Witness Name: PROF MARK WOOLHOUSE
Statement No.: M2/SAGE/02/MW
Exhibits: **MWO/001 - MWO/093**
Dated: 15/08/2023

UK COVID-19 INQUIRY

WITNESS STATEMENT OF
PROFESSOR MARK WOOLHOUSE

This statement follows a process of some initial communications under Rule 9 with the UK Covid Inquiry and initial discussions with them, and it is focussed on a large number of questions raised by the Inquiry, which I have addressed below.

Introduction

1. I am Professor of Infectious Disease Epidemiology at the University of Edinburgh. I studied biology at the University of Oxford, University of York and Queen's University (Canada) and then held research fellowships at the University of Zimbabwe, Imperial College London and the University of Oxford, before moving to Edinburgh. I have worked as an academic researcher on infectious diseases and global health since 1985 and have published more than 400 scientific papers, including highly cited articles on emerging infectious diseases and antimicrobial resistance. I have acted as an advisor to DEFRA, the Food Standards Agency and the World Health Organization. I was awarded an OBE in 2002 for services to the control of infectious diseases and am a Fellow of the Royal Society of Edinburgh, the Academy of Medical Sciences and the African Academy of Sciences.
2. I am a member of the Usher Institute, the University of Edinburgh's school of public health and part of our College of Medicine and Veterinary Medicine. Usher contains around 400 academic and support staff. Core research themes are global health, medical informatics, population health sciences and biomedicine, self and society. Usher hosts the Edinburgh Clinical Trials Unit, a WHO Collaborating Centre on population

health research/training and a working general practice, the Mackenzie Medical Centre, and is a delivery hub within the Data-Driven Innovation Initiative of the Edinburgh and South East Scotland City Region Deal.

3. I am Principal Investigator of the Epidemiology Research Group (Epigroup), comprising 20-30 postdoctoral researchers, PhD students and research assistants who report to me or who work as part of my team. We conduct scientific research on infectious disease epidemiology both in Scotland and globally. One of our main interests is novel emerging pathogens.
4. Epigroup's work on Covid-19 began in early January 2020 and continued throughout the pandemic. Our main areas of activity were: i) epidemiological modelling to support SPI-M-O; ii) epidemiological data analysis to support Scottish Government; iii) evidence synthesis and evaluation to support my work for the Scottish Covid-19 Advisory Group; iv) data collation and analysis and genome sequence data analysis to support WHO Africa Region's Pandemic Response team.

Science Advisory Groups

5. I joined SPI-M-O in January 2020 and attended my first meeting on the 27th of that month. I attended one meeting of NERVTAG (to discuss the alpha variant) on December 21st 2020. The sub-groups mostly worked independently from one another but there was some crossover (e.g. briefings to SPI-M-O by members of NERVTAG and SPI-B) and joint membership (e.g. some SPI-M-O members were also members of NERVTAG, SPI-B and C19AG in Scotland). I was not a member of SAGE so it is difficult for me to comment on how effectively it worked with its sub-groups. I have no knowledge of the workings of PHE Serology Working Group, CO-CIN, EMG, TFC, HOCI, Ethnicity Subgroup or SCWG.
6. I joined the Scottish Covid-19 Advisory Group (C19AG) in March 2020 and the first meeting was held on March 26th. I do not have access to the full details of the history or working practices of C19AG but I am told that these have been provided to the Inquiry by Scottish Government.
7. I believe that SPI-M-O's work (and that of NERVTAG and SPI-B) was consistently considered by SAGE, helped by several SAGE members also being members of those subgroups. I cannot say whether that work was invariably incorporated into SAGE's advice, though it often was. My impression is that SPI-M-O was a highly influential SAGE subgroup. I share the common perception that SPI-M-O's models were one of the main (though not the only) drivers of policy, particularly during the first few months of the pandemic. Later on, it became routine for Rob Harrison of the Cabinet Office to open

SPI-M-O meetings with a general assurance that the models were influencing policy decisions.

8. SPI-M-O performed multiple functions. One core function was the weekly estimation of the R number. Estimates were made by several groups and were combined into single estimate with confidence intervals. My own team did not contribute to this exercise. We did, however, make estimates of a related statistic, the weekly case ratio, for Scotland.
9. A second core function was to make short and medium term projections of numbers of cases, hospitalisations and deaths. Projections were made by several groups and collated as a single output. My own team did not contribute to this exercise.
10. Another core function, carried out intermittently, was prospective modelling of possible future long-term scenarios. Most commonly, this exercise was performed by groups from Imperial College London, the University of Warwick and the London School of Hygiene and Tropical Medicine. These scenarios were often (perhaps always, I do not know) shared with SAGE. My team did make these kinds of projections, particularly in the early stages of the pandemic, but using much simpler models that included minimal detail, sometimes referred to as 'toy' models. I have described our work as playing a 'support role' but it was sometimes shared with SAGE.
11. My team's models were not predictive. Their purpose was to improve our understanding of the dynamics of the epidemic by exploring many more parameter combinations than is feasible with more complex models, up to a million in a single modelling exercise. This tells us which parameters are most important in setting the course of the epidemic, how robust our outputs are likely to be and where the main uncertainties lie. The toy models thereby acted as a reality check on the more complex models. On occasion, for example during the omicron wave, this kind of exercise prompted me to challenge the outputs of the more complex models.
12. My team contributed some ad hoc modelling on our own initiative, notably our work on segmentation and shielding. We also contributed some empirical data analyses. For example: i) the relationship between school terms and epidemic trajectories; ii) the fraction of fatal infections acquired during lockdown.
13. Most of the work presented by committee members at SPI-M-O meetings was subjected to critique and challenge in general discussion. I contributed to those discussions.
14. I believe that most (though perhaps not all) of SPI-M-O's models were externally reviewed prior to being published in academic journals. Though this was not done in real time, it did provide sporadic opportunities to obtain an independent assessment of the work, possibly inviting refinement or improvement. I am not aware that any independent peer review of the models was instigated by SPI-M-O.

15. SPI-M-O was in large part an evidence-generating group. SAGE, as I understand its function, was an evidence evaluation and synthesis group. Those are different roles. Yet the only epidemiological modelling expertise on SAGE came from SPI-M-O, a situation I have described as SPI-M-O marking its own homework. I do not consider that this arrangement was best practice as evaluation of evidence should be done independently.
16. I am not able to comment on the relationship between SAGE and senior politicians. The SAGE subgroups I was on did not engage with politicians. I can say, however, that the Scottish C19AG did regularly brief ministers, including the First Minister, and I believe this was a fast and effective way of communicating advice.
17. I am not able to comment on whether SAGE took sufficient account of international perspectives in the early months of the pandemic. I can say, however, that the Scottish C19AG did regularly consider actions taken in other countries and their possible relevance for Scotland. In my view (expressed at the time), this activity was done poorly: the work was not systematic; it gave the appearance of cherry-picking examples to support arguments for or against one policy or another; it relied on overly hasty evaluations of which countries were doing well or badly; and it consistently failed to take into account that different countries had very different pandemics, so that it was naïve to claim that what worked in one setting would work equally well in Scotland.
18. The membership of SPI-M-O was exceptionally well qualified in epidemiology, epidemiological modelling and public health. The group was fit for purpose with regard to quantifying the direct health harms caused by Covid-19. However, SPI-M-O did not have the appropriate expertise to assess (using models or any other form of analysis) the harms being done to the economy, nor the harms to education, mental health or societal well-being.
19. The issue of lack of attention to wider harms was repeatedly raised by myself and others in general discussion during SPI-M-O meetings. We understood that this was not our role but neither DHSC officials nor Cabinet Office observers were able to advise on whose role it was. I am aware of two studies that attempted to fill this perceived gap, one from the University of Warwick and one from Imperial College.
20. The Warwick study was conducted in the first quarter of 2021 and first published in April that year. The report of the study was titled 'Optimal health and economic impact of non-pharmaceutical intervention measures' and is included here as Exhibit **MWO/001** {INQ000220375}. The study described a model-based analysis considering public health harms and economic harms in a single framework. I am not aware that it was submitted to SAGE and so the study is unlikely to have had any impact on policy.
21. The Imperial College study was published as their Report 35 and titled 'How can we keep schools and universities open?' and is included here as Exhibit **MWO/002**

{INQ000220361}. Differentiating closures by economic sector to optimize social and economic activity while containing SARS-CoV-2 transmission'. The report describes an integrated economic-epidemiological model called DAEDALUS. I'm not aware that it was submitted to SAGE and so the report is unlikely to have had any impact on policy.

