Witness statement for module 2 of the UK COVID-19 public inquiry

Witness Name: Steven Riley

Statement No. :1

Exhibits: 51

Dated:

UK COVID-19 INQUIRY

MODULE 2

WITNESS STATEMENT OF PROFESSOR STEVEN RILEY

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1. I, Professor Steven Riley, Imperial College London, Exhibition Rd, South Kensington, London SW7 2BX , will say as follows:

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1 Introduction

1.1. I am a Professor of Infectious Disease Dynamics at Imperial College London. Since October 4th 2021 I have been seconded 90% to the UK Health Security Agency as Director General for Data, Analytics and Surveillance. In my academic capacity, I was an associate member of the Scientific Pandemic Influenza - Modelling committee (SPI-M) prior to the pandemic and a member of its operational version SPI-M-O during the pandemic. From April 2020 to September 2021 I was a lead investigator in the REal-time Assessment of Community Transmission (REACT) study at Imperial College with a focus on the PCR-based REACT-1 study.

1.2 I was also a member of the Task and Finish Group for Children, which was a SAGE subgroup from 20 April 2020 to 15 December 2020. Between these dates I attended calls for the group and commented on documents. I did not attend SAGE in my academic capacity. I attended twice as a UKHSA official after 4 October 2021.

1.3 Since 2003, I have worked in teams to publish papers on the infectious disease dynamics using advanced analytics, transmission models, primary data collection and secondary data analyses. I have tried to generate and interpret evidence so as to improve decision-making during outbreaks. Between outbreaks, my work has been to discover features of underlying ecological and biological processes that could eventually enable better health security policy.

1.4 As a postdoctoral researcher at Imperial College, I had a lead role in early work on SARS-CoV-1 that first quantified the transmissibility of a severe human coronavirus and showed that the overall reduction in social mixing in Hong Kong likely contributed to ending the outbreak {SR/01 **- IN0000270158** }. Also, in addition to population-wide behaviour change, SARS-CoV-1 was controlled more easily than other respiratory viruses because the proportion of transmission arising from non-symptomatics was low {SR/02 - INQ000236271}.

1.5 After collaborating on SARS-CoV-1, I joined the University of Hong Kong's newly founded School of Public Health in 2004 and worked on influenza as a case study of a potentially pandemic pathogen {SR/03 - INQ000236306}. I also developed spatial models of infectious disease {SR/04 - IN0000269370}.

1.6 While working in Hong Kong, I started to gather primary data to directly address key questions about the transmission dynamics of infectious disease. During the 2009 influenza pandemic, I helped to initiate the Hong Kong Influenza Serological Study to accurately estimate the low infection fatality rate {SR/05 - INQ000236295} and also

helped to start the FluScape cohort in Guangzhou to collect serum samples and behaviour data from a spatially stratified urban-rural population {SR/06 - INQ000236270}. I returned to Imperial College in 2010. The FluScape study in Guangzhou continued up to the very start of the COVID-19 pandemic. I visited 3 or 4 times per year between late 2010 and 2019 and had regular calls with colleagues at universities and hospitals in mainland China.

1.7 I contributed substantially to the UK response to COVID-19 from the first Imperial College Report {SR/07 - INQ000236273 } on 17th January 2020, which highlighted the likely underestimation of infections in Wuhan at that time: the report was started on 16th January when the second exported infection was confirmed at the Japanese border.

1.8 I develop and use mechanistic models of infectious disease in my work. They are differentiated from other analytical methods by explicitly representing assumptions about the transmission process that allow them to produce epidemic curves. For example, a mechanistic model can produce an epidemic curve based on assumptions about the reproduction number of the pathogen, the generation time, population mixing patterns and population immunity. Mechanistic models are useful because risk of infection (and thus disease) can sometimes change very quickly. The speed of infectious disease epidemics is often driven by the underlying feedback mechanism of the transmission process in a naive population: at the start of an outbreak, the number of people in each new generation of infection is a multiple of the number in the prior generation, leading to exponential growth.

1.9 Mechanistic models are only one source of scientific evidence about the transmission dynamics of viral pathogens. As with any source of scientific evidence, the appropriate weighting given to results from mechanistic models should vary depending on the specific hypothesis or policy question for which the evidence is being generated.

2 SAGE and its sub-groups

2.1 My primary input to the early response was as a member of SPI-M-O, as set out above. I also participated in the Children's Task and Finish Group, but primarily as a discussant and reviewer. I did not join any SAGE meeting prior to my secondment into UKHSA in October 2021.

2.2 To the extent that I could observe, I thought that the sub-groups and sub-committees collaborated well with each other from the end of March 2021. Colleagues were on multiple committees and sub-groups which ensured that coordination was not left

solely to the chairs and the secretariat. The civil service secretariats were extremely effective in summarising and communicating the views of the different groups.

2.3 I understand that the inquiry is interested in the relationship between SAGE and its sub-groups and senior politicians. Because I did not attend SAGE prior to joining UKHSA, I do not feel qualified to comment on the relationships between SAGE and senior politicians. I am not aware of any direct contact between SPI-M-O and senior politicians. In my role as a member of the REACT senior team, I attended one virtual meeting with Lord Bethel on April 26 2020.

2.4 The process by which the CMO and GCSA acted as the primary link between scientists and ministers for scientific issues had strengths and weaknesses. It is my view that the two individuals in these roles were highly effective in digesting and synthesising evidence from a wide range of sources and thus were effective at informing a wide variety of policy issues. Therefore, the process by which they acted as a bridge was a strength because they could ensure quality and coherence of the scientific evidence being communicated to decision makers. However, regardless of the capabilities of individuals, it is my view that they must also have acted as a slightly unrealistic bottleneck if their role was to be the primary arbiter of scientific opinion.

2.5 I do not believe that SAGE and its sub-groups took sufficient account of international experiences during the early stages of the pandemic. In particular, the possibility of a national lockdown should have been actively considered from 23 January 2020 onwards.

2.6 SAGE and its sub-groups should have been more diverse during the early months of the pandemic. The lack of diversity was illustrated by the under-representation of women on SAGE and its subgroups, especially during the early stages of the pandemic. It is my impression that more women were appointed as members and asked to provide leadership from April 2020 onwards.

2.7 It is my view that SPI-M-O should not have been defined as a modelling committee. The committee was a link to the community of scientists whose work attempts to better understand the mechanisms that drive epidemics and pandemics and the relative effectiveness of different possible interventions. Mechanistic models are only one of the tools used by this community to generate evidence that may be of use to advisers and decision makers. For example, I would expect colleagues who identify as epidemiologists to be able to add value to a pandemic response with no less effectiveness on many issues than colleagues who identify as “modellers”. Further, I

would describe much of the evidence produced by members of SPI-M-O and considered by them as epidemiology rather than modelling. Therefore, it is also my view that the naming and recruitment of the committee as "a modelling committee" led to a less diverse membership than could have otherwise been the case.

2.8 It is my view that individual institutions and research groups may have been over-represented on SPI-M-O. For example, I would have been one of possibly 5 members of the Imperial College COVID-19 Response Team who attended some meetings. The meetings were large at some points during the pandemic, and I have not examined records of attendance so as to formally assess whether Imperial was over-represented compared to, for example, the London School of Hygiene and Tropical Medicine, or Manchester. Any over-representation likely reflects the branding of the committee as a modelling committee and the large relative size of some modelling groups. There were strengths and weaknesses to this over-representation of the larger groups which may have affected the robustness of advice. A strength is that if there were differences of view in the larger groups, then these differences were aired in the meeting itself, and input to what might have otherwise have been internal group debate could be obtained from colleagues at other institutions. A weakness is that in order to have a manageable committee size, fewer institutions or groups can be represented.

2.9 The primary interaction between SPI-M-O and SAGE was via SAGE commissioning SPI-M-O to answer specific questions. It is my view that during the early period of the response, some key commissions were too narrow. For example, during February 2020 we were asked for views on school closures and on the impact of other interventions in delaying the peak, and we were asked about reasonable worst-case scenarios. We were not asked about the likelihood that interventions could achieve ongoing containment, nor were we asked about most plausible scenarios.

2.10 It is my view that individual technical reports suggested greater confidence in likely future scenarios partly because they arose from narrow commissions. For example, the SAGE paper "Potential effect of non-pharmaceutical interventions on a COVID-19 epidemic," by the Imperial College COVID-129 Response Team (including myself) {SR/08 - INQ000236282}, gives the impression that a comprehensive set of policies had been considered and also that the impact of those interventions could be predicted with good accuracy, which I do not believe was the case at the time. I do not have a copy of the commission to which the report likely responded, but the commission was described in the following way in an email from the SPI-M-O

secretariat on 21 February 2020. "They [SAGE] have now issued a further commission for SPI-M to look at the impact of regional closures as well as for specific cohorts of children and how the resulting reduction in cases would fit with NHS operational planning. Our aim is to discuss this commission and how we could answer it under the agenda item on Monday." Risk of inappropriate apparent confidence could be avoided by ensuring that commissions were sufficiently broad that authors would be forced to set their work in a wider context. For example, commissions about the impact of specific interventions could explicitly ask authors for a view of any other relevant interventions not included in the commission.

2.11 It is my view that realistic single worst-case scenarios (RWCS) do not provide an appropriate structure for planning for major infectious disease threats. They are a useful and necessary planning tool for threats where the amplitude of the event is largely independent of the response, such as floods and some terrorist attacks. For these scenarios, the response can help mitigate the impact but will not fundamentally reduce the size of the event. Conversely, as shown by the variation of responses to COVID-19 around the world, early decisions can have a substantial impact on the overall size of the event. Therefore, the use of RWCS obscures the potential for early interventions to significantly reduce the amplitude of the harms. Also, if RWCS are being used for more complex and longer duration events, then "worst" needs to be clearly defined. Some scenarios might be fast but include many fatalities, while others will be of a much longer duration but perhaps not generate as many casualties. It is my view that infectious diseases and possibly other complex threats would be better served by multiple plausible indicative planning scenarios, each with a clear accompanying narrative.

2.12 I agree with the view of the Institute for Government that "in the initial months, ministers put too much weight on SAGE - relying on it to fill the gap in government strategy and decision-making that was not its role to fill." [Science Advice in a Crisis, pg 5] From October 2021, I had the opportunity to observe the larger system providing advice within the UK Government. The size of the teams in UKHSA, the Cabinet Office and other government departments, and the day-to-day outputs of those teams, suggests to me that in their absence in the early stages of the response, it is likely that ministers were overly reliant on SAGE.

