Witness Name: Professor Matthew Keeling
Statement Number 1
Exhibits: 8
Dated: 11th May 2023

UK COVID-19 INQUIRY

WITNESS STATEMENT OF PROFESSOR MATTHEW JAMES KEELING OBE

I, Matthew James Keeling, will say as follows: -

1. I am a Professor at the University of Warwick, and Director of the Zeeman Institute for Systems Biology and Infectious Disease Epidemiology Research ('SBIDER'). I have worked in the field of epidemiological modelling since 1997 and have studied multiple infectious diseases: from childhood infections (such as measles) to sexually transmitted infections (such as Human Papilomavirus ('HPV') and Mpox (previous known as Monkey pox) to livestock infections (such as foot-and-mouth disease).

2. I have considerable experience in leading successful research grants, having won in excess of £12M as principal investigator and £33M as co-investigator in my career. I have written or co-authored over 200 publications, mostly in infectious disease epidemiology, with an 'h-index' of 73 (meaning that I have 73 publications that have been cited 73 or more times).

3. I have been the director of the Zeeman Institute since its inception in 2016, and I have played a dominant role in two successful Engineering and Physical Sciences Research Council ('EPSRC') funded doctoral-training programmes. I have been closely involved with the UK response to Foot-and-Mouth, in both 2001 and 2007, and Pandemic Influenza in 2009, as well as providing model-based advice to the Department of Health and Social Care ('DHSC') on gender-neutral vaccination against HPV and age-targeting of the seasonal influenza vaccine.

4. Key publications during the period covered by Module 1 that are pertinent to pandemic planning include:
    - Black, A.J., House, T., Keeling, M.J. and Ross, J.V. (2012) Epidemiological consequences of household-based antiviral prophylaxis for pandemic influenza. *J. Roy. Soc. Interface* **10** 1742-5662 (exhibited at **MK/1 – INQ000184843**)
    - House, T., Inglis, N., Ross, J.V., Wilson, F., Suleman, S., Edeghere, O., Smith, G., Olowokure, B and Keeling, M.J. (2012) Estimation of outbreak severity and transmissibility: Influenza A(H1N1)pdm09 in households. *BMC Medicine* **10** 117 (exhibited at **MK/2 – INQ000184844**)
    - House, T., Baguelin, M., van Hoek, A.J., White, P.J., Sadique, Z., Eames, K., Read, J.M., Hens, N., Melegaro, A., Edmunds, W.J. and Keeling, M.J. (2001) Modelling the impact of local reactive school closures on critical care provision during an influenza pandemic. *Proc. Roy. Soc. Lond. B* **278** 2753-2760 (exhibited at **MK/3 – INQ000184845**)
    - Keeling, M.J. and White P.J. (2011) Targeting vaccination against novel infections: risk, age and spatial structure for pandemic influenza in Great Britain. *Journal of the Royal Society, Interface* **8** (58) 661-670 (exhibited at **MK/4 – INQ000184846**)

Role on Scientific Advisory Committees

5. During the period covered by Module 1, I was primarily involved with two main advisory committees: the Joint Committee on Vaccination and Immunisation ('JCVI') and Scientific Pandemic Influenza – Modelling ('SPI-M').

6. I joined JCVI on 20th May 2010, although I had been a member of its Influenza subcommittee since 2008. I applied for my position on JCVI as a member with experience in infectious disease modelling. I remained a member until May 2022. Over the period 2009-2020, the main JCVI committee met three times a year, with other subcommittees meeting as necessary. I generally attended all three meetings each year.

7. I joined SPI-M in early 2009, at the request of the chair at the time, Peter Grove. SPI-M tended to meet 3-4 times a year, although there were weekly meetings

during the height of the 2009 H1N1 (swine) 'flu pandemic. I generally attended all meetings whenever possible, subject to the constraints of my university position. During much of the 2009 pandemic, I was acting chair of SPI-M, freeing Peter Grove to conduct essential DHSC business.

8. I also attended the Scientific Advisor Group for Emergencies ('SAGE') in 2014 to discuss the Ebola outbreak in West Africa and during the period 2009-2020 also gave advice to the Department of Environment, Food and Rural Affairs ('Defra') on livestock outbreaks including foot-and-mouth disease, avian influenza and bovine tuberculosis.