22. In my view, the preponderance of expertise in clinical medicine, public health and epidemiology on SAGE and its sub-committees meant that the advice delivered to government was mainly concerned with minimising the public health harms of the pandemic and said too little about minimizing harms being done to the economy, education, mental health or societal well-being; that is, we were only looking at one side of the cost-benefit equation. If such work was being done elsewhere in the science advisory system then no details were made public nor made available to me as a scientific advisor.
23. The result was a lop-sided body of evidence. To give a simple illustration, if the policy goal of not overwhelming the NHS was met by imposing a lockdown then there was little incentive for advisors to come up with alternatives to lockdown for managing the public health burden – from their point of view they had already done their job. That incentive could have come from a formal analysis of the relationship between social distancing measures and the indirect harms they were causing, but (beyond the two preliminary analyses described above) none was ever presented at a SPI-M-O meeting that I attended.
24. This deficit could be remedied in the future by expanding the range of sub-committees reporting to SAGE to cover: impact on wider health care, impact on the economy, impact on education, impact on society (which would involve public engagement). SAGE would need a broader range of expertise to evaluate the evidence presented by these sub-committees. Its job would be to present to government an informed assessment of the full range of positive and negative impacts of different policy options, but leave the difficult question of how to balance those impacts to ministers.
25. I understand that a Treasury economist and others with backgrounds in economics were present at SAGE meetings. While that was obviously appropriate given the wider impacts of the social distancing measures and other interventions being discussed at SAGE meetings, it does not remedy the deficit in evidence. If a truly holistic view of the pandemic was being taken by SAGE then I would have expected a steady stream of detailed, quantitative analyses of actual and potential harms to wider health care, the economy, education and society. No such stream is visible in the SAGE meeting papers listed on the GovUK website. Overwhelmingly, the evidence considered by SAGE appears to have been about the public health burden of Covid-19.

26. This emphasis on direct public health harms was reflected in the idea that 'no death from novel coronavirus is acceptable' repeatedly expressed in the early months of the pandemic. As was discussed at SPI-M-O, if that statement were taken literally as a policy objective then our advice would be to go immediately into the strictest possible lockdown and stay there until a vaccine or cure became available.
27. Though in practice all UK administrations did gradually lift restrictions, the impression that Covid-19 deaths had a special status remained, given that society tolerates non-zero mortality rates from many other potentially avoidable causes. One consequence of the prioritisation of illness and death from Covid-19 was the well-recorded collapse in wider health care provision during the first wave.
28. I draw a distinction between advice and advocacy. I see my role as an advisor to help government understand the advantages and disadvantages of different policy options. I can only do that in terms of my area of expertise; for example, I am qualified to advise on the public health impact of a given intervention, but not its economic impact.
29. The minutes and consensus statements emerging from SAGE and its sub-committees generally took exactly this approach. I therefore disagree with suggestions that SAGE should, at various times, have been more forceful in "calling" for stronger action. Rather, particularly in February 2020, I think SAGE could have been blunter in its assessment of the scale and urgency of the imminent crisis but left others to do the "calling". I am uncomfortable with advisors publicly advocating for specific actions – such as calls for lockdown in October 2020.
30. I think it is correct to suggest that advice is more robust when it is provided by a broad group of experts rather than just one or two individual researchers. For example, best practice for epidemiological modelling has long stated that, wherever possible, policy advice should not be based on a single model. My understanding is that SPI-M-O was set up with multiple modelling teams for precisely this reason.
31. That said, I don't think it inappropriate that teams from Imperial College and LSHTM were among the most influential given the strength and depth of their expertise. With hindsight, however, not all the model outputs produced by these teams turned out to be reliable guides for policy makers. I think the problem here lies not so much within SPI-M-O but in the fact that senior figures on both these teams were also members of SAGE, so there was not independent scrutiny of their work at that level. The remedy would be to separate the roles of evidence generation and evidence evaluation and synthesis within the science advisory system.
32. I am unable to comment on the Institute of Government's conclusion that ministers put too much weight on SAGE in the initial months of the pandemic. I do, however, consider that the scientific advice provided to government at that time put too much emphasis on

and had too much confidence in the outputs of epidemiological models. I am concerned that policy makers did not fully understand just how uncertain those outputs were. I note that best practice for epidemiological modelling has long stated that models should be one of the inputs in decision making but never the only one.

33. I have described the relationship between science, scientific advice and policy as "sub-optimal". In my view, there were problems in both directions. A common complaint from advisors – aired at SPI-M-O meetings and in Select Committee – was that government did not set out a clear strategy for its pandemic response. For example, though the government was concerned with saving lives it was also concerned about damage to the economy, but SPI-M-O was never directed to consider this. Nor was SPI-M-O asked to explore ways of responding to the pandemic that both saved lives and negated the need for lockdown.
34. In the other direction, the advice from SPI-M-O tended to focus on the need for social distancing measures not because this was the only viable option for responding to the pandemic but because it was the type of intervention the models were designed to consider (though they would later be extended to cover vaccination). The net effect was that not all available policy options for tackling the pandemic received equal attention.
35. The two advisory groups that I was a member of – SPI-M-O and Scottish C19AG – both provided advice on the basis of consensus. One advantage of this is that it gives policy makers and officials greater clarity. One disadvantage is that consensus can be slow to form (which matters, for example, when policy decisions have to made quickly) and, once formed, can be even slower to shift. It is possible that this led to delays in communicating advice to ministers but I have no first-hand knowledge of examples.
36. Another weakness is that on many issues there was not complete consensus at the time and reporting what was effectively the majority view might have given an impression of groupthink. In my experience, minority views were not always communicated to officials and ministers.
37. I do not know the basis for the claim that resources for SAGE and its sub-groups were significantly overstretched. From my perspective, it is certainly true that my team was stretched to the limit, particularly in the first few months of the pandemic. I dealt with issues of funding, equipment and personnel as best I could through the University of Edinburgh, so I consider this an internal matter. I had no expectation that government would be able to help in this regard, reflecting my experience of earlier crises.

Infectious Disease Modelling: An Overview

38. The type of infectious disease modelling most relevant to the UK's pandemic response is variously described as mathematical modelling, mechanistic modelling or process modelling. The common feature is that the models incorporate a mathematical representation of the process(es) generating the data of interest, such as data on numbers of cases. The representation could be in the form of mathematical equations or in the form of computer simulation. The representation is inevitably a simplification of a complex reality but the intent is to capture the key processes that shape the course of an epidemic.
39. Statistical modelling involves the application of statistical models (linear regression being a simple example) to data. This allows us to test whether or not the data are consistent with the assumptions underpinning the model. The difference with mathematical modelling is that the underlying model is generic not specific; it could be applied to many different kinds of data and does not attempt to capture the actual process generating those data (e.g. transmission).
40. The difference between mathematical and statistical modelling can become blurred in two ways. First, statistical models can be used to extrapolate data using simple processes that are nonetheless appropriate for the data in question, e.g. exponential growth for the early stages of an epidemic. Second, techniques such as Bayesian estimation can be used to fit much more complex models to data than was possible in the past. This allows us, for example, to formally compare the fit of different models (incorporating different processes or making different assumptions) to data and identify those that best describe it.
41. The two types of models fill different roles: statistical models focus on patterns whereas mathematical models focus on process. Both can be used to guide or inform policy decisions during a pandemic. For example, risk factors for more severe outcomes of infection were identified using statistical models whereas the expected impacts of interventions were explored using mathematical models.
42. There are several different kinds of mathematical models. Compartmental models and individual-based models (IBMs) both distinguish between multiple states; for example, susceptible (uninfected and not previously infected), infected and recovered. Compartment models consider the fraction of the whole population in each state (i.e. compartment) whereas IBMs allocate each individual represented in the model to one or other state. IBMs are considerably more computationally intensive – especially if the population of interest is many millions – but have the advantage that it is more straightforward to capture differences in individual behaviours, e.g. different contact rates with other members of the population, and to express spatial structure, including household structure, though this can be done in a compartment model framework too.

43. There is also a distinction between stochastic and deterministic models. Stochastic models represent transitions between states as chance events with defined probabilities. Most IBMs are stochastic. Deterministic models assume that transitions between states occur at specified rates. One difference is that while every run of a deterministic model using the same settings will generate an identical result the outputs of stochastic models will vary through chance effects. That said, when the size of the population being modelled is large and there are sufficient cases then – all else equal – stochastic and deterministic models will behave almost identically. But in small populations and/or for very small numbers of cases stochastic models may capture behaviours that deterministic models cannot, e.g. local extinction of infection or delayed take-off of an epidemic after first introduction.
44. An excellent and much more in-depth explanation of different model types is available in the book Modelling Infectious Diseases by M.J. Keeling and P. Rohani (Princeton University Press, 2008).
45. One of the advantages of models is that they provide a formal framework for integrating data from a variety of sources to provide a holistic understanding of how an epidemic has developed and how it may develop in the future. The exercise is often useful in identifying key data or knowledge gaps.
46. However, all epidemiological models are simplified abstractions of a complex and often messy reality. For this reason alone, I prefer to interpret them as useful guides to the past, present and future evolution of an epidemic that should not be taken too literally. Other sources of understanding – not least expert opinion – must be considered, especially when there is disagreement.
47. That said, I have argued that mathematical models and computer code are, at least to those familiar with the language, more transparent than expert opinion because the steps leading to a particular result are available in a written format that allows inspection, criticism and change.
48. Good practice for epidemiological modelling demands that a model is subject to verification and validation.
49. Verification is the process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specifications. As such, it is a largely internal, technical exercise. Usually, it is considered acceptable if published reports of modelling work include a description of how the verification was done. On occasion there may be a case for doing the verification independently, but this is not common practice in infectious disease modelling. Open access publication of computer code and other technical details facilitates independent model verification.