3 Imperial College Covid-19 Response Team

3.1 The Imperial College Covid-19 Response Team generated large amounts of valuable evidence to support the Covid-19 response in the UK and worldwide. Effectively, it

was established by a meeting between myself, Professor Neil Ferguson, Doctor Illaria Dorigatti and Doctor Natsuko Imai at 4 pm on 16 January 2020 to discuss the implications of a second exported case of the novel coronavirus causing an outbreak of respiratory infections in Wuhan. I have no notes or minutes of the meeting. My recollection is that we spent our time discussing the analysis that would form the content of Imperial College Report 1 {SR/07 - INQ000236273}. The team was led by Professor Ferguson. It grew rapidly and met as and when needed over the course of the pandemic. To the best of my knowledge, the team did not formally reported onwards from Professor Ferguson.

3.2 I understand that Professor Ferguson is also submitting a witness statement for module 2 of the inquiry. He and other colleagues contributing to that statement will be better able than me to describe the makeup of the team, our way of interacting with SAGE and other government committees, our primary tools and other outputs.

4 The Early Stages of the Pandemic

4.1 As a member of SPI-M, I contributed directly to and vouched for a range of products that were communicated onwards to SAGE and then into the public domain. These products entered the public domain in different ways and in stages: by inclusion in SAGE papers that were then made public, published as preprints or university reports, and by being published in peer-reviewed academic journals. These products included, but were not limited to: estimations of the growth rate, incubation period and mortality rate; consensus estimates of the growth rate and reproduction number; short and medium-term projections; and responses to specific policy questions.

4.2 The growth rate describes the speed of increase or decrease of an epidemic and is usually applied to incidence. It should be estimated specifically for different observations, e.g.: prevalence of infection, cases, admissions, or deaths. At some stages during an epidemic, the growth rate for infections might be different from the growth rate for deaths. In theory, the growth rate can be observed directly from data. However, in practice, because data streams are lagged and have their own specific biases, there is considerable added value in additional analytics to estimate the current and most recent growth rate by correcting for lags and biases. The unit for growth rate is 1/time, which is not intuitive. For example, a case growth rate of 0.5 $weeks^{-1}$ means that, on average, the incidence of cases is increasing by 50% per week. Growth rates other than those close to zero can be converted directly into estimates of the time it takes for incidence to double, which are more intuitive. A growth rate of 0.5 $weeks^{-1}$ corresponds to a doubling time of 1.4 weeks. An early

example of the provision of growth rates is the estimate of a 2- to 4-day doubling time for the epidemic in Wuhan mentioned in minutes of the 2nd SAGE meeting {SR/09 - INQ000236298}.

4.3 The incubation period is the average time from a person being infected to the time they show symptoms. It is different from the latent period. The latent period is the average time from a person being infected to them being able to infect someone else. Because the moment of infection is difficult to observe, mechanistic models and other advanced analytical techniques – and high-quality individual-based data – are required to estimate the incubation period. These data need to contain information about when individuals were exposed to the virus and when they developed symptoms. This information is sometimes contained in contact tracing data. An example of the early and uncertain provision of incubation period estimates is in the minutes of the precautionary SAGE meeting 1, which state that "The incubation period is unclear – but appears to be within 5 to 10 days; 14 days after contact is a sensible outer limit to use." {SR/10 - INQ000236299}.

4.4 The mortality rate is a commonly used term for infectious diseases, but it is not sufficiently well defined to be useful for most possible applications. A lack of precision in this area of infectious disease epidemiology can lead to misunderstandings and low situational awareness for decision makers, as was clearly described after the 2009 influenza pandemic {SR/11 - INQ000236305}. The infection fatality rate (IFR) is the proportion of people who are infected who then die as a direct result of that infection. The case fatality rate (CFR) is the proportion of people who are counted as a case and then die as a result of that infection . Even though more difficult to measure, the IFR is far more appropriate for planning because it does not depend on case definitions which vary from population to population and even from study to study in the same population {SR/11 - INQ000236305}. Report 4 by the Imperial College COVID-19 Response Team is an example product in which estimates of IFR and CFRs are given {SR/12 - INQ000236277}.

4.5 The reproduction number is the average number of new infections generated by one typically infectious individual. It can be estimated in different ways for different pathogens. For outbreaks and epidemics of viral respiratory pathogens, it is usually estimated using the same data that are used for growth rate estimates. However, the generation time distribution (see below) must also be either assumed or jointly estimated in order to estimate R {SR/13 - NQ000269371}.

4.6 The generation time is the average time between one person being infected and when they cause infections in others. Because infection is difficult to observe, the generation time is challenging to observe directly. The generation time distribution reflects more than just the average time between infections. It describes how, for the same average time, some infections can be made quickly and some are made more slowly (a high variance generation time distribution), or they can all be made very close to the average time (a low variance generation time distribution). The degree of variation in the generation time distribution can be important for estimates of R {SR/13 - INQ000269371} and for estimates of the effectiveness of case-based interventions such as contact tracing, isolation and quarantine {SR/02 - INQ000236271}. Because infections are so difficult to observe, the generation time distribution is often approximated by the serial interval distribution. The serial interval is defined as the time between an infector showing symptoms and each of their infectees showing symptoms. An example of early high-quality evidence for the serial interval distribution is a study of cases and close contacts in Shenzen {SR/14 - INQ000236264}.

4.7 Later in 2020, SPI-M-O started to produce consensus estimates of the reproduction number R. These were based on input from multiple groups in which models were fit to UK data. In fitting these models, groups were choosing which outcomes to fit models to (e.g. cases or deaths) and making implicit assumptions about the generation time distribution. An example of consensus R estimates can be seen in the SPI-M-O Consensus Statement of 2 September 2020 {SR/15 - INQ000236300}.

4.8 Also, later in 2020, SPI-M-O started to produce consensus projections of numbers of hospitalisations and numbers of deaths for the next few weeks. The precise time horizon varied. These projections were obtained by teams fitting mechanistic models to current UK data and then extrapolating the results from those models to future times. Often, multiple future projections were made to reflect policy uncertainty. Common language that has now emerged for this type of work would describe these as scenarios because they were dependent on well-defined future choices that had not been made at the time the projections were made. The document *SPI-M-O: Medium-Term Projections and Scenarios, 28 October 2020* {SR/16 - INQ000236301} contains examples of medium-term projections for the subsequent six weeks that were dependent on policy decisions that were unknowable at the time.

4.9 More generally, SPI-M-O also provided evidence, interpretation and opinion on specific policy options. Some of these outputs used evidence from mechanistic models to directly address key policy questions. For example, work on the timing of

lockdowns, optimal household testing, and impact of contact tracing. While other contributions would rely on visualisation techniques, traditional epidemiological methods, or other forms of bespoke analysis or evidence synthesis. For example, I authored a paper for SAGE on the likely efficacy of facemasks in reducing the transmission of SARS-CoV-2 outside the household that was based on a rapid non-systematic review of the literature {SR/17 - INQ000236296}. I accepted this commission because I had previously led a secondary analysis {SR/18 - INQ000236284} of a highly cited study of facemask wearing as an intervention against influenza transmission {SR/19 - IINQ000236266}. It is my view that the variety in the methods used by members of SPI-M-O to provide evidence to support policy advice illustrates an important gap between the name of the group and its broad expertise. Even though members did produce important evidence directly from mechanistic models of COVID-19, we often made valuable and potentially significant contributions because of a more general ability to synthesise and interpret evidence in the context of SARS-CoV-2 transmission as a complex biological system.

4.10 Outside of the formal SAGE process, I contributed to the UK response in other ways prior to joining the UK Health Security Agency on 4th October 2021. Based on prior experience and knowledge, I commented publicly on scientific and policy issues, initially via Twitter but later via traditional broadcast and print media. I also generated evidence directly myself and in collaboration with teams at Imperial College by: using mechanistic models, synthesising other evidence, using other advanced analytics, reporting primary survey data (REACT) and conducting traditional epidemiological analysis of primary survey data. Data from REACT were used widely by other groups as a benchmark for the measurement of UK prevalence. Also, I communicated frequently with colleagues outside Imperial in the UK and worldwide to share key questions, knowledge, opinion and methods.

4.11 On 9 January 2020 I reached out to colleagues within Imperial and externally via Twitter to contribute to the scientific assessment of the virus that was emerging as a health threat in Wuhan:

> "Thanks @arambaut. It's better in many ways that this incarnation appears to be less severe once infected. However, our ability to control it is driven by our ability to find cases. If it being 'mild' makes it harder to find, it _could_ pose a greater health threat."

4.12 On 16 January, I read a report of a second exported case from Wuhan and became even more concerned. I tweeted,

"OK, I find this second export troubling. https://japantimes.co.jp/news/2020/01/16/national/science-health/japan-first-coronavirus-case/#.XiBQjv6gLuo

- did not visit market
- returned on the 6th
- already recovered

A version of SARS with a lower infection fatality rate _could_ be a much bigger public health problem."

4.13 I met with Professor Ferguson and two other colleagues for what would become the first meeting of the COVID-19 Response Team, on January 16 2020. In the meeting, colleagues reported the analytical plan and provisional results for what would become Reports 1 and 2 {SR/07- INQ000236273,SR/21 - INQ000236275}. I provided advice on the design of the analysis, the underlying assumptions and the interpretation. I edited drafts of the paper.

4.14 Imperial College Reports 1 and 2 {SR/07 - INQ000236273,SR/21 - INQ000236275} inferred that the true number of infections that had occurred in Wuhan was much greater than the number of cases currently being reported. Using data on the size of the city and the number of international flights made per day, we were able to show that under a broad range of assumptions, even two exported infections were not consistent with the number of cases being reported. Our findings were important because the larger the outbreak, the more likely it was that human-to-human transmission was occurring.

4.15 As the number of exported infections continued to increase, we expanded our analysis to explicitly identify a range of scenarios that were consistent with current observations, which we published as Report 3 {SR/22 - INQ000236276} on 25 January 2020. We stated that scenarios with a human-to-human reproduction number R less than 1 did not seem likely, given that transmission from the presumed market source should have stopped some time before. For infections to be continuing to rise, self-sustaining human-to-human transmission seemed likely. I provided advice on the design of the analysis, the underlying assumptions and the interpretation. I edited drafts of the paper.

4.16 The team focussed primarily on estimates of individual-level severity up to the publication of Report 4 on 10 February 2020 {SR/12 - INQ000236277}. This work synthesised a variety of data to estimate an infection fatality rate (IFR) of ~1%. The

result was important for the reasons I outlined in my draft quote to go with the press release of the paper:

> "As more data becomes available, we are able to estimate the severity of this novel coronavirus. Using a variety of data, and correcting for known biases, we estimate [that] approximately 1% of people infected with this virus will die. Although this is lower than diseases such as Ebola or SARS, it is considerably higher than seasonal influenza."