9. In addition, since October 2013, I have led the Mathematical and Economic Modelling for Vaccination and Immunisation Evaluation ('MEMVIE') projects: a National Institute for Health and Care Research ('NIHR')-funded programme of work providing a second opinion on health-economic modelling of vaccines, for JCVI and DHSC. This project primarily funds post-doctoral researchers to conduct modelling and health-economic studies under the guidance of myself and the other MEMVIE senior investigators. During the period covered by Module 1 this project primarily focused on vaccination against HPV and seasonal influenza and therefore is not concerned with pandemic planning.

Structure of the Advisory Groups

10. The JCVI's remit is "*To advise UK health departments on immunisations for the prevention of infections and/or disease following due consideration of the evidence on the burden of disease, on vaccine safety and efficacy and on the impact and cost effectiveness of immunisation strategies. To consider and identify factors for the successful and effective implementation of immunisation strategies. To identify important knowledge gaps relating to immunisations or immunisation programmes where further research and/or surveillance should be considered.*" This is set out in the JCVI code of practice which I exhibit at **MK/5 - INQ000184847.**

11. In JCVI, my role as a committee member is to provide scientific opinion and advice on the information presented to the committee. This information could range from publications on clinical trials, to reports from vaccine manufacturers, to full health-economic assessments of new vaccine programmes. As the sole epidemiological

modeller on the panel, I tended to focus my attention on the more quantitative studies, providing feed-back on statistical analysis and model projections.

12. During the period covered by Module 1, the JCVI Committee did not perform any pandemic-planning work, although it was kept informed of the latest research on pandemic influenza vaccines. In part, this is because the time needed to generate pandemic-specific vaccines would be sufficiently long to allow planning once epidemiological details were known.

13. SPI-M is an advisory group of DHSC that provides expert advice to the UK government based on infectious disease modelling and epidemiology. As such, I am one of many epidemiological modellers on SPI-M.

14. The role of SPI-M is to keep abreast of the latest insights into pandemic projections, with a strong focus on pandemic influenza given its potential to cause future outbreaks. This involves making the committee aware of the latest work in the area, including our own, and regularly updating the Modelling Summary to capture the latest insights into the likely scale of future pandemics. The Modelling Summary is exhibit **MK/6 - INQ000184850**. Although the Modelling Summary published in 2018 was primarily concerned with an outbreak of pandemic influenza (and chose parameters and assumptions accordingly) many of the insights are pertinent to the COVID-19 outbreak.

15. JCVI and SPI-M contain many of the country's leading experts in their field. JCVI has a more diverse makeup as it needs to deal with a range of questions pertaining to vaccination programmes, from immunology to practical delivery. This expertise is predominantly from the UK, although experts from Europe are also members; logistical constraints, especially when the meetings were in person, precluded members from further afield. SPI-M is more UK-focused and brings together the best epidemiological modellers with an interest in pandemic projection and prevention. All these modellers have a strong track-record of both cutting-edge modelling and bringing models to practical and challenging public health problems. I was not part of the process by which individuals were asked to join SPI-M, but there were no obvious omissions. Both committees also have participants from the UK Health Security Agency, ('UKHSA'), formerly known as Public Health England

('PHE'), DHSC and the health services of the devolved nations to ensure the smooth flow of information.

16. Neither JCVI nor SPI-M commissions work from its members. Instead, members provide scientific advice on existing pieces of work. Often these have been commissioned from UKHSA but I have not involved in how this commissioning process operates.

17. The MEMVIE project, which I lead, also gets commissioned by DHSC to undertake pieces of second opinion modelling work for JCVI. During the period covered by Module 1 none of these MEMVIE commissions related to pandemic planning. The work of all members of JCVI and SPI-M is given on a voluntary basis, in addition to normal working activities.

18. Academically, the UK is rightly regarded as a powerhouse in epidemiological modelling and analysis across a broad range of infections, including pandemic planning. Many UK university groups have considerable experience in this area and are world leaders in their field – for example providing advice to international agencies such as WHO. We are therefore in the incredibly fortunate position that there is a pool of expertise that can be called upon for both regular activities (such as the regular business of JCVI) and in extreme circumstances.

Pandemic Planning

19. Much of the pandemic planning by SPI-M in the period covered by Module 1, focused on the risks and potential scale of an influenza pandemic. Influenza still remains one of the most likely pandemic threats, and guidance based on an influenza pandemic was an excellent initial guide for the COVID-19 pandemic. This planning benefited from the experience of committee members with SARS, MERS and the 2009 H1N1 pandemic.