50. Validation means that a model is acceptable for its intended use because it meets specified performance requirements. Attempts at model validation are typically of three kinds:

    i) At a minimum, the model should recreate key features of the input data. In itself, this is not true validation. However, it is sometimes possible to derive model expectations independent of inputs, e.g. the expected prevalence of antibody positivity in the population when antibody survey data were not a model input.

    ii) Another validation step is comparison of outputs with previously developed models.

    iii) Ideally, model validation should involve comparison of model predictions with independent data (including on-going comparison of forward projections with actual data).

51. Criteria for model validation should be determined in advance of the modelling exercise. These should set out which model outputs need to be validated, how this is to be done, and what level of agreement constitutes an adequate fit. These criteria will reflect the aims of the modelling exercise.
52. Validating models in real-time during an emergency is challenging. At a minimum, reports of modelling exercises should set out what validation has been done. Where validation has not been possible this should be made clear and should influence policy makers' confidence in model outputs.

Covid-19 modelling

53. My understanding is that some teams on SPI-M-O were using individual based models and some were using compartmental models. My own team mainly used a very simple form of compartment model known as SIR models.
54. Regardless of model type, different models will often generate different outputs due to a combination of differences in parameter values and in underlying assumptions and model structure. To address this issue, SPI-M-O used a form of ensemble modelling approach to capture these differences and generate a 'consensus' view.
55. Ensemble modelling involves using a set of models to simulate one or more epidemic scenarios rather than relying on a single model, which is not regarded as best practice because of the risk that explicit or implicit assumptions or choices of parameter values lead to too narrow a range of outputs. Ensemble modelling will often capture a wider range of uncertainty but also indicate consensus where consensus exists, increasing

confidence in the outputs. Sometimes, the root cause(s) of differences between models can be identified and resolved, resulting in improved understanding of the epidemic.

56. A challenge for ensemble modelling is how to deal with outliers, particularly where their inclusion shifts the consensus outputs (less likely if there are a large enough number of models) or shifts the worst case scenario (more likely, and problematic in circumstances where the worst case scenario is of particular interest to policy makers).
57. Key data inputs into the models comprise both baseline inputs and real-time inputs. Here, I set out a high-level overview but for details of data requirements for individual models it would be best to consult the model developers directly.
58. Baseline inputs include population structure, demography and contact behaviour. The exact specification of input data needed depends on the details of the model. For population structure and demography this might include population size, geographic distribution, household sizes and age structure obtained from census data. Some models represented schools explicitly, including details on class sizes and staff-student ratios. Some models included workplace size and home-workplace travel. Baseline values for contact behaviour were based on pre-pandemic empirical estimates of age-specific contact rates within and between households and in schools and workplaces. To my knowledge, none of the core SPI-M-O models used in the early stages of the pandemic explicitly represented hospitals or care homes.
59. The models explicitly accounted for some sources of variation both in the risk of infection and in the risk of severe disease within the population; for example, age, setting (e.g. home, school or workplace), geographical region. As a general rule, however, this kind of approach will underestimate the degree of heterogeneity in the population. This is because it accounts only for the sources of heterogeneity in risk that have been identified and quantified – everything else is ignored. Underestimating heterogeneity can have significant consequences; for example, it may lead to an overestimation of the expected attack rate (the fraction infected) during an epidemic wave.
60. Other key inputs were estimates of parameters representing transmission rates, incubation and infectious periods, how these varied over time or across individuals, and how they were affected by immunity. They also included proportions of asymptomatic and symptomatic infections and the associated risks of hospitalisation, ICU admission and death. All of these could be stratified by age.
61. As the epidemic progressed these estimates were informed by fitting the models to UK data on the timelines of cases, hospital admissions, ICU admissions and deaths. This was not possible in the earliest stages of the epidemic however, so estimates had to be based on information from outside the UK, particularly China.

62. For all the models, the choice of parameter values were crucial. For the most part, that choice was left to individual teams but there were frequent discussions about parameter values at SPI-M-O meetings and the choices made were usually available for inspection and challenge.
63. The models used by SPI-M-O to generate possible future scenarios were detailed with complex structures and made a large number of assumptions. I am not aware that these assumptions have ever been set out in full but the key ones were well understood.
64. The assumptions made by the modelling teams were mostly based on the way that individual teams understood the available evidence, so reflected individual choices. This could change: for example, most early models assumed solid immune protection following infection, the classic 'SIR' framework. Once re-infections began to be reported later in 2020 that (optimistic) assumption had to be amended.
65. One set of assumptions concerned human behaviour, how those behaviours translate into transmission opportunities for the virus and, crucially, how they changed over time. As the epidemic progressed behavioural changes could be inferred retrospectively (under the umbrella heading 'precautionary behaviours') but prospective modelling necessarily relied on assumptions about future behavioural changes that were essentially guesses. There was no way around this but it introduced considerable uncertainty into model outputs.
66. A second set of assumptions concerned the impact of government interventions, particularly the non-pharmaceutical interventions that were critical for the first 18 months of the pandemic. Where these were expected to change contact rates their effects could be modelled explicitly, with the caveat that the extent of behaviour change in response to interventions by government was not robustly predictable. However, many of the interventions affected transmission in other ways; these included face coverings, contact tracing and self-isolation, self-testing, ventilation, shielding, infection control in hospitals and biosecurity for care homes. To my knowledge, none of these could be modelled explicitly and their impact was even harder to predict than changes in contact rates. The consequence was that more weight was given to reducing contact rates (which could be modelled) than making contacts safe (which was much harder to model).
67. The default assumption that the only drivers of behavioural change were the imposition and relaxation of government-imposed restrictions was especially problematic. This assumption had a major impact on the scenarios presented to policy makers, for example, in the build-up to the first lockdown in March 2020. I am concerned that this assumption and its implications were not communicated by modellers nor were understood by policy makers and the public.

68. This issue arose again in the modelling of subsequent waves through the winter of 2020-21 and the delta and omicron waves later in 2021. It is a crucial point because the default assumption leads to an overestimation of the impact of imposing restrictions and an overestimation of the impact of relaxing them, thereby overstating both the need for restrictions in the first place and the need for keeping them in place.
69. Another set of assumptions concerned immunity following natural infection and/or vaccination. This was unimportant during the first and second waves – few people were exposed (less than 10%) and no-one was vaccinated at that stage. However, the impact of immunity became critical in 2021 after the large alpha wave and as vaccination was rolled out.
70. Empirical analyses of the impact of vaccine-induced immunity on the risks of infection and of severe disease were conducted in a timely fashion throughout and the results were incorporated into the models as soon as they were available. Nonetheless, lack of information about the long-term impact of immunity – e.g. waning of protection or the appearance of immune escape variants – continued to make long-term prospective modelling highly uncertain.
71. Finally, the appearance of new variants was impossible to predict. For every new variant key parameters including transmission rate and impact of immunity had to be re-estimated, inevitably from initially limited data and so introducing further uncertainty.
72. Uncertainty in the values of inputs, and particularly the value of key parameters such as the transmission rate, can be explored using sensitivity analyses. Sensitivity analysis is a structured exploration of the impact of specified parameter values or combinations of parameter values on the outputs.
73. Sensitivity analyses do not remove uncertainty but they do illustrate its consequences. Typically, model outputs are more sensitive to the values of some parameters than others and sensitivity analyses indicate which parameters matter most. This helps us judge the robustness of the models: if we are confident in our estimates of the most influential input parameters then we are more confident in the outputs.
74. Alternatively, sensitivity analyses may indicate that our outputs are not robust. My team reached this conclusion in January 2021 when exploring the consequences of relaxing Covid restrictions over the next six months – there were too many uncertainties to make useful predictions of what would happen over such a long timescale. Our reports of these analysis are included here as Exhibits **MWO/003** {INQ000220380} and **MWO/004** {INQ000220379}.
75. One important limitation of sensitivity analyses is that choosing the range of parameter values to be explored is usually a subjective decision. If we make poor choices at that stage then the results of the sensitivity analyses can be misleading.