4.17 I provided advice on the design of the analysis, the underlying assumptions and the interpretation. I suggested edits to drafts of the paper. On reflection, the text of the report emphasises the case fatality rate (CFR) more than the IFR. Our estimate of the IFR of 0·66% (0·39–1·33) was refined and described more precisely in the final published version of the report {SR/23 - INQ000236303}.

4.18 I provided advice, feedback, interpretation and edits on Imperial Reports 5, 6, 7 and 8 {SR/24 - INQ000236278, SR/25 - INQ000236279, SR/26 - INQ000236280, SR/27 - INQ000236281}. Report 7 on 9 March 2020 highlighted that there was no trend of increasing prevalence of infection in people leaving Wuhan which was important because it suggested, based on relatively straightforward empirical evidence, that stringent social distancing in Wuhan had achieved a reduction in the reproduction number to less than 1.

4.19 On 7 February 2020, I reached out to an economist at the Council on Foreign Relations in the US. I explained that I thought the intervention in Wuhan was working but that the economic impact might be so high it would be difficult to sustain and also difficult for other populations to follow. He introduced me over email to Jens Nordvig at Exante Data and shared Exante's reports that included descriptions of Chinese regional economic activity based on mobile phone data. The introduction led to a project that eventually became Report 11 published on 24 March 2020 {SR/28 - INQ000236274}. It was later published and peer-reviewed at Wellcome Open {SR/29 - INQ000236263}. This report was important because it showed how: initially, transmission and economic activity were closely linked and that lockdowns stopped both transmission and almost all economically productive human movement. However, the Exante data and our analysis showed that movement had recovered without accompanying transmission. China was likely achieving a successful partial "decoupling" of transmission and economic activity.

4.20 I understand that the inquiry is interested in the content of my discussions with Professor Ferguson about the pandemic generally and about the ideas on which my reports of 10 March 2020 {SR/30 - INQ000269367} and 16 March 2020 {SR/30 - INQ000269367} were based. From the end of January, my discussions with Professor Ferguson included the following topics: the speed with which early epidemics of the virus would progress, the degree to which spontaneous behaviour change would affect that speed, the likely success or failure of the lockdown in Wuhan; and appropriate assumptions and model structures for the initial wave of the pandemic in the UK. My description of our views on these topics comes from a review of email conversations between myself and Professor Ferguson.

4.21 From late January, we discussed the likely speed of the pandemic with respect to vaccine investment decisions. Prof Fergurson's view was that the initial wave of the global pandemic would be rapid. My view was that behaviour change - either spontaneous or mandated - could reduce transmission sufficiently so that the first wave of the pandemic was much slower and that there was the potential that vaccines could be produced before people had been infected.

4.22 After its imposition, we discussed the likely success or failure of the lock down intervention in Wuhan. Here, the initial definition of success could be stated simply that the stringent social distancing would reduce transmission sufficiently that the incidence of infection would decline to very low levels before a substantial proportion of the population had been infected. My view was that there was a reasonable chance that the intervention could succeed, Professor Ferguson's view was that success was unlikely.

4.23 For mechanistic models, there is no set of assumptions nor model structure that is best for all different questions that might be asked during any given epidemic. Rather, the assumptions and structure should be assessed against the question being answered, the data available and the implications of the results. With this in mind, Professor Ferguson and I discussed model assumptions and structure on a number of occasions with respect to the likely size and duration of initial national waves of the pandemic and how interventions would be effective in that context. For example, when asked to provide evidence about the likely consequences of school closure, I used a relatively simple compartmental approach with fewer assumptions, whereas Professor Ferguson preferred an individual-based approach with more assumptions.

4.24 During the early morning of 9 March 2023, I heard a report on the radio that Cobra would be meeting that day and that the Prime Minister would be considering the use of social distancing. I sent an email to Professor Graham Medley and the SPI-M mailbox giving reasons for the UK: not to delay closing schools, to move to working from home and to implement any other possible social distancing, with a suggested initial duration of additional interventions of three weeks {SR/32 - INO000269365}. I supported this recommendation with a number of points that can be summarised as: we knew for certain that the world was going to look very different in three weeks time and, for a variety of reasons, it seemed likely that if we did not implement social distancing on 9 March, three weeks later we would wish that we had. I also stated clearly that as a nation, we might chose to lift all restrictions three weeks later and that if we did it would be a much more informed decision. I stated that this recommendation was my professional view as a biological scientist who had studied outbreaks and pandemics of respiratory viruses for almost my entire career. I acknowledged that this recommendation did not rely on any model output but that I believed it was my right to clearly communicate a recommendation even though SPI-M was technically defined as a modelling committee.

4.25 At 6.02 on 10 March 2023 I sent an email to Sir Jeremy Farrar and to the SPI-M mailbox {SR/33 - INQ000269366} that included my report "Mitigation of COVID-19 epidemics will likely fail if the population reduces rates of transmission in response to the saturation of critical care facilities" {SR/30 - - INQ000269367}. In his book [Spike, p105] Sir Jeremy quotes the interview I had with his co-author in which I referred to this email and report: "there was clearly a sense within government that there could be a fast way through this epidemic, that we could weather it by letting it pass through us quickly. The point of my note was to say 'no.'" I expand on this in the following paragraphs.

4.26 The GCSA and CMO repeatedly refered to models during their news conference of 9 March 2020 in a way which suggests that models supported the delay strategy. My report of 10 March 2020 {SR/30 - - INQ000269367} contained context, evidence and interpretation that was intended to be read alongside any other model-based reports being used to justify the delay strategy. As stated clearly in the report, I did not propose that the evidence in my report was necessary to justify a policy of stringent social distancing, which I thought was justified by international comparisons and the precautionary principle, as discussed above and in my email of the previous day

{SR/32 - INQ000269365}. I reproduce the summary of the report here and highlight key introductory points, findings and interpretations in the following paragraphs:

> "The UK is currently planning a mitigation response to the COVID-19 epidemic rather than ongoing containment. This strategy is informed by prior modelling studies and analysis of the severe 1918 influenza pandemic. The primary benefit of mitigation is that the epidemic will be over more quickly than might otherwise be the case, with the population having acquired herd immunity and also having experienced a relatively low peak. Here, we use simple compartmental models and recent infection fatality rate estimates for the UK to explicitly examine the implications of the UK population responding to a severe pathogen more strongly than did populations in 1918. We show that critical care facilities in the UK would be saturated quickly. If populations spontaneously reduce transmission close to threshold values when this occurs, any possible benefits of attempting mitigation are lost. The country would then have to either struggle on to the availability of a vaccine without a functioning health system or attempt the most stringent possible interventions to lower incidence back to containment levels. Over the same period of time, either of these scenarios would likely have far greater economic costs than would result from an immediate switch now to ongoing containment. These results directly support current advice from the World Health Organisation and are consistent with policy decisions made by China, Hong Kong, Singapore, Japan, South Korea and most recently Italy. Even if ongoing containment were to fail, we would have gained time and knowledge with which to decide our next strategy."

4.27 The introduction to report {SR/30 - INQ000269367} categorises response strategies at the time as either ongoing containment (e.g. China, Hong Kong and Singapore) or mitigation (e.g. UK and USA). It asserts that the initial stringency of the Wuhan intervention was sufficient to achieve containment but that it may not have been necessary, i.e. less severe versions of lockdown may also be able to achieve control. It also asserts that China's stated current policy at that time was to continue to control the virus and restart the economy "using rapid testing and advanced, technology-enabled, public health processes." Although my description of China's policy was not supported by a citation, from memory it should have called out the "Report of the WHO-China joint mission on coronavirus disease 2019 (COVID-19)" {SR/34 - INQ000236304}, which I mention in line at the end of the report.

4.28 The introduction to my report {SR/30 - INQ000269367} mentions that current response plans were informed by pandemic influenza plans which were themselves informed by observations of the 1918 influenza pandemic and by disease-dynamic modelling studies. It mentions that the world of 2020 is very different to the world of 1918 in ways that are important for human behaviour, such as the speed with which information can be disseminated. It also mentions that more recent outbreaks of severe pathogens have seen substantial reductions in behaviours that contribute to transmission. Despite these two observations, the disease-dynamic models that were used to inform pandemic influenza preparedness didn't include spontaneous behaviour change. As an example, I call out a well-cited study that I co-led {SR/03 - INQ000236306}.

4.29 I examined four key scenarios: an unmitigated epidemic (UE), "successful" mitigation (SM, where "success" is defined as the completion of the current apparent plan, not as a successful response), unsuccessful mitigation (UM) and ongoing containment (OC). I assumed a 1% infection fatality rate when ICUs had capacity and a 5% IFR when they were full. If the population behaved exactly as normal while the virus went through it, I estimated 2,650,000 deaths over 18 months. The wider context of the report makes clear I did not think that was a plausible scenario.

4.30 "Successful" mitigation was defined as a scenario where the country would experience almost exactly as many infections as were needed to achieve herd immunity. I state clearly in the report that I did not consider this to be a desirable outcome. Nonetheless, in my view, SM described an optimal version of the then enacted "delay" phase. If we know the unmitigated R value, under some gross simplifications, it is straightforward to estimate how successful interventions would need to be to get to just the number of infections needed for herd immunity. I estimated this to be a 23% reduction in transmission. Under this scenario, I estimated 1,740,000 deaths over 18 months.

4.31 My estimates for an unmitigated epidemic and for "successful" mitigation are higher than some other studies because they assume that the IFR would have increased to ~5% when ICUs were full.

4.32 The "unsuccessful mitigation" scenario UM describes a situation where the country is mixing exactly as much as is required to achieve herd immunity prior to ICUs being saturated. When ICUs become full and the age-averaged IFR is 5%, people further reduce their social mixing to bring about an effective R of 1.0. The key point is that ICU capacity is relatively low and ICUs would become saturated quickly. Hence the

epidemic would slow down with only few infections being generated and it would take a long time to achieve herd immunity: with repeated fluctuations in behaviour, after 18 months, I estimated that there would be 446,000 deaths and we would only have achieved 28% of herd immunity.

4.33 The final scenario assumes that the UK switched immediately to ongoing containment (OC), achieves a low R value and that there is no rebound from this state. I estimated at that point that it was still feasible that the UK could have as few as 2,670 COVID-19 deaths. It was my view then and now, that these four scenarios reflected an appropriate study design and fully supported immediate social distancing as the correct policy choice. It was also my view that immediate stringent social distancing was supported by international comparisons and the precautionary principle. The OC policy objective was more commonly referred to as "suppression" from around this time.