20. This planning is captured in the SPI-M Modelling Summary which I exhibit at **MK/6 - INQ000184850**. I was part of the committee that reviewed and approved this work, which I still feel represents a comprehensive description of pandemic risks, although the COVID-19 pandemic has highlighted additional potential control options. While this document considers the likely scale of a future pandemic and

the likely impact of different controls, it is not a planning document – it is a summary of scientific evidence which others could use as a basis for pandemic planning. As stated in the SPI-M Modelling Summary "*Preparatory work between epidemics is necessary to enable governments and institutions to react appropriately when threats emerge*".

21. There are multiple statements in the SPI-M Modelling Summary that are extremely pertinent to what unfolded during the early phase of the COVID-19 pandemic, despite the document's focus on pandemic influenza.

22. Disease surveillance and case-contact studies are highlighted as being particularly valuable in providing an early understanding of the outbreak, as is the need to "*ensure systems are in place to estimate pandemic severity*" and the need to "*facilitate the early collection and sharing of data*" as stated in the SPI-M Modelling Summary.

23. While some aggregate information was collected and shared during the early stages of the pandemic, there was a slow ramping-up of important population-level studies such as the ONS and REACT surveys (ONS began on 27th April 2020, while REACT-1 began on 1st May 2020). Similarly, the demands of confidentiality and the large scale of some data sets, meant that much useful data was slow to be shared. Unfortunately, this situation did not improve with the 2022 Mpox outbreak, where information was even more tightly restricted. Better methods to share early data is clearly a priority for the future.

24. It was noted in the SPI-M Modelling Summary that travel restrictions into the UK from the country of pandemic origin would be "*compromised by travel into the UK from intermediate countries that develop their own epidemics*". This proved to be the case as on 4th February 2020, the Foreign & Commonwealth Office advised against 'all but essential' travel to/from mainland China; but on 31st January, Italy had already seen its first cases – highlighting the rapid international spread of this virus.

25. Behavioural factors and behavioural interventions were also highlighted as likely to be important in the SPI-M Modelling Summary.

26. It was stressed in the SPI-M Modelling Summary that "*setting priorities for the objectives of such interventions*" was essential. During the COVID-19 pandemic, the modelling community in SPI-MO, repeatedly asked for a set of priorities (such as keeping hospital admissions below a threshold) that could be used to generate optimal control scenarios. This was never forthcoming, making it difficult to gauge which planning scenarios would be acceptable.

27. In terms of social distancing, the SPI-M Modelling Summary has three main statements that closely mirror experiences with COVID-19:

    a. "*Voluntary home isolation will decrease the number of contacts between infected and uninfected individuals, and hence is likely to decrease the spread of infection*";

    b. "*The combined effects of various social distancing measures if started very early …. may have a significant impact on reducing transmission*";

    c. "*All social distance measures depend on compliance by the population which, in turn, depends on the social acceptability of the measures. Without good behavioural research on these it is difficult to predict the impact of such measures being deployed in a future pandemic*."

28. It has been recognized that an understanding of behavioural responses to the pandemic was somewhat lacking in the early stages. While model projections did seek to explore a range of future behavioural responses, there was limited sociological data to refine the uncertainty. Ongoing work is addressing some of these issues, attempting to bridge the disciplinary divide between behavioural research and predictive models.

29. Additionally, the reasonable worst case outlined in the SPI-M Modelling Summary, described an epidemic in which cases, hospital admissions and deaths doubled in under a week, not unlike the early COVID-19 dynamics. The reasonable worst case (for pandemic influenza) also considered an infection: hospitalisation ratio of 2.4% and an infection: fatality ratio of 1.5% (assuming around 60% of infections become detected cases) - which compares to the ratios of around 2-3% and 1% for early COVID-19 infections.

30. As such the reasonable worst case provided a suitable estimate for what transpired, and a useful set of scenarios that government agencies could have used for planning purposes – although such reasonable worst-case models were rapidly overtaken by more bespoke projections in March/April 2020 once information on SARS-CoV-2 became available.

31. From my perspective as an epidemiological modeller, I can only reasonably comment on the preparations for delivering quantitative analysis and projections. Other elements, in terms of how the government prepared for the pandemic were beyond my experience – although precautions such as access to the necessary PPI equipment, standing capacity for testing-and-trace, or plans for the additional hospital burden would have universal benefit against many future pandemics.

32. There are four main factors that could ideally have been improved upon to provide more rapid insights at the start of the pandemic. Firstly, an extremely large proportion of the UK funding is concentrated within one or two academic groups[1], these were therefore the only groups with sufficient core funding and standing capacity to maintain bespoke pandemic models. Other groups involved in SPI-MO (the operational version of SPI-M) modelling suffered an initial lag while pandemic models were developed.