76. I was concerned – and raised at a SPI-M-O meeting in the autumn of 2020 during a period where was extensive discussion of this issue – that we were not giving enough attention to how those choices were made and that this was having an impact on the worst case scenarios produced by the models. This matters because worst case scenarios tend to receive the most attention and can have a disproportionate influence on policy making. The issue re-surfaced in a public discussion in December 2021 as indicated by the e-mail trail included as Exhibit **MWO/005** {INQ000220373}.
77. In the initial stages of an epidemic of a novel pathogen there is, inevitably, little data to draw upon. Nonetheless, preliminary but useful insights can still be obtained with a minimum of information; specifically, estimates of the basic reproduction number, the generation time and the infection fatality rate. Using these numbers as inputs into the simplest possible epidemiological model allows us to generate crude estimates of the fraction of the population infected during the epidemic (the attack rate), timescale of the epidemic and fraction dying (or being hospitalised). For Covid-19 those estimates proved useful for communicating the potential scale of the public health crisis to come as early as January 2020 (based, at that time, on information from China).
78. In my view, the claim that [epidemiological] models cannot be relied on to provide accurate forecasts misses the mark. First, the short and medium term projections provided by SPI-M-O throughout the pandemic were reasonably accurate; it is the long-term modelling that was much more problematic.
79. However, the long-term modelling was not used to generate "forecasts", it was used to explore a range of possible scenarios. Each scenario incorporated a mixture of assumptions about the epidemiology of Covid-19 (captured in the range of parameter values used) and about people's behaviour together with representations of different future circumstances (e.g. different interventions the government might potentially introduce). Though not all scenarios would be considered a priori to be equally likely we can only know which one actually applied with hindsight – this is not forecasting as I understand the term.
80. I do not know what is implied by the assertion that "evidence-based policy has become policy-based evidence." If the implication is that models were developed to support policy decisions already made then I have no personal knowledge of any such thing happening. I was, however, on occasion concerned when SPI-M-O was instructed to explore unrealistic scenarios. One example is an instance where SPI-M-O modellers were asked to consider a scenario where children were as infectious as adults, at a stage where we knew this not to be the case. I do not know how those outputs were to be used. If they were used simply to understand what difference the lower infectiousness of children was

making to the course of the epidemic then that would be entirely legitimate. If they were being used to make the case for closing schools then, in my view, that would not.

81. I understand that omicron modelling in Denmark is judged to have been more accurate than in the UK. I think the reasons for that were not so much to do with differences in the details of the models or access to different information as they were to do with problems with the models used by SPI-M-O, problems that had been discussed within SPI-M-O meetings. Those problems were: the assumptions about vaccine effectiveness were too pessimistic; the assumptions about omicron's severity were too pessimistic; the impact of schools was overestimated; the assumptions about drivers of behavioural change did not allow for spontaneous behaviour change independent of government interventions.
82. My team's own models of the omicron wave generated a wider range of possible scenarios. We could reproduce some of the severe waves modelled by SPI-M, but only if our assumptions were consistently pessimistic. Most of our more optimistic simulations did not generate large numbers of hospitalisations and deaths, especially once we factored in the reduced severity and shorter generation time of omicron. We submitted multiple briefings reporting our results to SPI-M in December 2021. Yet the scenarios considered by SAGE – as recorded in meeting minutes – didn't admit the possibility an omicron wave that caused a relatively minor public health problem, though that is what transpired in practice.
83. The omicron modelling episode is an illustration of the lesson that models should focus on key parameters and do not always need to be overly detailed. Vaccine effectiveness, omicron severity, transmission in schools and behavioural change were the key aspects – if we didn't get those right then how well the models represented a myriad of additional features is almost irrelevant.
84. Prior to 2020, SPI-M's main focus was on modelling influenza epidemics. In my view, the influenza pedigree did have an impact on whether or not SPI-M-O's models were truly fit for purpose. On the one hand, it was an advantage that pre-developed models were available. Even though they had to be adapted to address a different challenge, influenza and Covid-19 are both respiratory infections and the basic model structure was already there. On the other hand, the influenza models explicitly represented epidemiological features that were less relevant to Covid-19 and ignored others that were more relevant.
85. A good example is that influenza models explicitly represented schools not care homes, though a substantial fraction of Covid-19 deaths occurred in care homes, and almost none in schools. Another key issue is that influenza models tend to focus on social distancing as the preferred intervention, for two reasons. First, because influenza has a short generation time and a high proportion of asymptomatic cases, contact tracing is not

considered a useful intervention and so was not incorporated into the models. It is, however, a key intervention for more SARS-like infections such as Covid-19. Second, because influenza has a lower basic reproduction number (the maximum R number) than Covid-19 the social distancing measures required to keep an epidemic manageable can be considerably less drastic than full lockdown. Lockdown was not part of the UK's pandemic preparedness planning at all.

86. In my view, the net effect of the influenza pedigree of SPI-M-O's models was to focus attention on social distancing measures rather than alternative interventions and thereby direct policy along a path that led to lockdown. I note that many countries – mainly in SE Asia – whose preparedness planning was directed more towards SARS than influenza managed to control Covid-19 without resorting to national lockdowns.

The Early Stage of the Pandemic

87. I first e-mailed Catherine Calderwood – the then Chief Medical Officer (CMO) Scotland – about the pandemic on January 21st, 25th and 26th 2020. The full e-mail exchange is provided as **MWO/006** {INQ000103352}, **MWO/007** {INQ000103354}, **MWO/008** {INQ000103353}, **MWO/009** {INQ000103355}, **MWO/010** {INQ000103347}, **MWO/011** {INQ000103348}, **MWO/012** {INQ000103349}, **MWO/013** {INQ000103367}, and **MWO/014** {INQ000103350}.
88. I copied my January 21st briefing to Anne Glover – then president of the Royal Society of Edinburgh – and did the same with subsequent briefings. I also copied in Sheila Rowan – then Chief Scientist for Scotland – on January 21st. I received no reply though I understand that she was also contacted by Anne Glover. The full e-mail exchanges are provided as **MWO/015** {INQ000103364}, **MWO/016** {INQ000103363}, **MWO/017** {INQ000103362}, **MWO/018** {INQ000103361}, **MWO/019** {INQ000103360}, **MWO/020** {INQ000103358}, **MWO/021** {INQ000103365}, **MWO/022** {INQ000103366}, **MWO/023** {INQ000103356}
89. I have stated I was not convinced by any of the responses I received to those e-mails. This is because I considered the matter to be extremely serious and equally urgent but felt there was little sense of either from the CMO Scotland and CSA Scotland.
90. I first discussed the pandemic with Jeremy Farrar on the morning of Jan 21st. Neil Ferguson joined that conversation on Jan 25th. These discussions were wide-ranging but with an emphasis on knowledge of key parameters: basic reproduction number, doubling time and (especially) the infection/case fatality rate. They also touched upon events in China, mitigation strategies for the UK, engagement with Chief Medical Officers and Chief Scientific Advisors and with the media. The full e-mail exchange is provided as

MWO/024 {INQ000103344}, MWO/025 {INQ000103324}, MWO/026 {INQ000103322}, MWO/027 {INQ000103323}, MWO/02 {INQ000103305}-, MWO/02 {INQ000103234}, MWO/030 {INQ000103219}, MWO/03 {INQ000103226}, MWO/03 {INQ000103227}, MWO/033 {INQ000103228}, MWO/034 {INQ000103229}, MWO/035 {INQ000103230}, MWO/036 {INQ000103231}, MWO/037 {INQ000103232}, MWO/038 {INQ000103233}, MWO/039 {INQ000103220}, MWO/040 {INQ000103225}, MWO/041 {INQ000103221}, MWO/042 {INQ000103223}, MWO/01 {INQ000103349}, MWO/014 {INQ000103350}

91. I attended my first meeting of SPI-M-O on 27th January 2020. The meeting had two main components: updates from groups already working on Covid-19; and a discussion of data access and other requirements for modelling the UK epidemic going forward. I contributed one of several estimates of the basic reproduction number and there was general agreement that the value in China was between 2 and 3.5 with doubling times in the range 3-4 days.
92. I first met with Catherine Calderwood on 28th February 2020 (and only then because Sally Davies – ex-CMO England – kindly brokered the meeting). I provided an informal briefing by e-mail ahead of that meeting on 27th February 2020. This summarised my views on the Reasonable Worst Case scenario and the pros and cons of social distancing interventions. The briefing is provided in full here as MWO/043 {INQ000103216}. The meeting itself covered the same points as my briefing and emphasized the urgency, the indirect impact of social distancing measures and the need for an exit strategy. My notes of the meeting (sent by e-mail on 29th February 2020) are provided as MWO/044 {INQ000103215}.
93. On 2nd March 2020 I sent Catherine Calderwood a technical briefing on how different timings and intensities of social distancing measures influence the epidemic curve. This was a slightly modified version of a briefing I had already shared with SPI-M-O (on 29th February 2020) and with colleagues at Health Protection Scotland (via e-mail to Chris Robertson on 29th February 2020). I summarise this briefing below when describing the research my team conducted for SPI-M-O during the early stages of the pandemic and it is provided as MWO/045 {INQ000103517}. The version sent to CMO Scotland is provided here as MWO/046 INQ000103516}.
94. I met again with Catherine Calderwood on 6th March 2020. The main topics discussed were the likely impact of different social distancing measures, current uncertainty around the modelling including the impact of spontaneous behaviour change, timings and trigger points for interventions. My notes of the meeting (sent by e-mail on 6th March 2020) are provided as MWO/047 {INQ000103492} – these include further discussion of the role of school closures.

