.org/content/10.1101/2020.02.16.20023754v2*
    3. *Proportion of contacts that takes place in school/work/home/leisure by different age groups in POLYMOD and BBC datasets (SPI-M request dated 19.3.2020)*
    4. *Report: R0 reductions due to social distancing interventions: comparison of POLYMOD and BBC contact data (19.03.2020)*

    Key points:

    - *using BBC matrices would give a smaller reduction in transmission for interventions considered yesterday than using POLYMOD (either for all contacts or physical contacts only)*
    - *none of the interventions considered result in the reduction of transmission observed in 2009 due to changes in mixing patterns during holiday time that were linked with reducing the 2009 H1N1 pandemic transmission over the summer.*

    5. *Contributed to the Paper from SPI-M on the role of children in the transmission of COVID-19. It was considered at SAGE 26 on 16 April 2020.*

    Summary: SPI-M, with input from NERVTAG and SPI-B, has considered the role of children in transmission of COVID-19 through five angles:

    a. Clinical evidence on susceptibility, infectiousness and presentation, and the implications for transmission

    b. Transmission in schools and other institutional settings, including evidence on the impact of school closures and openings at different point of the epidemic

    c. Transmission within households, including evidence of susceptibility and infectivity

    d. Transmission outside of schools, other institutional settings, and households

    e. Wider impacts of current and possible interventions on children

6. *Report - SPI-Kids report: evaluating the increase in transmission for different back-to-school scenarios (April 26 2020)*

   Summary: Evaluate increase in transmission for different scenarios for school re-opening using the analysis of contact matrices from BBC Pandemic study filled with missing data from POLYMOD for under 13-year-olds.

7. *Contributing analysis to the Interdisciplinary Task and Finish Group on the Role of Children in Transmission: Modelling and behavioural science responses to scenarios for relaxing school closures (April 30, 2020)*

   Summary: This paper presents the findings from a collaborative analysis conducted by SPI-M and SPI-B, to explore the modelling outcomes and behavioural science aspects of 7 school closure scenarios identified by the Department for Education (DfE), in comparison with schools either staying shut (Baseline 1), or remaining fully open (Baseline 2).

   https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/886994/s0257-sage-sub-group-modelling-behavioural-science-relaxing-school-closures-sage30.pdf

8. *International vaccination: Potential impact on viral evolution and UK public health, 21 July 2021,*
   This paper summarises the current scientific consensus and hypothesis on the role of global vaccination in emergence and importation of new variants, and identifies key areas of uncertainty for making future projections and policies. We highlight key considerations for future policymaking, and where that could be guided by new evidence. Some aspects relate to medium-term decisions (3 months) and others to long-term issues (12 months) as travel and behaviour returns to baseline.

   https://www.gov.uk/government/publications/international-vaccination-potential-impact-on-viral-evolution-and-uk-public-health-21-july-2021

9. *During my maternity leave several pieces of work that I have started to lead on with the RAMP group of Prof. Deirdre Hollingsworth were presented to SPI-M-O. These papers are now published:*
   - *(i) Contact tracing is an imperfect tool for controlling COVID-19 transmission and relies on population adherence https://www.nature.com/articles/s41467-021-25531-5*
   - *(ii) Engagement and adherence trade-offs for SARS-CoV-2 contact tracing. https://royalsocietypublishing.org/doi/10.1098/rstb.2020.0270*
   - *(iii) Dynamics of SARS-CoV-2 with waning immunity in the UK population https://royalsocietypublishing.org/doi/full/10.1098/rstb.2020.0274*

5. A summary of any articles you have written, interviews and/or evidence you have given regarding the work of the above-mentioned groups and/or the UK's response to the Covid-19 pandemic. Please include links to those documents where possible.