4.34 The report did have a number of limitations, and I discussed these in relation to the main claims. The code used for the results was age-structured and parameterised for UK mixing data. However, even though I could have included age structured results, I chose not to. The scale of difference between the outcomes of the scenarios was so large, I did not think the additional detail would have added substantially to the evidence. Also, the simplicity of the model made it easily reproducible without any input from me. Finally, I wanted to circulate the report as quickly as possible.

4.35 I did not explicitly include age-targeted shielding of the elderly as a comparative intervention, which, again, the code was setup to do. I did not believe this to be a well described intervention. See paragraph 6.1 of this statement for additional comment.4.35a My assumptions about behaviour change were influenced by my early work on SARS-CoV-1 in 2003 which quantified the transmissibility of a human coronavirus and showed that the overall reduction in social mixing in Hong Kong likely contributed to ending the outbreak {SR/01 - INQ000270158}.

4.36 Graham Medley mentioned in an email on 10 March 2020 that the report circulated on 10 March {SR/30 - IN0000269367} had been brought up at SAGE. I do not know why the advice was not adopted by SAGE until 16 March 2020. However, the report did generate a number of email conversations within the community of scientists who were part of SPI-M-O.

4.37 I was included in two substantial email discussions motivated by the report circulated on 10 March 2020 {SR/30 - IN0000269367} among scientists who contributed to SPI-

M-O. The first started at 21:44 on 9 March 2020 and continued until 12:05 on 12 March 2020 {SR/35 - INO000269369}. There were a number of branches to this discussion and I include the conversation that was either to the whole group or between myself and Professor Ferguson. I sent a copy of the note I had already sent to Jeremy Farrar to the group at 08:37 on 10 March 2020 and Graham Medley asked everyone to read it. There was agreement from Mark Woolhouse that the report described an interesting scenario by which the current plan may not achieve its aims. Professor Ferguson agreed that we should ensure policy makers understood what successful mitigation looks like and also that we should give a hard-nosed assessment of how difficult ongoing containment might be. I disagreed strongly on the latter point. I did not feel it was our job to say how containment might work. I suggested that if the country attempted containment it would involve a substantial proportion of government effort and we could not anticipate how it would look. I commented that the level of threat from COVID in terms of deaths was comparable with prior UK experiences where rapid innovation had been a key factor in our success. I also asked that we could include economics in the meeting discussion, even though it was not our area of expertise, because that was the only reason one would not attempt ongoing containment at that point. Professor Ferguson responded that his view was that we did need to say how containment would work if we were going to recommend it. He thought that we would not be listened to if we said that we thought containment was preferable but we couldn't say how it would be achieved. His view was that there was significant momentum behind the current strategy at that time and that the government was aware of the projected incidence, health system demand and mortality impact.

4.38 I understand that the inquiry is interested in my discussions with Professor Ferguson on science advocacy. Professor Ferguson and I discussed appropriate interpretation of results obtained from these models during the email exchange among members of SPI-M that occurred on 10 March 2020 {SR/35 - INO000269369}. The group was asked by Prof Medley to give a view on a report I had circulated that morning {SR/30 - INQ000269367}. During that discussion, as part of his response to Prof Medley's request, Professor Ferguson stated "I do feel strongly that we should focus on providing an evidence based assessment of what the policy choices are and their likely impacts, rather than advocate for a particular policy. At least in our role on SPI-M." The use of the term "scientific advocacy" in this context is used to contrast with "scientific evidence" and implies an absence of evidence. It is my view that Professor

Ferguson was describing my work as advocacy and he was making clear his view that it did not constitute additional scientific evidence.

4.39 There was then a slight misunderstanding. I incorrectly interpreted Professor Ferguson's comments about us needing to say how containment would work as being about the appropriateness of me recommending specific policy options. In a continuation of our private exchange to clarify this misunderstanding, Professor Ferguson gave his view that the government would only change course if we could detail an alternative strategy. In response, I argued that the lack of support for more than three or four months of stringent social distancing was driven by the belief that there was a viable alternative (a rapid epidemic followed by population immunity) . Professor Ferguson then commented that treasury advice was that six months of social distancing would drive a deep recession with massive business failure and job losses. I replied that I didn't think they had a model for the alternative that the virus would keep R below 1. I also commented that I couldn't believe that it was better to let the virus decide how our society would change rather than the government.

4.40 The second email discussion motivated by the report circulated on 10 March 2020 {SR/30 - INQ000269367} among scientists who contributed to SPI-M-O took place between 21:54 on March 10 2020 and 11:46 on 11 March 2020 {**SR/48 - INQ000273746}.** **I was** copied into this conversation but didn't become aware of it until after the SPI-M-O meeting on 11 March 2020. In this conversation, colleagues circulate and discuss a position paper initially drafted by Graham Medley and they propose refinements to the ongoing containment strategy. John Edmunds suggests a hybrid of mitigation and containment that would still result in population immunity but that would be achieved by alternating periods of stringent social distancing with periods where restrictions were more relaxed. Mark Woolhouse implemented John's suggestion in a model with his team and provided preliminary results. These results were presented alongside my paper in the SPI-M-O meeting held later on 11 March 2020.

4.41 On 16th March 2020, I authored a report titled 'Low critical care capacity and high severity of COVID-19 mean there is little functional difference between successful 'flattening the curve' and ongoing containment' {SR/31 - INQ000269368} which was considered at the SAGE meeting on 16th March 2020. This report included a copy of my report from the previous week as an appendix. In the short main report of 16 March 2020 {SR/31 - INQ000269368} I make an argument against the cyclical use of interventions as suggested by John Edmunds and discussed at the SPI-M-O meeting of 11 January 2020. I suggest that population immunity may arise as a consequence

of an intervention but should not be an objective because it would take too long to occur. If population immunity is not an objective, then there is no benefit to cyclical interventions: the average R value can be close to one under full suppression at very low prevalence or can average 1 at higher prevalence with the healthcare system being constantly challenged. So there is no net benefit to the population of prooceeding with high prevalence and R close to 1. The argument I make is similar to "the dance" part of the "hammer and dance" idea described by Tomas Pueyo a few days later {SR/36 - INQ000236272}. To the best of my knowledge, the main section of my report of 16 March 2020 was not used to inform SAGE advice.

4.42 I later discussed some of the concepts of my report of 16 March 2020 {SR/31 - INO000269368} in an email exchange with Graham Medley and Mark Woolhouse {INQ000103475}. This discussion was related to a commission to SPI-M-O to provide modelling input to support decisions around the end of the initial three week period of stringent social distancing. My view was that we needed to be careful not to assume implicitly that the long term objective did not include low levels of incidence. I acknowledged Mark Woolhouse's views that the interventions themselves had negative consequences, but argued that we should not suggest that the UK was not capable of operating at lower levels of incidence. By this point, we had already published our report on China showing signs of a "successful" exit from their initial lockdowns {SR/28 - INQ000236274} and I was concerned that we were not being sufficiently ambitious for UK objectives. I also asked if there was a treasury team that we could work with to obtain economic assessments of different options, i.e. if we did aim for sustained low incidence, what would be a reasonable level of economic activity we might expect compared to some combination of cycling periods of stringent social distancing with more relaxed periods with R greater than 1. I cannot find any record of a response to my request to work with a team from the treasury.

5 The Timing of the First National Lockdown

5.1 My view is that the first national period of stringent social distancing (lockdown) should have been introduced on or around 9 March 2020. I communicated that at the time in a number of ways, as described in section 4 of this statement. On reflection, the key point is that by the weekend of 7 and 8 March 2020 we had recorded a number of unlinked lab-confirmed deaths caused by the SARS-CoV-2 virus. Given the levels of testing being conducted at that time and our knowledge of the severity of the virus from other countries, it was absolutely the case that unless levels of social mixing were dramatically reduced our healthcare system would be overwhelmed. Based on

my recollection of the mainstream media at that time, the UK population did not appreciate this point. While it is conceivable to me that the UK government could choose to allow the healthcare system to be completely overwhelmed if it thought that the trade-offs justified such an outcome and that there was generally good understanding across the population of what those tradeoffs would entail, it was not conceivable to me at that time that the UK government could deliberately choose that path with the population apparently unaware of the consequences.

5.2 The DHSC action plan of 3 March 2020 {SR/37 - INQ000236268} suggests reasons why the first period of national lockdown was delayed. In paragraph 2.6 numerical estimates of age-specific hospitalisation or death rates are not given even though those were available, suggesting that there was some uncertainty on that point. In paragraph 3.5 it states principles to "slow the spread". Given observations from overseas, including the already stated objective of China to control the virus {SR/34 - INQ000236304}, this implies that there was no intention to achieve control in our initial plan. The same principle is reflected in paragraph 3.9. Paragraph 4.3 states that the system wide response plans are based on the stability of the economy, but does not indicate that there is any potential trade-off between high levels of virus transmission and economic activity. Paragraph 4.25 reiterates that our plan was only to slow the spread. Paragraph 4.26 states that one of the objectives is to prevent the main wave of the SARS-CoV-2 pandemic overlapping with seasonal flu. Based on already public evidence at that point, the amplitude of the SARS-CoV-2 healthcare demand was going to be orders of magnitude higher than any influenza wave since the 1918 pandemic.

5.3 I understand that the inquiry is interested in the possibility that there was a degree of "groupthink" within the UK response which I interpret as the possibility that groups made poor decisions without sufficient external challenge. It was my view at the time that groupthink did prevent the UK response system from considering a wider range of options earlier in the pandemic. The SPI-M-O meeting had an in-person option on 11 March 2020 and I attended at 39 Victoria Street. After the meeting closed, members of the SPI-M secretariat approached me and assured me that I was being listened to and that the UK government was considering a change of course, but that this would take time if it happened. I replied that we did not have time. I then asked if there were any guards against groupthink. I asked if they had formed any kind of red team and I mentioned the names of some management consultancies who I thought would be able to understand the issues quickly enough to pull together a challenge.

5.4 I agree with Sir Jeremy Farrar that SAGE should have been "blunter" in "calling for stronger action"? [Sir Jeremy Farrar, Spike: The Virus vs the People, pg 130]. There was a common view that social distancing measures such as home quarantine and isolation would only be maintained for a short time, therefore they should be timed to coincide with the peak of healthcare demand. This potential limit on the duration of interventions was sometimes referred to as behavioural fatigue {letterfatigue,latterfatiguesigs}. Given that there was no initial attempt to achieve ongoing containment, the belief that the duration of interventions would be time limited was additional motivation not to impose interventions earlier.