95. Between March 9th and March 20th 2020 I provided Catherine Calderwood and the then Deputy CMO Scotland Gregor Smith with high-level readouts from SPI-M-O meetings.
96. I have asked Scottish Government if they have records of my meetings with Catherine Calderwood but had received no reply by the date of this submission.
97. During the period January to March 2020 SPI-M-O worked on a wide range of topics. I do not have full access to meeting agendas, minutes or consensus statements from that period so my list may not be complete. To my knowledge, topics covered included: estimation of the basic reproduction number, doubling time, serial interval, case fatality rate, case hospitalisation rate and incubation period; consideration of data from Italy, the severity of disease and the impact of age on severity; surveillance strategies; transmission in children; traveller-focussed interventions; potential impact of a range of social distancing measures with a heavy focus on school closures; potential impact of cocooning elderly individuals; short-term projections of cases and deaths; long-term future epidemic scenarios; specification of the reasonable worst case scenario.
98. My team's work for SPI-M-O during the early stages of the pandemic included the preparation and submission of reports on four model-based studies intended to inform policy development.
99. My team's report for SPI-M-O dated 29th February 2020 used a simple epidemiological model to help understand – in general terms – how different timings and intensities of social distancing measures influence the epidemic curve. The exercise illustrated that the outcome is highly sensitive to the details of both the epidemiological situation and the interventions deployed. An important conclusion was that it was hard to identify the 'best' intervention strategy in advance, i.e. this was going to be a difficult epidemic to manage. A copy of this report is provided as **MWO/04** {INQ000103517}. I am not aware that it was submitted to SAGE.
100. My team produced a briefing 'Optimising trigger times for social distancing measures' on that was submitted to SPI-M-O on 4th March 2020 and was considered at the thirteenth meeting of SAGE on 5th March 2020. A copy of this briefing is provided as **MWO/048** {INQ000103518}. Our analysis used a simple model to explore the relationship between the timing, intensity and duration of social distancing measures and the expected peak and total number of cases. The key conclusion was that less intense measures should begin earlier and we advised that if less intense measures were preferred by policy makers then they might have to be implemented immediately. I was not invited to the thirteenth SAGE meeting to discuss this analysis. The published minutes of that meeting do not record any discussion about a trade-off between less intense social distancing measures and earlier implementation so I doubt that our analysis had an influence on policy.

101. Our report dated 11th March 2020 used the same simple model structure to illustrate a possible epidemic course over the longer term. The results indicated the possibility of (two) 12-week lockdowns and (three) epidemic waves over a two year period. Though this was not an exercise in predictive modelling it does indicate that the actual course of the epidemic should not have come as any surprise; the possibility of second and third waves was raised even before the first lockdown was imposed. A copy of this report is provided as **MWO/04** {INQ000103532}. I am not aware that it was submitted to SAGE.

102. Our report dated 29th March 2020 used the same simple model structure to illustrate the possible impact of an extended lockdown on demand for ICUs. The results indicated that an extended first lockdown could negate the need for a second full lockdown if the policy aim was not to exceed ICU capacity, given that capacity could be more than doubled during the extended lockdown. We noted, however, that more people in ICUs was likely to correspond to more deaths and so would be inconsistent with a policy objective of minimizing the death rate. We did not develop this model as the more complex models available were better suited to answering quantitative questions about projected ICU use. A copy of this report is provided as **MWO/050** NQ000103448}. I am not aware that it was submitted to SAGE.

103. I note that our 11th March 2020 report provided as **MWO/049** NQ000103532} was a clear warning to policy makers that a second wave was a possibility they should be prepared for. Although I have no direct knowledge of ministerial discussions of this matter, my impression from the public discussion at the time is that there was a narrow focus on getting through the first wave and the possibility of further waves was not widely understood. This is an important point because drastic interventions such as lockdown are much better justified if they are expected to bring an end to the epidemic. I believe that this was many people's expectation and that it was misplaced.

104. As I was not part of their discussions I am unable to say why SAGE did not consider three papers published in The Lancet in January, papers that the journal's editor reportedly described as "truly alarming". Nor can I say whether or not there was any outreach from SAGE to scientists in China, though it is correct that Chinese scientists were publishing important papers in the first three months of the pandemic.

105. I share the concern expressed in a Reuters article dated 7th April 2020 and provided as Exhibit **MWO/051** Q000220374} that the minutes of meetings of SAGE and its subcommittees did not communicate the seriousness and urgency of the situation as it developed in January and February 2020. This attitude was echoed by Public Health England's setting of the risk level, which had remained at Moderate until March 12th. I and colleagues had been well aware of the possible scale of the threat since mid-January and had communicated that to officials (see e-mails trails in Exhibits **MWO/006**

{INQ000103352} **MWO/00** {INQ000103354}, **MWO/008** INQ000103353}, **MWO/009** {INQ000103355}, **MWO/010** {INQ000103347} **MWO/011** {INQ000103348}, **MWO/012** {INQ000103349}, **MWO/013** {INQ000103367}, and **MWO/014** {INQ000103350}). I have previously suggested there was "optimism bias" – the hope that things wouldn't turn out as badly as was being suggested – among policy makers and some advisors.

106. I believe a contributing factor to this lack of urgency was the failure of the World Health Organization (WHO) to declare a Public Health Emergency of International Concern until January 30th (nine days after I first wrote to the CMO Scotland) and its failure to declare a pandemic until March 11th. I think it is self-evident that the warnings that I and my colleagues were sending to officials in early 2020 would have carried more weight if WHO had made these declarations earlier. February 2020 has been described as the "lost month" in terms of the world's – not just the UK's – pandemic response. This issue was highlighted in the May 2021 report by the WHO-instigated Independent Panel for Pandemic Preparedness and Response.

107. I also believe there was some complacency regarding the UK's pandemic response planning. The problem was that this planning was undertaken with an influenza pandemic in mind. Covid-19 wasn't flu and required an even more vigorous response. In SPI-M-O meetings in February 2020 I expressed the view that the reasonable worst case scenario developed for an influenza pandemic did not fully capture the potential public health threat posed by Covid-19.

108. I am concerned that experience of the swine flu pandemic in 2009 might also have influenced policy makers. At the time, some scientists were confidently predicting a crisis on a scale far beyond what actually transpired. This may have encouraged to some policy makers and politicians to downplay the warnings about Covid-19.

109. Countries that were faster to implement an effective response include Taiwan. Taiwan first responded – with health checks for arrivals from Wuhan – as early as December 31st 2019. This was extended to all international arrivals by the end of January, together with strict isolation of cases and contacts. By that time the UK's response had only just begun (with quarantine of arrivals from Wuhan).

110. I share the view among global health colleagues that southeast Asian countries were better positioned to respond to Covid-19 because their pandemic preparedness planning focussed on SARS rather than flu. The viruses causing SARS and Covid-19 are closely related and their epidemiologies are similar in key respects, so those countries' planning was better suited to the crisis at hand.

The 'R' Number and Herd Immunity

111. The R number is a measure of whether an epidemic is growing or declining (but not how fast). It is defined as the average number of 'secondary' cases generated by a single 'index' case. If R has a constant value greater than one then the number of cases is growing exponentially. If it has a constant value less than one then the number of cases is declining exponentially. The formal definition of the phrase 'getting the epidemic under control' is achieving a reduction in R from above one to below one.

112. The basic reproduction number – referred to as R0 – is a measure of the transmission potential of a given infection in a given population and can be thought of as the maximum possible value of the R number. This maximum value is typically only realised during the initial stages of an epidemic before there is any build-up of herd immunity and in the absence of any countermeasures.

113. The R number was an output not an input of the Covid-19 models. A key input determining the value of R was the transmission rate (the other key input, the generation time, did not change significantly during 2020). The transmission rate is most simply estimated from doubling times of case numbers. Uncertainties in estimates of the transmission rate translate into uncertainties in estimates of the R number. Transmission rates – and therefore the R number – can vary between subpopulations and localities.

114. The R number is a parameter of interest for epidemiologists but, in my view, it is not a useful operational public health tool. The doubling time is a more direct measure of the rate of growth of cases, and can be applied to hospitalisations and deaths too, which the R number cannot.

115. In practice, the R number estimates provided by SPI-M-O were 1-2 weeks out of date by the time they were available so were slow to detect changes in trajectory (up or down) that would have had policy implications. My team preferred a metric termed the weekly ratio – a version of the doubling time – and we shared our weekly ratio estimates for Scotland with the Scottish Government in real time throughout 2020.

116. The R number refers only to infections (both symptomatic and asymptomatic, detected and undetected). It says nothing (directly) about hospitalisations and deaths or the burden on the NHS. The R number estimate provided by SPI-M-O applied to the whole population as if it were a single entity; it does not capture different epidemic trajectories in different geographic locations nor in specific settings, such as care homes and hospitals.

117. R does capture the extent to which interventions have succeeded in 'suppressing the virus', which was widely equated with keeping R below one. However, it does not say anything (directly) about policy objectives such as minimizing the loss of life or preventing the NHS from being overwhelmed. Practical interventions such as improved

patient care or better protection for vulnerable people in care homes or the wider community have almost no effect on R.

118. A possible pandemic response that is directly informed by the R number is an elimination, or Zero Covid, strategy. This is how the R number was used during the UK's 2001 foot-and-mouth epidemic. In that event, elimination was the unambiguous policy objective and the R number – which was estimated by my own team at the time – was a measure of whether we were on track, i.e. R was below one. As elimination was not the policy objective for Covid-19 it is hard to see how the emphasis on R was helpful.