33. Secondly, there needed to be a step-change in fitting mathematical models to data. This improved during the pandemic, but at the start no groups had the methodology or data access to fit (and project) pandemic models. Ideally, before the next pandemic multiple independent methodologies should be in place, such that a suite of early projections can be made and differences between results discussed in terms of the underlying assumptions. This would require core funding to maintain such capacity at different institutions. Ideally, much of this capacity should reside within UKHSA or be shared between academia and UKHSA. There is also the potential for greater interaction between industry, academia, DHSC, NHS and UKHSA, to be better prepared in terms of data assimilation, model development and projection.

[1] Imperial College with the MRC-funded Centre for Global Infectious Disease Analysis; and Imperial College and LSHTM (London School of Hygiene and Tropical Medicine) with the NIHR-funded HPRU in Modelling and Health Economics.

34. Thirdly, models are only as good as the data that feeds into them, and modern models are often data-hungry. UKHSA and NHS control access to much of this data. I fully appreciate the ethics of data confidentiality, but often there were substantial bottlenecks that could have impacted what was achieved. Pre-pandemic planning also needs to consider ways in which data needs (as set out in the SPI-M Modelling Summary) can be safely shared with all involved parties. The data needs for modelling the COVID-19 pandemic in the UK were discussed as early as 27th January 2020 in the first SPI-M meeting about the pandemic.

    As we move globally to new protocols in working with large data sources, it is important that the interface between public health data holders and academia matches these innovations. Either academic institutions need to be trusted with large volumes of anonymised data, such that the power of university computer systems can be used to analyse the dynamics, or data access needs to be provided in secure environments with plenty of flexibility and processing power such that the same analyses can be performed.

    During the pandemic, the involvement of the Defence Science and Technology Laboratory ('DSTL') meant that many of the disparate data sources were efficiently collated into a unified data file, ensuring all modellers were working with the same underlying data and streamlining the data processing steps. Rapid facilitation of access to such unified data is another key lesson for future outbreaks.

35. Finally, there is the need for more horizon scanning and ideally the development of a suite of documents for different broad categories of pathogen. Very different controls are needed for COVID-19 which predominantly affected the elderly, pandemic influenza which may affect both the young and the elderly, and Mpox which found a niche in the most sexually active individuals – therefore different planning scenarios are required.

36. It is worth noting that SPI-M (and SPI-MO) has not been asked to consider the cost-effectiveness of policies, nor the wider economic or social impacts of pandemics and control measures. Indeed, such considerations are beyond its remit. Having such information available to policy-makers would inevitably be

highly beneficial in any future outbreak, but this would require considerable multi-disciplinary interaction between epidemiological and economic modellers.

Role of the Advisory Groups during the Pandemic

37. In emergency situations, such as the COVID-19 pandemic, many things change – in particular, the frequency of meetings and the volume of information that needs to be reviewed. Both JCVI and SPI-M switched to a weekly cycle during the COVID-19 pandemic, often with multiple meetings within a week (focusing on different questions). For JCVI, the focus of most members remained providing advice on pressing matters requested by DHSC or the Secretary of State, which generally consists of weighing the available evidence. However, during the COVID-19 pandemic, myself and UKHSA colleagues often performed modelling and analysis that was pertinent to the problem being discussed; this provided much-needed UK-specific evidence in a rapidly evolving outbreak.

38. SPI-M, due to its modelling focus, operated differently to JCVI during the pandemic – it became SPI-MO (O standing for operational), providing information and advice directly to SAGE on a regular basic. SPI-MO also had a different remit to SPI-M, providing multiple lines of analysis and projections for the unfolding outbreak. SPI-MO also had an extended membership to involve a wide array of expert modellers and statisticians, to broaden our understanding of the pandemic. During the pandemic, activities were far more coordinated (although still not officially commissioned and still provided on an unpaid voluntary basis) with all parties agreeing to investigate one or two specific problems for more general discussion.

39. The ability of both JCVI and SPI-MO groups to step-up to the increased demand during the COVID-19 pandemic was primarily due to the selfless nature of the individuals involved – freely giving of their time whilst trying to balance a changing and demanding work environment. Fortunately, holding meetings remotely helped to reduce some of the burden by removing travel times. I know I was not alone in working very long hours and most weekends to deliver results and analyse the latest data – often to the detriment of our academic careers. Given the seriousness

of the pandemic, we were all happy to give of our time without financial renumeration.

40. In part the success of JCVI and SPI-MO during the COVID-19 pandemic can also be attributed to the fantastic secretariats – who shouldered much of the administrative burden and ensured the smooth running of both committees.