5.5 When asked to comment on whether the UK should have entered lockdown earlier than 23rd March 2020, Professor John Edmunds stated that "it would have been very hard to pull the trigger at that point." [Guardian article, 7th June 2020] Although I agree with this to some extent, I think the statement implicitly accepts that containment could never have been an objective. Had everything else about the response been the same up to 9 March 2020 and then the government had tried to impose full lockdown, then I agree, based on my own recollection of people's sentiment around me, it is not clear that the population would have supported the decision. However, had the possibility of stringent social distancing been communicated pro-actively from mid-February (when we were seeing real signs that the Wuhan intervention was working) then the situation could have been quite different. Our study of social mixing during this period {SR/38 - INQ000236294} shows that population mixing started to reduce substantially on or around the 16 March 2020 and had already dropped over half way towards its low April 2020 average by 23 March 2020. This change would have been influenced by a number of factors, not least reports of the impact of the virus in northern Italy. However, the drop coincides precisely with the intense media attention on Report 9 from the Imperial College Response team {SR/39 - INQ000270159}. It is my view that it will never be known with confidence if it would have been possible to effectively reduce social mixing earlier than 16 March 2020. Had social mixing dropped sooner in March 2020 in the UK then the number of deaths during the first wave could have been reduced substantially. Imperial college report 24 {SR/40 - INQ000236294} was later published as a peer-reviewed article {jeffrey2020}.

5.6 I agree with the Institute for Government that the desire of ministers to avoid a lockdown framed the advice commissioned from SAGE, and contributed to the delay

in considering and implementing these measures. [Institute for Government Report, Decision-Making in a Crisis, pg 42]. Also, I understand that the inquiry is interested in my discussions with Professor Ferguson, who was attending SAGE at this time, about topics that relate to my report of 10 March 2023 {SR/30 - INQ000269367}. Some of these discussions with Professor Ferguson about the report inform my view about the Institute for Government's conclusion. On 1 March 2020, I drafted and circulated a report titled "The potential benefits of ongoing containment as a UK policy objective for the 2020 COVID-19 outbreak" {riley006} that I hoped could become an Imperial College Response team report. On reflection this was almost certainly motivated by the publication of the WHO China report on 28 February 2020 {SR/34 - INQ000236304}. It was an early version of what became my report of 10 March 2020 {SR/30 - INQ000269367}. The 1 March version did not contain any quantitative analysis of how mitigation might fail, nor of the impact of saturating intensive care in increasing the fatality rate. In this preliminary analysis, I pointed out that a rapid wave similar to the realistic worst case scenario could lead to 464,000 deaths. I also included a successful immediate ongoing control scenario in which there were 148 deaths. I stated my view that at that time there was no evidence that containment was possible in the UK but that it was the stated policy objective of China as of 28 February 2020 {SR/34 - INQ000236304}. Professor Ferguson's view at the time was that "everyone in policy circles" knew that R could be brought below 1 but that there was no appetite for the draconian measures that would be required. My response to this point included four additional points:

> "- The Wuhan data establishes a clear precedent for a dramatic reduction in R0 via change in human behaviour, independent of the precise mechanism by which that change was achieved.
>
> - Wuhan _may_ have brought transmission substantially below 1.
>
> - We do not know what our UK baseline will be in terms of R0 (Scenario B in my note is crucial).
>
> - Stating that we should consider policy options that _may_ bring R0 _close_ to 1 because of what Wuhan have achieved is not the same as saying we should do exactly the same interventions as Wuhan. I'm quite worried that "everyone in policy circles" are also not getting this point."

Professor Ferguson also commented that we were currently driving UK preparedness and planning and that we were trusted by the government. He added that this was not

the same as saying we never disagreed with government policy or the CMO, but that we did so privately and constructively.

5.7 I had another discussion with Professor Ferguson on 8 March 2020 that also informs my support of the Institute for Government's conclusions that the desire of ministers to avoid a lockdown framed the advice commissioned from SAGE, and contributed to the delay in considering and implementing these measures. [Institute for Government Report, Decision-Making in a Crisis, pg 42]. The discussion was in response to my circulating an updated version of my report that was much closer to the version of 10 March 2020 {SR/30 - INQ000269367}. When I circulated the updated draft (on 7 March 2020), I stated that I wanted to get these ideas "out there" sometime on 8 March 2020 and that I wanted it to be a published as an Imperial College COVID-19 Response Team report. In his reply, Professor Ferguson was critical of the draft. He compared the underlying analysis to some economic models that were, in his view, only rhetorical tools. His view was that the report would have no value for the CMO and GCSA because it didn't, in his view, contain anything they didn't already know other than the "failed mitigation" scenario. His view of that scenario was that it was not supported by behavioural science. He stated that the point of science advice for policy is to present the evidence around interventions and develop potential new ones. I did not agree with those views. I thought that careful consideration of possible spontaneous behaviour change was crucial for formulating policy during outbreaks of severe respiratory infections.

5.8 He suggested I submit it as an opinion piece to a journal if I wished but that I should "best leave reference to the Centre out of it." I interpreted his request as a refusal to allow me to further pursue the publication of the report as an Imperial College report and a request that I not include the MRC Centre for Global Infectious Disease Analysis as an affiliation if I did distribute the report further. My view was that Professor Ferguson was the head of the MRC Centre at Imperial and the response team lead: therefore I should respect his choice not to further pursue publication of the report as a team output and also his request that I not use the MRC Centre affiliation. However, in my capacity as an independent academic at Imperial and a member of SPI-M, I chose to distribute my report on 10 March 2020 rather than to submit it to a peer-reviewed scientific journal.

6 April 2020 onwards

6.1 I understand that the inquiry is interested in the discussion I had via email with Professor Graham Medley and others on 6th April 2020 {INQ000103458} during which

I requested that "we discuss shielding as an exit strategy this morning" I stated that "my feeling is that enhanced shielding is incredibly important as a policy in its own right and should be part of all exit strategies. But I don't feel it is, in itself, a strategy." By this I meant that if there was a significant prevalence of the virus in the population, we should always have policies that reduce the probability that the most vulnerable become infected, but that we would need other policies as well. My view then and now is that the proportion of the population that we would consider high-risk was so large and so integrated with the low-risk group that it would not be possible to protect them sufficiently to allow the virus to progress rapidly through the low-risk population without causing high levels of infection in the high-risk group. Therefore, in addition to shielding, we also needed to protect the high-risk group by keeping prevalence low in the low-risk group. Hence shielding would be necessary but never sufficient as an exit strategy. I did not agree with Professor Medley's criticism that my thinking was "rather linear and health-based," because I didn't think we had any evidence at all that shielding such a high proportion of the population as an exit strategy was feasible, so any hypothetical economic benefits were less relevant.

6.2 Also during that discussion, Mark Woolhouse noted that it was a "problem...that none of the models incorporate shielding explicitly." {INQ000103460} I agreed that "there is definitely scope to improve our thinking here" because at that time I did not believe that models were explicitly representing hospitals or care homes. I also stated that we "may have under-rated the potential value of compartmental models for this question," because I had used a compartmental model of hospital transmission of SARS-CoV-1 during the early 2000s to estimate the relative importance of different routes of transmission in hospitals {SR/40 - INQ000236283}. I understand that substantial effort was devoted to understanding the transmission dynamics of the virus in hospitals and care homes by other members of SPI-M-O.

6.3 During this discussion I also stated "I haven't seen anything from the Treasury and I don't expect to. We've been asking for months for them to tell us comparative costs of...pretty much anything!" {INQ000103460}. It was my feeling at the time that SPI-M had been requesting details of economic models being run at the Treasury since early March. For example, in my email exchange with Graham Medley and SPI-M on 9 March 2020 {SR/32 - INQ000269365}, I mentioned that people seemed to imply that economic analyses suggested we couldn't use stringent social distancing and I offered to "go sit in a room" somewhere and review evidence. The next day, Professor Ferguson mentioned economic modelling from the Treasury during our email discussion (see paragraph 4.37 above and {SR/35 - INQ000269369}). Also, my

recollection of introducing my report verbally to the SPI-M-O meeting on 11 March 2020 is that I stated that I understood that there may be good economic arguments against the policies we were discussing, but that we had not been able to see those arguments so we could not assume that they were sufficient to rule out stringent social distancing.

6.4 During the email discussion of 6 April 2020 {INQ000103460}, I stated that "after the lockdown policy, I was really hoping to see an assessment of cyclical stringent interventions." I had hoped that there would be public predictions of the impact of interventions on the economy, perhaps in terms of predicted changes in GDP. I also expressed a concern that "because we are the ones 'stepping up,' we are the default committee of COVID intervention design and assessment." This second comment reflected my continued frustration that there was no public economic modelling of the impact of interventions or of the likely consequences of not intervening. Therefore, the public was seeing our views of the epidemiological consequences of taking action (or not) without any countervailing economic views: we were "stepping up" in the sense of providing public evidence to support very difficult policy decisions while I perceived that other important actors in the system were not. I am not aware that the imbalance has ever been addressed. In particular, I am not aware of any economic counterfactual from the Treasury for the UK choosing not to mandate stringent social distancing on 23 March 2020 nor of the UK population initiating a substantial reduction in social mixing prior to 16 March 2020.

6.5 The Institute for Government noted that there was a "lack of joined-up thinking" in government decision-making as the UK exited the first national lockdown. [Institute for Government Report, Science Advice in a Crisis, pg 20]. I agree with this observation. I understand that the inquiry is interested in my view of the Treasury's view that "we would be able to stay ahead of the virus" after lifting restrictions?"[Chancellor's Statement to the House, 5th November 2020]. This statement was not consistent with results from the REACT-1 study published on 29 October 2020 in which we measured the round-to-round doubling time of prevalence to be 9 days (see Figure 1 of {SR/41 - INQ000236287}).

6.6 Professor Mark Woolhouse commented that the sequencing of relaxations in summer 2020 "often felt arbitrary, given that the policy objective was still to keep the R number low. There were no reliable estimates of how much transmission was occurring in places like gyms, hairdressers or churches." [Professor Mark Woolhouse, The Year The World Went Mad, pg 149]. I agree that some decisions felt arbitrary but I also

appreciate that the government was taking a view on almost every aspect of daily life and could only do so with the evidence that was available to it.

6.7 The Eat Out to Help Out scheme ran through August 2020. While the scheme would have almost certainly increased transmission, it was during a period of very low prevalence. It seems likely from REACT-1 results {SR/42 - INQ000236286} that incidence had started to grow prior to the commencement of the scheme. I did not attend SAGE prior to being seconded to UKHSA and can therefore not comment on the degree to which SAGE was consulted on this scheme nor on other similar policy choices prior to October 2021. Overall, my view of the scheme is that it can only be justified on economic grounds. With prevalence so low at that time and schools closed, I can see a rationale for stimulating this section of the economy. However, I have no knowledge of the economic benefits that arose from the scheme in terms of business failures averted or subsidy reduction. Therefore, I am unable to comment further.