119. A single UK-wide or Scotland-wide estimate of R does not tell anyone about the current risk to them or those around them. That risk is determined by the prevalence of infection in the local community and measured by the incidence of new infections. Both these variables are (for all practical purposes) entirely independent of R. Nor is the risk homogeneous, it can vary substantially across geographical location and epidemiological settings, e.g. community or care home, and even more across individuals.

120. As the R number is relevant only for infections, it says nothing about the risk of severe illness if infected, which is far more relevant to people attempting to manage the risk to themselves and those about them.

121. For all these reasons, I regarded the intense focus on R throughout 2020 as an unfortunate and unhelpful distraction. I also note that, to the extent that keeping R below one became a de facto policy objective, it favoured population-wide interventions to reduce the transmission rate – such as lockdown – over interventions targeted at reducing the public health burden by protecting those most vulnerable.

122. Herd immunity refers to the fraction of the population that are immunologically resistant to infection (so they cannot become infected and therefore cannot pass the infection on to others). Immunological resistance may be acquired either through prior infection or through vaccination. The bigger the resistant fraction the more difficult it is for the infection to spread through the population. If the resistant fraction is high enough an epidemic cannot take off and any outbreaks will ultimately be self-limiting, i.e. they will die out of their own accord.

123. The minimum level of herd immunity to prevent an epidemic from taking off is termed the herd immunity threshold. The value of the herd immunity threshold is set by R0, the maximum possible value of the R number for that infection in that population. At the herd immunity threshold the R number itself (the average number of cases generated by a single case) equals one.

124. Herd immunity was incorporated into the epidemiological models used to guide policy during the early stages of the UK epidemic. That is standard practice for epidemiological

models of an acute viral infection – the models would be considered deficient if they did not incorporate herd immunity.

125. There was an important caveat, however, that in the early stages of the pandemic we could not know whether immunological resistance following natural infection would be 100% effective in preventing re-infection. In practice, it turns out that it was not 100% effective and this made the herd immunity threshold harder to attain. This lack of knowledge about the degree of immunological resistance introduced considerable uncertainty into long-term scenarios. However, in the early stages of the epidemic few people had been infected, so the level of herd immunity would be low and would have minimal impact on the course of the epidemic. This situation applied through the first wave and well into 2020.

126. That said, there was no question that herd immunity would be an important (quite likely, the most important) determinant of the long term course of the UK's epidemic. Since I regarded this as inevitable I had difficulty in understanding the term "herd immunity strategy" made in reference to possible approaches to the UK's pandemic response in March 2020. Almost every conceivable long-term strategy for tackling the pandemic would involve herd immunity. The only possible exception would be a Zero Covid strategy but that, in my opinion, had not been a realistic option for the UK since late February 2020.

127. My view is that the discussion about herd immunity during the early stages of the pandemic was a symptom of a tendency to give too much weight to model-based expectations of the long-term (up to two years) course of the epidemic. While I completely agree that long term planning was always important, there was too much uncertainty to be confident in the outputs of models looking so far ahead, a view I expressed at the time. Prospective modelling over longer time periods did provide some valuable insights – such as flagging the possibility of second and third waves – but quantitative predictions (for example, expected numbers of deaths) were always going to be far more reliable over the short term (weeks) than the long term (years).

Imperial College Covid-19 Response Team: Report 9

128. Imperial College's Report 9 published on March 16th 2020 compared a 'suppression' strategy with a 'mitigation' strategy for responding to the UK's Covid-19 epidemic. In their usage, suppression focuses on population-wide social distancing measures, including lockdown, and mitigation focuses on case isolation and household quarantine coupled with some protection of the vulnerable. They concluded that a mitigation strategy would not prevent the NHS from being overwhelmed. However, they also concluded that it was

uncertain whether suppression would succeed in the long term, reflecting the by then well-known result that time-limited lockdowns delay but do not prevent an epidemic.

129. The report presented (as Figure 1) a single graph for deaths in the UK during a completely uncontrolled epidemic, indicating there would be over 500,000 in total. It also reported simulations of the impacts of a range of combinations of intervention, both suppression-type and mitigation-type.

130. The analysis accounted for uncertainty in the basic reproduction number by considering a range of values. However, no indication was provided of the impacts of the many other uncertainties that existed at the time, including both the role of herd immunity and the way that people's behaviour would change over time both because of and independently of government actions.

131. Much of the analysis concentrated on long term (2-year) time lines. But in March 2020 there was considerable uncertainty about the course of the epidemic even in the short term and inevitably far greater uncertainty in the long term. In my view, this made such scenarios an unreliable basis for informing policy. In practice, a complex series of unfolding events influenced the course of the epidemic over the two years from March 2020 that could not have been foreseen in any detail and certainly not in enough detail to model.

132. For those reasons, Report 9 was not, in my view, a good basis for making policy. The popular interpretation of the outputs that without drastic interventions half a million people would die was misleading. That figure emerges from a completely unrealistic scenario (noting that Report 9 itself describes it as "unlikely") where there are no interventions at all by government and no voluntary changes in behaviour by individuals or institutions as the epidemic progresses and hundreds of thousands of people are dying.

133. The important conclusion that mitigation alone would not be enough to control the epidemic (resulting in around 250,000 deaths) also depends on the same assumption that there would be no voluntary behaviour change, and is based on a single set of assumptions about the types of mitigation measures deployed and their impacts. Again, I do not consider that this result, by itself, was robust enough to drive policy. The same applies to the implication that less drastic social distancing measures than full lockdown would be insufficient.

134. Overall, I regard Report 9 as a useful contribution to the epidemiological evidence available to policy makers at the time but not one that should have had a disproportionate influence on policy without explicit corroboration from SPI-M-O and other sources of evidence.

135. A subsequent counterfactual analysis of the impact of lockdowns on Covid-19 epidemics in Europe was published by the Imperial College team in the journal Nature in June 2020. The paper concludes that lockdowns had a large effect on transmission and, in many countries including the UK, a decisive effect; i.e. national epidemics could not have been controlled without lockdowns. However, the countries analysed included Sweden, which did not introduce a national lockdown, so the analysis is forced to conclude that interventions that had only a marginal impact elsewhere had a much greater impact – equivalent to lockdown – in Sweden. I, and many others, regard this conclusion as implausible and the paper has been heavily criticised.

136. The main basis of this criticism is that the analysis takes no account of people changing their behaviour independently of government-imposed restrictions. I regard the (implicit) assumption that there are no voluntary changes in behaviour at all as a fundamental weakness of this analysis, of Report 9, and of many of the models used by SPI-M-O during 2020.

137. To the best of my knowledge, this problem was not fully recognised until well into 2021 and even then not adequately addressed (for example, in modelling the delta variant wave). I note that assuming restrictions imposed by government are the sole drivers of changes in people's behaviour can only exaggerate the estimated impact of those restrictions on the course of the epidemic; it therefore exaggerates the impact of lockdowns.

138. Other retrospective studies of the impact of lockdown in the UK reached different conclusions than the Imperial College publication in Nature in June 2020. Two key results were that, contrary to the Nature study, the UK epidemic came under control before lockdown began and that the marginal benefit of stay-at-home orders was small.

139. One explanation for such different conclusions is, again, the implicit assumption in the Nature paper that government-imposed restrictions are the only driver of people's behaviour. This is clearly incorrect – the public, businesses and institutions can and do take their own steps to manage their own risks and that has had a major impact on the course of the epidemic.

140. The inference of behavioural change in advance of lockdown made by the retrospective analyses is strongly supported by Google mobility data for March 2020, though these data were not made available when the decision to impose lockdown was made on March 23rd.

141. I am unable to comment on whether Report 9 was instrumental in the UK government's decision to impose a national lockdown on March 23rd 2020 as I was not party to any discussion with ministers or officials. I note that SPI-M-O's March 20th consensus statement (Exhibit **MWO/052**{INQ000220363}, paragraph 10) was clear is

saying that we did not consider it possible to meaningfully model the impact of additional measures at present, reflecting the many uncertainties that existed at the time, uncertainties that had not been fully reflected in Imperial College's Report 9 published four days earlier.

The timing of the first national lockdown

142. The UK government introduced an escalating series of restrictions in March 2020. I do not think that this so-called 'gradualist' (or 'ramping up') approach to introducing interventions was the wrong policy and I note that interventions were stepped up a similar time period by almost every country in the world.

143. In my team's modelling work we considered lockdowns that were ramped up or imposed immediately and of various lengths, mainly six or twelve weeks. As explained in our briefing 'Optimising trigger times for social distancing measures' (Exhibit **MWO/053** {INQ000103519}) that was considered by SAGE, both the planned length and intensity of social distancing measures affect when they should be introduced. That briefing was authored by myself and my University of Edinburgh colleague Dr Bram van Bunnik.

144. Our results indicated that, as a general rule, less intense social distancing can be effective but has to be implemented earlier and maintained for longer. The choices of lockdown durations modelled reflected discussions at SPI-M-O over the preceding weeks. When lockdown was announced on March 23rd 2020 the PM said the policy would be reviewed every 3 weeks, though it seemed to me unlikely that any restrictions would be removed after the first 3 weeks.