41. From a personal perspective, two streams of funding made much of my work during the pandemic possible. Firstly, the award of the MEMVIE project[2] in 2019 (to provide second opinion modelling for JCVI and DHSC) provided post-doctoral support to help with the modelling of vaccination. Secondly, the award of funding for the JUNIPER consortium[3] in late 2020 to seven universities, again allowed the recruitment of post-doctoral researchers and provided the institutions with sufficient funds such that the investigators were able to reduce some of their normal university commitments. JUNIPER provided a fantastic opportunity for different institutions to work closely together, tackling pressing challenges from multiple angles to present a completed body of work to SPI-MO. As the pandemic wanes, and pandemic-specific funding comes to an end, it would be extraordinarily difficult to rapidly escalate back to the high intensity we were operating at during 2020/21, and there is a risk that much of the specific expertise could be lost.

Lessons Learned.

42. With the benefit of hindsight there are several things that could be done to better prepare for the next pandemic. As stated above there needs to be a broad and diverse standing capacity to respond to future pandemic threats, the Centre for Disease Control's Disease Forecasting Center (USA) provides a useful template for this approach and shows what can be achieved with sufficient commitment of resources; there needs to be clear channels for data access and the development of methodological pipelines such that model fitting and projection can be undertaken rapidly; there also needs to be consideration given to key strategic decisions for different pathogens – I believe that Defra's Foot and Mouth Disease control Strategy for Great Britain provides a good example of structured guidance

[2] MEMVIE is funded by DHSC through the NIHR (National Institute for Health and Care Research).
[3] JUNIPER is funded by UKRI (UK Research and Innovation).

for decision making during the early phase of an outbreak. This is exhibited at **MK/7 - INQ000184848.**

43. I feel there needs to be a national dialogue about how to respond to future outbreaks, such that the UK is primed to respond to the next threat. This can either be conceptualised as driven by the nature of the disease (considering the most appropriate actions for a given type of infection) or could be action focused (considering under which scenarios different control measures are appropriate and acceptable). For example, we may wish to consider when masks, movement restrictions, lockdowns or school closures are an appropriate response. Clearly these become more acceptable as the severity of the infection increases, such that for a high-mortality haemorrhagic fever we may be prepared to enact very strong protective measures. A consultation on how we respond rapidly and appropriately next time, together with a structured document that outlines key early decision steps, would be an important legacy from this pandemic.

44. As part of this forward-looking activity, consideration also ought to be given to the speed with which a test-trace-and-isolate system could be initiated (and the degree to which differing sections of the public are likely to comply), and similarly the speed with which a surveillance system (like the ONS or REACT surveys) could be put in place to provide real-time monitoring of the unfolding outbreak.

45. The 100 Days Mission to respond to future pandemic threats[4] (exhibited at **MK/8 – INQ000184849**) is likely to lead to a step-change in our ability to provide medical treatments and vaccines against the next pandemic. This 100-day time-scale, may change the types of measures we are prepared to accept for a short period, before suitable treatments and vaccines become available.

[4] A G7 document which sets out the goals of developing pharmaceutical interventions against the next pandemic within 100 days.

Statement of Truth

I believe that the facts stated in this witness statement are true. I understand that proceedings may be brought against anyone who makes, or causes to be made, a false statement in a document verified by a statement of truth without an honest belief of its truth.

Signed: Personal Data

Dated: 11th May 2023

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SCHEDULE TO WITNESS STATEMENT OF PROFESSOR MATTHEW JAMES KEELING OBE

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1. Exhibit MK1 – INQ000184843:
   http://dx.doi.org/10.1098/rsif.2012.1019

2. Exhibit MK2 – INQ000184844:
   http://www.biomedcentral.com/1741-7015/10/117

3. Exhibit MK3 – INQ000184845:
   http://dx.doi.org/10.1098/rspb.2010.2688

4. Exhibit MK4 – INQ000184846:
   http://dx.doi.org/10.1098/rsif.2010.0474

5. Exhibit MK5 – INQ000184847:
   https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/224864/JCVI_Code_of_Practice_revision_2013_-_final.pdf

6. Exhibit MK6 – INQ000184850: https://www.gov.uk/government/publications/spi-m-publish-updated-modelling-summary

7. Exhibit MK7 – INQ000184848: https://www.gov.uk/government/publications/foot-and-mouth-disease-control-strategy-for-great-britain

8. Exhibit MK8 – INQ000184849: https://www.gov.uk/government/publications/100-days-mission-to-respond-to-future-pandemic-threats