6.8 From 4 July 2020 to 14 October 2020, local lockdowns were used in an attempt to prevent increases in the prevalence of SARS-CoV-2. From 14 October 2020 to 5 November 2020 the first version of local tiers was used in an attempt to prevent increases in the prevalence of SARS-CoV-2. From 5 November 2020 to 2 December 2020, the second national lockdown was used to prevent increases in SARS-CoV-2 prevalence. From 2 December 2020 to 6 January 2021 the second version of tiers was used in an attempt to prevent increases in SARS-CoV-2 prevalence. The third national lockdown began on 6 January 2020. The effect of regional modifications to the second version of tiers was that the second national lockdown was largely already in place over the period of Christmas 2020.

6.9 At the fifty-eighth meeting of SAGE on 21st September 2020, it was recommended that a national 'circuit-breaker' lockdown should be considered for immediate introduction. However, the government decided not to implement a lockdown for another six weeks.

6.10 On 17 December 2020 the Vaccines and Related Biological Products Advisory Committee of the US Federal Drug Administration published the Sponsor Briefing Document Addendum of the meeting that day on the Moderna product mRNA-1273 {SR/43 - INQ000236269}. Figure 1 of that document presents a comparison of how vaccine and placebo groups developed COVID-19 after their enrolment in the trial (as a Kaplan-Meier plot). Those data constitute strong evidence that the Moderna vaccine would be highly effective.

6.11 Results from the REACT-1 study suggested consistently that only national lockdowns were effective at preventing the overall increase of SARS-CoV-2 prevalence in the UK between August 2020 and December 2020, inclusive {SR/44 - INQ000236292}. Therefore, every week that there was not a national lockdown contributed to increasing the peak prevalence of infections in unvaccinated at-risk individuals at the start of January and hence to the total number of infections in at-risk individuals during the second wave. Continuing the second national lockdown through December 2020 into the new year could have substantially reduced excess deaths during the second wave.

6.12 With hindsight, my view is that local restrictions during this period were not stringent enough, were implemented on too small a scale and did not have sufficient accompanying movement control to be effective. I do not have a clear view that more stringent regional controls would have worked. However, evidence suggests that stringent national policies did work.

6.13 On balance and with hindsight, I think a national circuit-breaker during September would have been a good policy. It was suggested for a period during which many students had a break from school and it was early in the period of exponential growth. Therefore, had policies during the second wave been otherwise the same, the eventual peak may have been substantially smaller had there been an additional period of stringent national interventions during September. However, I am not familiar with how decision makers were trading off direct harms from the virus with other harms during this period. Therefore, I cannot assess how a slowing of the epidemic in September would or would not have interfered with the triggering of the second or third national lockdowns.

6.14 Professor Mark Woolhouse stated that the UK government "could and should have done far more to protect the most vulnerable during the second wave." [Professor Mark Woolhouse, The Year The World Went Mad, pg 170]. Statements about the timing of national lockdowns notwithstanding, I feel other colleagues who worked on the transmission dynamics of the virus in hospitals and care homes are more qualified to comment on what more the government could or should have done for the most vulnerable.

6.15 In December 2020 Professor John Edmunds stated that "this is the worst moment of the whole epidemic" [Manchester Evening News article, 19th December 2020] and in January 2021 that "really major additional measures" were needed. [Cambridge News article, 4th January 2021]. My view is that neither ministers nor the public could

possibly have had better data with which to develop situational awareness than was provided during this period by case data and other data such as those from REACT and the ONS CIS study. Also, from 17 December 2020 there was a strong likelihood of an effective vaccine (or sooner possibly from non-public sources). As already commented above, every additional week of national lockdown would have reduced the height of the peak and reduced the number of people who were infected prior to receiving a vaccination.

6.16 Between August 2020 and December 2020, despite the quantity and quality of surveillance data, there was still substantial debate about trends in prevalence and the potential for large numbers of excess deaths, with some high profile commentators stating with apparent confidence that there was little risk of a large second wave in the UK. I am interested in the inquiry's view on the degree to which poorly informed opinion degraded the situational awareness of ministers and the general public and may have led to a reduction in the number of weeks that the country was in national lockdown during that crucial period.

7 Access to, Sharing and Quality of Data

7.1 I note here that I have also contributed to section 5 of the UKHSA Module 2 witness statement which describes how data was used by UKHSA and its sender organisations during the pandemic. In that document, we comment how the capacity of organisations and/or the design of data systems may have affected the timely delivery of effective epidemiological analysis and on whether there was sufficient collaboration with data providers so as to enable modelling groups to understand and utilise the data streams.

7.2 At the fourth SAGE meeting on 4th February 2020, it was noted that a "lack of data-sharing is seriously hampering understanding of WN-CoV." I did not attend SAGE prior to being seconded to UKHSA and was not present at the meeting of 4 February 2020.

7.3 SAGE minutes mention that there was a "5-7 day lag in data provision for modelling" [SAGE 15 minutes, 13th March 2020]. This delay did not affect the key reports that I have mentioned in this statement substantially {SR/30 - INQ000269367, SR/31 - INQ000269368}, which did not use models that were being calibrated to current cases.

7.4 I understand that Professor Ferguson has also contributed a witness statement to module 2 of the inquiry. He is well-placed to comment on whether the lack of accurate

data was an issue in the production of reasonable worst case scenarios by the Imperial College COVID-19 Response Team.

7.5 The use of models to generate disease-dynamic evidence is hindered to some extent when key parameters such as the length of immunity conferred by infection are not known. However, it is almost always the case that there are significant uncertainties in some parameters of a mechanistic model. Therefore, uncertainty in model output should be assessed with respect to key conclusions. Also, it may be appropriate to adopt the precautionary principle, if there is clear asymmetric risk associated with a key assumption. For example, when we did not know the maximum duration that a population would endure stringent social distancing, it is my view that it was important to avoid only presenting results based on the assumption that the maximum duration would be short.

7.6 I was a Lead Investigator in the Real-time Assessment of Community Transmission (REACT) programme (https://www.imperial.ac.uk/medicine/research-and-impact/groups/react-study/). The first round of the REACT-1 study was commissioned in April 2020 by DHSC in April 2020. The studies were designed to help the Government understand COVID-19 in different areas of the country including in people who do not have any symptoms. Some material in the following paragraphs is adapted from the REACT Programme website and from other documents prepared by the REACT team.

7.7 Data collection for REACT-1 commenced on 1 May 2020 during the first national lockdown in England. It continued for a total of 19 discrete rounds of data collection, ending at the height of the second Omicron wave (BA.2) on 31 March 2022. In all, over 3 million individuals (aged 5+ years) took part in response to over 17 million invite letters distributed. In REACT-1, participants collected a self-administered throat and nose swab at home which was then sent for testing by polymerase chain reaction (PCR) in a single commercial laboratory, with samples testing positive being sent for viral genome sequencing.

7.8 By use of random samples of the population, REACT-1 included asymptomatic as well as symptomatic infections, providing real-time estimates of population SARS-CoV-2 prevalence, by time, person, and place, thus reducing biases introduced by test availability and test-seeking behaviour. The study provided reliable and timely estimates of the reproduction number R through weekly reports to government that directly influenced policy, including the early detection of new waves of infection and, through viral genome sequencing, the identification of the variants responsible. Thus

the REACT team was the first to detect the rise in infections in London, Essex and Kent at the start of the second wave in August-September 2020 (caused by Alpha variant){SR/45 - INQ000236291}, and documented the rapid replacement of Alpha by the Delta variant in May 2021 as the third wave in England took hold. They estimated vaccine effectiveness against infection (18 to 64 years) of 49% from June to July 2021, rising to 58% for strong positives.{SR/44 - INQ000236292} In September 2021, at the start of the autumn school term in England, infections increased exponentially among (largely unvaccinated) children aged 5-17 years; in adults, following two vaccine doses, raised prevalence of swab-positivity at 3 to 6 months post-vaccination suggested increased risk of breakthrough infections 3 months post-vaccination.{SR/46 - INQ000236290}. The REACT team subsequently identified the extremely rapid rise of infections in December 2021 as Omicron (BA.1) replaced Delta {SR/47 - INQ000236293}.

7.9 The REACT-2 programme measured the prevalence of antibodies to SARS-CoV-2 in a random sample of the adult population in England. From June 2020 to May 2021, over 900,000 people took part, helping us to understand how many people had been infected with the virus and to identify the groups most at risk. It also measured the waning of antibodies over time, and the impact of the vaccination programme on antibody prevalence in the population. The findings provided the Government with data on the unequal burden of COVID-19 and the likely impact of previous infection and vaccination.

7.10 The REACT Long COVID (REACT-LC) study involves follow-up of over 120,000 people to understand why some people who are infected continue to have symptoms for several weeks or months – a condition called Long COVID – while others don't. REACT-LC is well placed to include a large and diverse group of people from the wider REACT programme who have had different experiences of COVID-19. REACT-LC aims to identify new approaches to diagnosing, supporting and managing Long COVID.

7.11 REACT-GE looked for biological 'signatures', such as molecules in the blood or variations in people's genes, that could help explain why some infected individuals experience serious illness while others don't. This research was expanded to look for biological factors that could be linked with developing Long COVID. 8,000 people – half of whom report long-term symptoms following COVID – are having their DNA code read, alongside a variety of other tests looking at the brain and immune system. The researchers are using statistical analysis and machine learning to find markers

that give people a higher risk of Long COVID, which could highlight new treatment and diagnostic avenues. REACT GE is a partnership between Imperial, Genomics England and Edinburgh University.

7.12 Some children with COVID-19 experience symptoms for several weeks or months (Long COVID), while others have a short illness or no symptoms. We have little understanding of why this happens. The REACT Children and Young People (REACT-CYP) study involves follow-up of over 10,000 children aged 5-17 years to investigate socio-demographic factors affecting why some children get Long COVID and others don't, and what impact Long COVID has on their longer term education and health outcomes, cognitive function and health-related quality of life. REACT-CYP is well placed to include a large and diverse group of children aged 5-17 years from the wider REACT programme who have had different experiences of COVID-19. REACT-CYP aims to identify new approaches to diagnosing, supporting and managing children and young people with Long COVID. The team is working closely with people who have Long COVID to understand their varied symptoms and experiences. The researchers are also looking at how people's biological makeup, their environment and social factors affect their likelihood of experiencing this illness, and the relationship between these. A number of people are also being asked to take part in an interview study to document and analyse their experiences in depth. The study is being carried out in partnership with Queen Mary University of London, the Francis Crick Institute, Leiden University, Birmingham University and Newcastle University.