   My contributions to English-speaking media stopped when I became the regular attendee of SPI-M-O. Prior to that I have written an opinion in The Guardian "What we scientists have discovered about how each age group spreads Covid-19" 17.03.2020.
   Summary: how to control outbreaks of infectious diseases, explanation of R and R0, analysis of contact data and what contacts can individual easily reduce to decrease their risk of getting infected
   https://www.theguardian.com/commentisfree/2020/mar/17/scientists-age-groups-covid-19-workplaces-shops-restaurants

   Interviewed for Atlantic piece on " The UK's Coronavirus 'Herd Immunity' Debacle' by Ed Yong 16.03.2020
   https://www.theatlantic.com/health/archive/2020/03/coronavirus-pandemic-herd-immunity-uk-boris-johnson/608065/

   LSHTM live Q&A - Friday 1 May at 14.30 GMT – London School of Hygiene & Tropical Medicine (LSHTM) experts Professor John Edmunds OBE and Dr Petra Klepac share findings and answer questions on COVID-19 in a live broadcast Q&A session. https://www.youtube.com/watch?v=f2tFqT6yUtA

6. Your views as to whether the work of the above-mentioned groups in responding to the Covid-19 pandemic (or the UK's response more generally) succeeded in its aims. This may include, but is not limited to, your views on:

   a. The composition of the groups and/or their diversity of expertise;

   The groups were initially relying heavily on influenza modellers, but the SPI-M-O quickly increased to include more researcher and more early- and mid-career researchers and could provide a number of different models and approaches which were important to address the structural uncertainty in the early modelling of the pandemic.

   b. The way in which the groups were commissioned to work on the relevant issues;

   The work commissioned was often limited to particular scenarios being considered. That works well when we know how the transmission works and what intervention scenarios we want to compare, but early on in the modelling process can be limiting. The modellers communicated the limitations and assumptions of the models well.

   Commissions often came on a Friday with the work needing to be submitted that Sunday, which is a very short turn over. This is what happens in a crisis, and a lot of modelling will have to happen on a very short notice.

c. The resources and support that were available;

The data streams were continuously improved as the feedback from the modellers was incorporated.

d. The advice given and/or recommendations that were made;

The advice given was always based on the modelling that incorporated the best available evidence on the transmission and epidemiological parameters of the pathogen. With increased data, our knowledge of the pathogen and its spread increased and the models were accordingly updated. Sensitivity analysis was performed to better understand the uncertainty in the models and our confidence in the advice.

e. The extent to which the groups worked effectively together;

The groups really came together and worked very effectively, and the research output was remarkable on short time-scales. Reports were often interdisciplinary and written by people working in different institutions. This collaborative spirit was nicely captured in the JUNIPER consortium that was formed as a result of a number of researchers at different institutions working and collaborating on SPI-M-O questions. The inclusion of early- and mid-career researchers was crucial here I think as it allows more easier exchange of views and ideas and allows for a variety of approaches to address the same questions which increases our confidence in recommendations based on modelling evidence. This is not achieved as easily in meetings dominated by one or two senior people. The subgroups were especially efficient, as the expertise was further focused on specific tasks that further promoted collaboration in smaller groups.

f. The extent to which applicable structures and policies were utilised and/or complied with and their effectiveness.

The role of scientists is to provide scientific advice not policies.

7. Your views as to any lessons that can be learned from the UK's response to the Covid-19 pandemic, in particular relating to the work of the above-mentioned groups. Please describe any changes that have already been made, and set out any recommendations for further changes that you think the Inquiry should consider making.

Interdisciplinarity is key, having dynamic group of collaborative researchers and systems already in place that you can quickly mobilise is very important. A lot of early modelling was based on existing pandemic modelling of influenza and having a good starting point is crucial for addressing the questions we were asked quickly. The importance of having multiple groups and multiple models addressing the same questions enabled us to assess the uncertainty in the models and provide more confident advice. This is impossible to do if there are only one or two modelling groups.

There is unique opportunity to build on the expertise of this pandemic and assess the modelling and data gaps that can be address in preparation for the next pandemic so that there are already data streams in place to facilitate quick relevant analysis.

One thing that can be improved in the future is to have perhaps two approaches to modelling. One that deals in the crisis mode and this very short turn-over of 2-3 days, and one that allows a turn-over of 2-3 weeks because some questions we can anticipate (for example, once schools are closed, how to safely open them, or once interventions are in place, start working immediately on guidelines and modelling for relaxing of interventions).

8. A brief description of documentation relating to these matters that you hold (including soft copy material held electronically). Please retain all such material. I am not asking for you to provide us with this material at this stage, but I may request that you do so in due course.

   I have the reports and analyses that I have done for the SPI-M-O work, the code that I have written to perform the analyses.