145. I am sceptical of the assertion that had we introduced lockdown a week earlier than March 23rd half as many people would have died. There are several factors to consider.

146. A common assumption made by the epidemiological models in use at that time was that the only drivers of the changes in behaviour affecting Covid-19 transmission rates were measures imposed by government. This was always a dubious assumption and has subsequently proved to be incorrect. Any analysis that does not take into account spontaneous changes in behaviour could be misleading. For example, an assumption that there would have been no changes in behaviour from March 23rd if the government had not imposed lockdown – even though cases, hospitalisations and deaths were rising rapidly – seems a priori to be most unlikely to be correct. I would expect any analysis making that assumption to overestimate the reduction in deaths that would have resulted from an earlier lockdown.

147. Moreover, there is good evidence from Google mobility data that people's behaviour changed dramatically in the week before lockdown was imposed on March 23rd. For this

reason, some published retrospective studies have suggested that the lockdown had relatively little impact on the course of the epidemic. The same observation also suggests that an earlier lockdown would have had less of an effect than might otherwise be expected, simply because people were already changing their behaviour anyway.

148. Another factor to consider is that between one-third and half of all Covid-19 deaths during the first wave occurred in hospital patients (and some staff) and in care homes not in the wider community. These settings have their own infection dynamics that are partly independent of community transmission (the main target of lockdown). Steps taken or not taken to improve infection control in hospitals and biosecurity for care homes will have had an impact on the number of deaths regardless of the timing of any lockdown. Indeed, studies have suggested that a significant fraction of deaths of vulnerable people during the first lockdown occurred precisely because these individuals could not isolate themselves from the health and/or social care systems – lockdown did not protect those individuals from the risks they faced.

149. For these reasons, I am doubtful that an earlier lockdown would have had the degree of impact that some have claimed. That is not to say it would have had no impact at all, though I have yet to see a convincing analysis. I think this makes the assessment that it would have been 'hard to pull the trigger' a week earlier less of an issue. In my view, the more important question is why more proportionate and sustainable interventions than full lockdown were not introduced even earlier, perhaps as early as March 4th. A partial answer to that question is that, as far as I know, the advisory groups were only considering the direct public health impact of Covid-19 at the time. The question 'what could we do to avoid going into lockdown?' was never asked.

150. In my view, the timing of the first national lockdown was influenced by a number of factors. These included: the state of the UK epidemic; experience elsewhere, especially northern Italy; an understandable hesitation from policy-makers to take such a drastic, unprecedented and unplanned step; and the lack of a sense of urgency in the minutes of SAGE meetings.

151. With hindsight, I think there were several circumstances that could have precipitated earlier action: pandemic preparedness plans that included the possibility of full lockdown (the UK's plan did not); a clear exit strategy from lockdown (none was agreed as we went into lockdown); earlier implementation of interventions other than lockdown (in the expectation that these would have been more palatable to government); earlier interventions (possibly including lockdown) for London, where the epidemic was approximately 7 days further advanced than elsewhere in the UK; and explicit recognition that the epidemic was out of control on March 12th 2020 when the UK moved

from the Contain to Delay phase of its pandemic response and abandoned community testing.

152. The concept of behavioural fatigue was part of the public discussion about the pandemic response in March 2020. However, I did not mention it in my own briefings to SPI-M-O and CMO Scotland. The topic was raised at SPI-M-O meetings where I expressed the view that the group did not have the necessary expertise and we should be guided by SPI-B's views on this issue. In my team's work we did not directly consider the possibility of behavioural fatigue. However, because of that and other uncertainties in the public's willingness to adhere to lockdown, including, we did consider lockdowns of different duration and effectiveness.

153. I do not agree with the Institute of Government's suggestion that the desire to avoid lockdown framed the advice commissioned from SAGE, though I accept that government may have been reluctant to impose lockdown. My interpretation of the models that initially suggested that lockdown might have to be implemented (such as Imperial College's Report 9) was that they had identified an additional hazard to be avoided – lockdown – as well as the estimating the public health threat from Covid-19. Yet, as I pointed out earlier, SPI-M-O was never asked to suggest strategies for avoiding lockdown in the early stages of the pandemic.

154. The bulk of SPI-M-O's work throughout the pandemic concerned the potential role of social distancing measures. Much less attention (though not none) was paid to the contribution of case detection and self-isolation, contact tracing and self-isolation, shielding, infection control in hospitals, biosecurity in care homes, or the impact of Covid-safe measures such as face coverings, respiratory hygiene and ventilation.

155. There was a straightforward reason for this: the models used by SPI-M-O were designed to consider the rate of contact between individuals (where a contact is an opportunity for transmission to occur), how contact rate influenced the course of the epidemic, and what impact manipulating the contact rate would have. As a consequence, social distancing measures – designed to reduce the contact rate – were much easier to model than other kinds of intervention.

156. Moreover, there was greater confidence in model outputs relating to social distancing measures than other kinds of intervention because that is what the models were designed to explore. In my view, the structure of the models – a product of model development decisions made very early on, sometimes pre-dating the pandemic – heavily the influenced the advice that SPI-M-O (and therefore SAGE) provided, biasing that advice strongly towards social distancing measures and away from alternatives. I am concerned that this inbuilt limitation was not fully understood by policy makers.

157. I am not able to comment on the view expressed by some SAGE members that advice concerning the first lockdown was influenced by a belief amongst scientists that this would be "politically unpalatable" as I was not party to those discussions. I do, however, recognise the issue. I don't think it is possible for advisors to know what policy-makers might or might not regard as "palatable" in the midst of an unprecedented crisis, so there is an obvious risk of misunderstanding and miscommunication.

158. I take the comment that decisions to ban certain activities are "entirely political" to be a restatement of the maxim 'advisors advice, ministers decide'. Decisions about lockdown – which has negative consequences for the whole of society – need to take into account a wide range of considerations (and, preferably, evidence) extending beyond public health to the economy, education and the functioning of society.

159. I was concerned throughout the build-up to the UK going into lockdown on March 23rd 2020 that we would merely be swapping one problem for another. I expressed my concerns in a letter (drafted and shared with colleagues but never sent) to the Director General of the World Health Organization dated March 19th 2020. In that draft letter I raised three issues with lockdown: i) at a global level the strategy was not working, the pandemic was growing fast; ii) drastic social distancing measures, up to an including lockdown, were causing immense social and economic damage; iii) there was no exit strategy. I stressed the need for interventions that are effective, proportionate and sustainable. I also emphasised the importance of doing more to protect those most vulnerable to severe Covid-19 disease. The draft letter is provided as Exhibit **MWO/054** {INQ000220369}.

160. Nonetheless, I supported SPI-M-O's recommendation for an immediate national lockdown on March 23rd 2020. For me, the key driver of that recommendation was not model outputs, it was data on the rapid doubling times of hospitalisations and deaths – both 3-4 days, indicating that the public health burden was growing rapidly. It was clear that effective action was needed immediately and there was no other option available (measures such as improved case detection, contact tracing and Covid-safety would take far too long to implement).

161. With hindsight, at the March 23rd SPI-M-O meeting we were missing key information on the changes in people's behaviour that had already occurred in the preceding week. Google mobility data subsequently indicated that significant reductions in people's movements had preceded lockdown, and there was relatively little further change following lockdown. Some retrospective analyses have indicated that this made full lockdown superfluous, though we could not know that at the time.

162. I consider this a plausible conclusion given that the UK government had introduced a series of measures prior to March 23rd: people with symptoms were required to self-

isolate from March 12th; advice to avoid non-essential travel, work from home, avoid social venues and for vulnerable people to shield was issued on March 16th; schools were largely closed on March 16th; and most public venues were closed on March 20th. These were substantial interventions and, importantly, were coupled with people and institutions choosing to change their behaviour independently of government too.

163. Together, it appears that this was enough to bring the epidemic under control without any need for full lockdown. If at least some of those measures had been taken earlier (in what was described as a ramping up strategy) then there would have been time to establish whether or not they had been sufficient. As events played out in practice, there was not.

The effectiveness of lockdown

164. In my view, it was always possible to tackle the Covid-19 epidemic in ways that would have lessened the need for social distancing measures and would have been more effective. The single most important intervention was always to protect those most vulnerable to severe disease. Much more could have been done in that regard.

165. There could also have been a concerted effort to shift away from social distancing toward Covid-safe measures, including respiratory hygiene, face coverings, physical distancing and ventilation. More could have been done to improve case detection and contact tracing and to support self-isolation. Mass self-testing could have been implemented sooner, enabling people to manage the risk to themselves and those around them more directly (this approach appears to have worked well during the omicron wave). When social distancing measures were imposed they could and should have been removed much more quickly.

166. Lockdown does not solve the Covid-19 problem it just defers it. To illustrate this point, take a simple epidemiological model of a single epidemic wave and then introduce a short interruption to transmission (a lockdown) early on in the wave. According to the model, you thereby alter the shape of the epidemic curve, delaying the peak, but (to a good approximation) the same number of people end up infected. The same happens if you replace the one lockdown with a series of lockdowns. The possible justification for lockdown, therefore, lies in how we use any time we have gained, for example in improving our capacity to deliver the alternative interventions listed above.