7.13 It is my understanding that the REACT programme directly influenced the UK government's response to the COVID-19 pandemic. Weekly reports were provided to government, advisory bodies (including DHSC, the UK Health Security Agency [UKHSA] and the Scientific Advisory Group for Emergencies [SAGE]), with rapid publication of interim (on occasion) and final results per round to government, the scientific community and the general public (48 reports published over the nearly two years of the study).

7.14 The REACT independent calculations of R and the related data were used by the Scientific Pandemic Influenza Group on Modelling (SPI-M) to calibrate models for SAGE. These contributions were cited in multiple UK government press releases, where the REACT-1 programme was noted to be "…the largest, most significant piece of research looking at how the virus is spreading across the country".

7.15 In a letter thanking the REACT investigators (June 2022 {riley007}), the UK Secretary of State for Health and Social Care, the Rt Hon Sajid Javid MP, wrote: "Your scientific and academic teams' investigatory passion and effective gathering of intelligence…has been instrumental in detecting waves of the virus… Through your leadership and teamwork, the REACT programme has provided vital insight into COVID-19 symptoms, identifying the most common beyond the '3 core' symptoms. Your ground-breaking research has showcased how Long COVID-19, may have affected over two million people in England. The REACT-2 studies also signposted early insights into antibody levels in the population and later how effective vaccines are but that antibody levels do wane over time and much more… All your papers have been accompanied by…accurate, unbiased assessments of the current COVID-19 situation, expanding the media and public's understanding of COVID-19 which enabled them to make informed decisions about their actions. Your work has been vital to our nation's response to this pandemic."

7.16 I was quoted in an article in the Spectator magazine about the REACT study, which claimed that my words did not stand up to scrutiny. It was suggested that the REACT study was "deeply problematic," that the value of the information was "reduced because of its intermittent nature" and that the data was "unreliable." [The Spectator article, 23rd January 2021]. I agree that the data were intermittent and that this was sometimes a limitation. However, I do not agree with the remainder of the comments. The Spectator article refers to a finding in our interim report for round 8 of REACT-1, published on 21 January 2021. This finding was based on the within-round data, not on a between round comparison, which seems to be the assumption in the Spectator article. Our main finding in the summary for the report of 21 January 2021 was that "we found no strong evidence for either growth or decay averaged across the period; rather, based on data from a limited number of days, prevalence may have started to rise at the end of round 8a," which was unexpected given the timing of the start of the third national lockdown. However, subsequent analysis of data from the ONS CIS study also found an unexpected plateau for the same period {SR/49 - INQ000236288}.

7.17 The design and value of insight from the REACT studies have been held up as an international example of high-value innovative surveillance during the COVID-19 pandemic, for example by senior colleagues at the US Centers for Disease Control, who provided a commentary on a recent summary publication about REACT-1 and stated that

"The methods and execution of REACT-1 proved successful in maintaining situational awareness as reported in more than 15 publications and numerous public health reports, leading to meaningful policies and mitigations with significant positive public health impact." {SR/50 - INQ000236289}.

8 The Use of Modelling during the Covid-19 Pandemic

8.1 I understand that the inquiry is interested in the modelling work that was conducted by the Imperial College Covid-19 Response Team, specifically the details of the number and types of models that were used, developed and fed into the UK government's response to the pandemic. I understand that Professor Ferguson is also submitting a witness statement for module 2 of the inquiry. He is well-qualified to address these questions for the majority of modelling work conducted by the team at Imperial College. Elsewhere in this statement, I have commented on some of the early results.

9 The 'R' Number

9.1 The R number is the average number of new infections generated by one typically infectious individual. When the number of new infections is increasing, R is above 1. When the number of new cases is decreasing, R is less than 1.

9.2 The R number is a useful public health tool when the objective of policy is to either achieve ongoing control of the epidemic or keep epidemic growth to a low level. R describes how 'fast' the epidemic is increasing in a way that is meaningful for policy decisions. If R is 2, then each new case is generating 2 new additional cases. Therefore, to reverse growth, any additional interventions or spontaneous behaviour changes would have to eliminate 50% of transmission. Similarly, if R were only 1.2 then only 17% of transmission would need to be eliminated to halt the growth of new infections.

9.3 The policy of keeping R below 1 was appropriate in the absence of a vaccine. However, it is my view that policy related to R was not sufficiently well linked to maintaining low prevalence {SR/31 - INQ000269368}. The UK population experienced interventions and spontaneous behaviour changes such that average R must have been close to 1 over the period February 2020 to July 2021. However, because this average arose from long period of R above 1 followed by long periods of R below 1, we experienced periods of high prevalence with associated high mortality. It is my view that it was feasible that the UK population could have experienced similar average levels of reduced social mixing but with far lower average

prevalence, as was achieved in other populations. Regardless of the degree to which this was realistically achievable in the UK during the COVID-19 pandemic, during which the likelihood of an effective vaccine was often assumed to be low; it is my view that for future respiratory pandemics our initial assumption will be that there is a high likelihood of an effective vaccine. Therefore, until this is shown not to be the case, a default initial objective presented for the UK may be that we should keep R just below 1 with low prevalence and with the maximum degree of social mixing and economic activity. This would enable us to efficiently give many high risk people the opportunity to receive a vaccine prior to them suffering a natural infection. It is possible to envisage many scenarios where such a strategy would not be possible, for example, if the initial R value was very large or severity was sufficiently low that there was no support for mitigation. However, it is my view that, following our experience of the COVID-19 pandemic, ministers would want to consider an initial strategy of keeping R below 1 and low prevalence until we have strong evidence that this is not the appropriate.

10 Imperial College Report 9

10.1 On 16th March 2020, the Imperial College Covid-19 Response Team published Report 9, which concluded that "epidemic suppression is the only viable strategy at the current time."{ SR/39 - INQ000270159}. I am a co-author of the report. My understanding is that this report and its conclusion arose from a series of prior reports looking at different combinations of NPIs and from the debate within the SPI-M community that had followed the circulation of my report on 10 March 2020. Professor Azra Ghani emailed the Imperial College COVID-19 Response Team a powerpoint file at 09:50 on 15 March 2020 that had been sent to the GCSA overnight and was to be presented at COBR that day. Professor Ghani drafted the report during the day and members of the team suggested edits. The report was finalised the following day.

10.2 Report 9 considered the effects of different combinations of interventions over a period of two years. Professor Mark Woolhouse commented that "no-one could predict the course of this epidemic over such a long timescale" [Professor Mark Woolhouse, The Year The World Went Mad, pg 44]. These charts were not intended as predictions. They were intended as illustrative scenarios to show broadly what the consequences would be of a sustained period of cyclical interventions.

10.3 The model used to produce Report 9 generated a worst case scenario of over 500,000 coronavirus deaths in the UK by the end of July 2020. Professor Mark Woolhouse's asserted that Report 9 "was condensed to the simple but misleading message that, if

the government didn't impose full lockdown immediately, over half a million people would die." [Professor Mark Woolhouse, The Year The World Went Mad, pg 44]. The report contains a number of different scenarios, which are not reflected in the simple conclusion described by Prof Woolhouse. However, I note that the report does not contain a clear counterfactual in which spontaneous behaviour change would lead to a much longer epidemic even in the absence of stringent interventions, which I had argued for in my earlier report {SR/30 - INO000269367}.

10.4 The Imperial College model used for Report 9 assumed that closing schools would increase contact rates within affected families by 50%, and that it would also increase contact rates by 25% in the general community. It has been suggested that "the changes in contact rates assumed in this model are never justified and, in fact, appear to be entirely arbitrary and in some cases clearly Inaccurate." [Policy Implications of Models of the Spread of Coronavirus: Perspectives and Opportunities for Economists, pg 25] Although this is a legitimate criticism, these parameter values are very clearly stated and were not represented as having any more support than was the case. As described elsewhere in this statement, my preference was for less complex models that would have required fewer assumptions and therefore perhaps be considered more transparent. However, it is common practice in the field of infectious disease dynamics to use more complex models for illustrative scenarios with the understanding that the accompanying narrative will provide sufficient context that the parametric uncertainty referred to above is understood by the reader.

10.5 It is understood that the outputs of the study were based upon a single set of assumptions about the impact of each intervention. It has been suggested that the language of Report 9 "suggests a degree of certainty that is simply not justified." [National Bureau of Economic Research Paper, April 2020, pg 27]. See paragraph above. Although this is a legitimate criticism, the assumptions are very clearly stated.

10.6 It has been suggested that the Imperial College forecasts were "almost hysterical" and that Report 9 was "so fundamentally flawed by debatable assumptions - for example, the percentage of people who were asymptomatic but still infectious - that it loses all value as a predictive tool." [Washington Post article, 8th May 2020]. The report was not intended as a predictive study, in my view. It was intended to illustrate the need for stringent interventions and to estimate the scale of harms associated with different broad policy choices.

10.7 The source code for the Imperial College model was released on 27th April 2020. I was not involved in the release of the code.

10.8 In a counterfactual analysis of the impact of lockdown dated 8th June 2020, Imperial College found that "across eleven countries, 3.1 million deaths have been averted owing to interventions since the beginning of the epidemic." [https://www.nature.com/articles/s41586-020-2405-7] It has been suggested that this analysis ignored voluntary behaviour changes and "exaggerated the impact of lockdown." [Mark Woolhouse, The Year The World Went Mad, pg 52]. This is a legitimate criticism of the work, but would have been very difficult to address within the scope of the project at that time.

10.9 I understand that the inquiry is interested in my view of the degree to which Imperial College Report 9 contributed to the change in government policy over lockdowns. It was widely reported that Report 9 was instrumental in the Government's decision to impose a national lockdown on 23rd March 2020. [See, for example, BBC news article, 17th March 2020]. However, in his testimony to the Science and Technology Committee on 26 May 2021, Dominic Cummings suggests that "Plan B" was created in the Prime Minister's office between the 11 and 13 March 2020 {**SR/51** - INQ000236267}, while Imperial College Report 9 was not in draft form until the weekend of 14 / 15 March 2020. I appreciate that many groups and individuals reached out to the government including the Prime Minister's office during the week of 9 March 2020 to highlight their concerns over the plan that was in place at the time. I also appreciate that many different factors contribute to major policy changes. However, it seems possible that my report of 10 March did contribute substantially to the change of policy that occurred that week. I note that Ben Warner attended SAGE on 10 March 2020 when my report was discussed, and that the sketched charts on the whiteboard in the Prime Minister's office on Friday 13th are consistent with those in that report {SR/20 - INQ000236302}. I also understand that members of Ben Warner's team reached out to Christophe Fraser during that week and that he gave a view that the rapid saturation of ICUs would increase the infection fatality rate, which was a key assumption in my report of 10 March 20202 {SR/30 - INO000269367} but was not an assumption in the later-distributed Imperial Report 9 {SR/39 - INQ000270159}.

10.10 It is my view that there were times and issues for which there was an inappropriate reliance on evidence from mechanistic models during the pandemic. However, I do not agree that the use of modelling was a "national scandal" which "created a climate of manipulated fear." [Covid-19: Forecasting and modelling]. From April 2020 onwards

I focussed on improving situational awareness for decision makers in England by working on the REACT program. One of my motivations for working on REACT was that the policy stakes were so high, it was justified to gather the best possible survey data with which to inform policy choices, rather than relying only on existing data streams and advanced modelling techniques. However, more generally, evidence from mechanistic models is not fundamentally different from evidence from studies like REACT or any other forms of scientific evidence. It needs to be assessed against the wider context of knowledge and other available evidence with respect to each individual policy decision it informs.

10.11 Economic modelling could have formed part of the SAGE advice system remit. I did not attend SAGE prior to being seconded to UKHSA. Therefore, I do not have an informed view on the specific suggestion that SAGE's members "did not always have a shared understanding of the extent to which it should consider the economic and social implications of its advice." [Institute for Government Report, Decision-Making in a Crisis, pg 7] However, it is my view that members of SPI-M-O did not always have a shared understanding of the extent to which we should have considered economic and social implications of its results and interpretations. For example, it is my recollection that Prof Medley would often introduce topics for discussion with the caveat that it was not our role to assess the economic impact of policy, while on other occasions, we actively investigated possible economic consequences, e.g. {roysoceco}.

11 Transparency and Communication of Scientific Advice

11.1 It has been suggested that the UK government "did not see transparency of evidence as an integral part of managing the Covid-19 crisis"? [Sense about Science Report, pg 62]. From my experience, this was a fair criticism of the early stages of the pandemic response but is not justified later in the pandemic. For example, SAGE papers were published rapidly and data from ONS and REACT were made available in near real time. The COVID-19 dashboard provided API access to very granular data.

11.2 Although I understand that SAGE is an ad hoc committee and is shaped to respond to specific outbreaks, it can be so influential, it would seem appropriate for there to be some kind of recruitment process for a pool of people who could be asked to attend. It would then be possible to monitor and manage diversity in many different dimensions.

11.3 John Edmunds stated that it was a "massive failure" of the government not to share the economic evidence or to explain how this evidence informed its decision-making. [Policy and Practice - Three Sages on Improving Scientific Advice to Government, 25th February 2022] I agree with this statement.

11.4 I do not feel sufficiently well informed to comment on the science advisory structures in other countries.

11.5 The Institute for Government noted that "decision-making at the centre of government was too often chaotic and ministers failed to clearly communicate their priorities to science advisers." I did not have sufficient exposure to ministers or senior advisors prior to joining UKHSA to take a view on this statement. This was not the situation I observed after joining UKHSA in October 2021. I have no comment on whether ministers' lack of clarity about strategy "delayed decisions and made it harder for scientific advisers to provide useful advice." [Institute for Government Report, Science Advice in a Crisis, pgs 5 and 17]. However, on reflection and with hindsight, it may be possible to define objectives that would drive government strategies for some specific scenarios. For example, for future respiratory virus pandemics, we would likely assume that an effective vaccine is feasible until we generated good evidence that it was not. Therefore our initial response objectives might be to maximise the number of at-risk individuals who receive an effective vaccine prior to being infected naturally, while minimising any indirect harms of the interventions we employ to achieve that. I suggest these objectives as illustrative examples. More generally, it is my view the UK should consider agreeing objectives now for similar threats, as part of our learning from the COVID-19 pandemic. Agreed objectives would likely drive a much clearer strategy.

11.6 The boundaries between scientific advice and decision-making were not adequately communicated to the public at times, including the presentation of data and statistics. I agree to some degree that "ministers' insistence that they were 'following the science' was inaccurate and damaging"? [Institute for Government Report, Science Advice in a Crisis, pg 16] The phrase 'following the science' blurred the line between scientific advice and policy decisions. My experience as an independent scientist and as a seconded civil servant is that science can and should only ever be part of a policy decision. It is not my experience that senior advisors, civil servants or ministers ever suggest otherwise. Therefore, "following the science," doesn't quite make sense and is somewhat misleading. I am sure there were times that ministers were relying heavily on specific scientific and epidemiological evidence, but that is a different

message. The concept that ministers were relying only on science implied inappropriate influence for non-ministerial actors in the system, which, to me, seems unlikely to have been the case.

12 Lessons Learned

12.1 I am currently seconded to the UK Health Security Agency as Director General for Data, Analytics and Surveillance and a member of the executive committee. My comments here are my own and do not necessarily reflect the agreed view of UKHSA.

12.2 Lessons from the early stages of the COVID-19 about the provision of scientific advice can be learned at many levels, from the specific to the general. The value from the inquiry looking at different issues will be a function of how generalizable those lessons are and how impactful the learnings are.

12.3 I encourage the inquiry to look for specific learnings about viral respiratory threats such as COVID-19 and influenza, in addition to learnings about more generic threats and structural recommendations. Respiratory viruses pose an ongoing substantial threat to the health security of the UK population, and we have learned a lot about how we respond as a population to those types of threat in the past ~3 years. Successful learning of lessons about viral respiratory pathogens, and subsequent investment, will lead to substantially increased health security for the UK population for a prolonged period of time. A minimum reasonable expectation from the UK population is that if a similar threat were to arise in the near future, we would make substantial improvements in our response.

12.4 Having a very clear plan could create a risk that we would not be flexible enough when the next threat were different in an unexpected way. Technology, people and processes need to be constantly challenged with simulated exercises and guided by outside thinking, to ensure that the future response is sufficiently flexible. Very clear plans do not necessarily lead to an inflexible response.

12.5 Social mixing drives the transmission rate of respiratory pathogens. If the consequences of infection are severe, people will reduce their social mixing and therefore their contribution to the economy. In our developed economy, there is no plausible scenario where social mixing stays even approximately constant and hundreds of thousands of people die during a rapid epidemic of a respiratory pathogen.

12.6 The people of the UK can accept mandated changes in their behaviour for a long period of time and will respond to non-mandated messaging around infectious disease threats with substantial reductions in their social mixing.

12.7 Large scale changes in social mixing as a result of either a spontaneous reaction to the presence of a severe pathogen or as a result of government mandation have substantial negative indirect effects. We need to reflect on our experience of the acute phase of the COVID-19 pandemic so as to better mitigate the indirect impact of any changes in social mixing.

12.8 With sufficient information and communication, the period from January to July 2021 (the "Roadmap" period) has shown us that stringent social distancing can be relaxed in a controlled and stepwise manner.

12.9 Technology is available to produce effective safe vaccines against specific coronaviruses and possibly other viral threats, in a short period of time with sufficient investment.

12.10 In future scenarios that could lead to situations similar to those of March 2020, scientific advice should be structured so as to best support the most important decisions, e.g. those around the initiation of vaccine manufacturing and possible implementation of social distancing. As an example outline of a plan that could be agreed in advance: if a severe respiratory pathogen were circulating in the UK we should: ensure vaccine development production is already be underway; consider rapid social distancing sufficiently strong to ensure that incidence of infection immediately goes into decline; be able to accurately and rapidly assess infection incidence trends; after a very short period (when we are sure incidence of infection is declining) immediately implement a stepwise relaxation of social distancing with ministers deciding on priorities for relaxation (a very rapid "roadmap"); with excellent surveillance, ensure we achieve the maximum possible social mixing and economic activity but without allowing the prevalence of infection to increase; vaccinate primarily according to individual risk and relax all social distancing as soon as acceptable. Some countries around the world did achieve close to this sequence of policies during the COVID-19 pandemic and had far less excess mortality and far less disruption to their economy than was the case in the UK.

12.11 To be in a position to confidently consider the type of plan outlined above, the UK needs to make substantial investments: rapid high volume onshoring of mRNA vaccine production should continue to be a priority as should active consideration of

other vaccine technologies; technology, people and processes must be created and maintained to immediately recognise when we may be heading to a scenario similar to that of March 2020, so that evidence can be generated to support key decisions and inform the public. We will not be able to rapidly upscale the capabilities that are required to know if we need to upscale capabilities. Sound underlying science is required for key policies and technology that might be used to rapidly relax social distancing if it were used – that science can be done now. The scale of these investments should be compared with investments in defence, intelligence and climate threats. Investments in pandemic preparedness should not be judged solely alongside the yearly health and social care budget.

12.12 The scientific advisory process could be even more transparent. Evidence provided to meetings could be made available in near real time and any analytics used to support advice could be required to be open source and open data at the time of use. These increases in levels of transparency would greatly facilitate the ability of ministers and other politicians to scrutinise advice. However, independent scientists would require considerably more support in order to be able to work this way.

12.13 I consider that the split-role of independent scientists a) advising government; and b) contributing to public debate, is an unavoidable situation. Government scientists who need to maintain the trust of ministers and hear internal government discussions cannot be independently engaged with the media. However, any emergency response will always need to engage non-government scientists and they must be free to speak with the media.

12.14 Transparency and public scrutiny of modelling could be improved if government and independent scientists were better able to explain the underlying biology and epidemiology of their findings and not rely on the concept of "the model says…" It would also be improved if all code and data used to provide advice could be open immediately to public scrutiny. This was often the case in the UK later in the pandemic with our excellent dashboard and the many groups using github. With sufficient resource the government could ensure it was able to reproduce external modelling results as and when needed, as was the case when the medium term projections were passed from SPI-M-O to the DAS group in UKHSA. It would also be desirable to have a culture of formal forecasting of infectious disease trends so that decision-makers and the science-public are familiar with key concepts prior to any future emergencies.

12.15 To prepare for the next infectious disease emergency, it would be desirable for Treasury officials to work with health officials to come to a shared view on key counterfactuals for the COVID-19 pandemic. This would provide a baseline for economic counterfactuals during any future similar scenario. At the very least, with the benefit of hindsight, it should be possible for different disciplines to agree on how they could have better assessed trade-offs between the economy and health at key moments of the acute phase of the COVID-19 pandemic. If this work were public, it could inspire substantial progress in academic collaborations between health scientists and economists.

Statement of Truth

13. 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: 5 September 2023