167. Lockdown is clearly not a sustainable intervention; if it were then an attractive pandemic response strategy would be to go into immediate lockdown and stay there until a vaccine or cure became available. However, the cumulative impact of indirect harms to healthcare access, education, the economy and society as a whole preclude that

approach. Some studies have suggested that lockdown is not proportionate either, i.e. the indirect harms outweigh the direct public health benefit. This is a difficult question to answer definitively given the different natures of the harms but I agree it is a question that needed to be asked.

168. That said, and as I described earlier, the first lockdown was difficult to avoid with the information available at the time, though it does look to have been avoidable both with hindsight and with reference to countries such as Sweden and Japan. But there was ample time to put the systems in place to deliver the alternative interventions to social distancing that would have allowed us to avoid the second and third lockdowns.

169. Given that these alternatives could have been made available but were not developed and delivered with sufficient urgency in 2020, I think it is fair to describe lockdown not as a public health policy but as a failure of public health policy; lockdown is what you do when you have failed to control the epidemic in other, more sustainable ways.

170. To develop and deliver alternative interventions to lockdown in a timely fashion would have required much more effort and investment in those alternatives from an early stage. I believe that government would have been more likely to make that investment and effort had they understood from early on that Covid-19 was here to stay and that the epidemic would last years not weeks. I am concerned that government did not understand this for most of 2020. Lockdown, however, could be implemented quickly and easily. For that reason, I have described it as a lazy solution to the epidemic as well as a hugely damaging one.

171. The main aim of a lockdown is to reduce the R number from above one to below one. If the R number is at a steady value above one then the epidemic is increasing in size exponentially (e.g. doubling every 3-4 days as in mid-March 2020). This exponential increase is one of the main arguments for early intervention and is often used to justify stronger intervention too (though that is a more arguable inference).

172. Conversely, if the R number is at a steady value below one then the epidemic is decreasing in size exponentially (e.g. halving every 2 weeks as in May 2020). This exponential decay should be a strong argument for the early relaxation of restrictions just as exponential increase is a strong argument from their early imposition. The logic is that if the epidemic halves in size over the first two weeks then 50% of the public health benefit has already been achieved. The next two weeks will deliver only half as much benefit, the following two weeks only a quarter, and so on. On the other hand, the harms caused by lockdown will be the same for each two-week period, so the cost-benefit ratio is getting worse (exponentially worse). In my view, this makes it difficult to justify extended lockdowns.

173. Another argument for the early imposition of lockdown is that the time lags between infection, hospitalisations and deaths mean that increases in the public health burden over the next few weeks are already 'baked in'. That is a strong argument and was – appropriately in my view – used to justify the March 23rd lockdown. However, exactly the same applies when the epidemic is in decline during lockdown: decreases in the public health burden are already baked in. That should be an equally strong argument for the earlier relaxation of restrictions, but in practice it was disregarded.

174. Though, in my view, the combination of exponential decay and time lags mean that full lockdown restrictions could have been relaxed much sooner than they were – I am referring to a partial relaxation not a complete removal of restrictions. There would need to be careful consideration as to what measures could be removed without allowing the R number to rise above one and the epidemic to take off again. However, we could have removed some measures safely: for example, as early as April 2020 we already had evidence that outdoor activities were safe and that schools were not contributing much to transmission or illness.

175. As I understand it, the Great Barrington Declaration – published in October 2020 – advocated an approach where vulnerable individuals are protected but the virus is left to circulate until enough people have been infected to reach the herd immunity threshold. I had three concerns about that approach at the time, and declined to sign the declaration when invited to do so.

176. First, I thought that the size of the resulting epidemic would be so large that the public health burden just in the low risk segment of the population would be enough to overwhelm the NHS, noting that low risk is not zero risk and some of these individuals would develop severe disease.

177. Second, it wasn't made clear how well the vulnerable segment could be protected from infection in practice. It certainly couldn't be 100% and that meant a further, also potentially very large, burden on the NHS.

178. Finally, the Great Barrington approach assumed that there would be solid post-infection immunity and that the herd immunity threshold could be reached in a matter of months. I was concerned that this might not be the reality, in which case the threshold might not be reached for years, or not at all, and the strategy would fail. We now know that post-infection immunity does not give 100% protection, that individuals can be re-infected multiple times, and that the herd immunity threshold is almost certainly unattainable. This undermines a core premise of the Great Barrington approach.

179. In my view, the optimal approach would have involved a combination of interventions designed to protect the vulnerable and interventions designed to reduce the transmission rate, the latter achieved as far as possible using measures other than enforced social

distancing. The logic is straightforward: the better we do one the less we need the other. In principle, taking that approach could have both saved lives and kept us out of full lockdown.

180. I do not believe that there was widespread acceptance that we would end up 'living with the virus' until well into 2021. The alternative outcome was that the virus would be eliminated from the UK and, presumably, eventually eradicated from the world. This was never realistic. However, the implicit notion that we were trying to 'get rid of' the virus did, I believe, influence the public health approach to Covid-19 in the UK.

181. One example is lockdown, which was first introduced in Wuhan, China in an explicit (and locally successful) attempt to eliminate the virus. At that time, lockdown was not intended to be a sustainable intervention for a virus that was here to stay.

182. Another example is the attitude of policy makers and public health agencies to risk. If the ultimate aim is to eliminate the virus then there is some justification for taking a zero tolerance approach to even the tiniest risk of transmission, not least because there is an expectation that measures will only be needed for a limited period of time. However, once it is accepted that we will be living with the virus then it becomes much more important that the measures taken are proportionate and sustainable.

183. It follows that if we had accepted that we would be living with the virus earlier – and I personally believed this would the case from February 2020 – then we would have been less likely to have imposed lockdown, more willing to relax restrictions earlier, and quicker to ease disproportionate regulations (e.g. excessively long self-isolation periods).

184. Precision public health is an umbrella term for public health strategies that aim to deliver the right intervention, at the right time, to the right people. It is a risk-based approach. Protecting individuals we know to be vulnerable to Covid-19 is a precision public health approach; lockdown, which affects even those at the very lowest risk from Covid-19, is the opposite. Among other advantages, a precision public health approach is always likely to be more cost-effective because it targets interventions where are they are expected to deliver most benefit.

April 2020 onwards

185. My main concern about UK government decision-making in the summer of 2020 is that we were far too slow to translate new evidence into the lifting of restrictions.

186. A clear example was the restriction on outdoor activities. Studies in China had demonstrated by April 2020 that outdoor transmission was exceptionally rare and this was subsequently backed up by further research. Given that evidence, I did not understand why people were told to stay indoors or, later on, why restrictions on outdoor

activities were not removed much sooner. I am not aware of any evidence that those restrictions delivered any significant public health benefit. It was possible in principle to distinguish indoor and outdoor contacts from March 2020 onwards using data from the CoMix study of contact behaviour but I do not know if this information was incorporated in the models.

187. A second example is the closing and re-opening of schools. When we entered lockdown in March 2020 there was no evidence that schools were making a significant contribution to transmission, for the very good reason that they were not. There was also no evidence that school-aged children were at significant risk from Covid-19, again for the very good reason that they were not. It took slightly longer to establish that teachers were not at elevated risk compared with other people-facing professions (such as supermarket workers), but the evidence was there by June 2020 and, again, there had never been any positive evidence of teachers being at elevated risk because they were not.

188. I note that through February 2020 minutes of SPI-M-O meetings (see Exhibit **MWO/055** {INQ000220359} and **MWO/056**{INQ000220358}) indicate doubts about the effectiveness of school closures – I do not know what evidence (other than modelling) led to a change of tone from mid-March onwards.

189. My view is that drastic interventions such as a legal requirement to stay indoors or closing schools should be taken on the basis of evidence. If, as on this occasion, they are taken on a precautionary basis then we should urgently seek evidence to confirm that our caution is justified, and be prepared change course when that evidence is not forthcoming. In my view, schools could have safely been re-opened in May or June 2020 as cases fell (as was done on Denmark without any significant problems), and I note that they did remain open in November 2020 when levels of infection were higher and were rising.

190. A particularly chaotic feature of the UK government's response in the summer of 2020 was travel restrictions. The scientific advice throughout the pandemic was that travel restrictions would only have a very limited impact once Covid-19 was established in the UK (i.e. from mid to late February 2020). The kinds of reactive, targeted restrictions on individual countries that came and went at a high frequency during that summer are unlikely to have delivered any meaningful public health benefit. A comprehensive travel ban might have had some impact, but even that could not have reduced the importation of new cases to zero.

191. This issue was revisited later in 2020 and in 2021 when variants became a concern. In December 2020 the UK government objected when other European countries imposed restrictions on travel from the UK when the alpha variant emerged here. Then in

2021 the UK imposed similar restrictions on travel from India when the delta variant emerged there and again on South Africa when the omicron variant emerged there. In both cases, although restrictions were imposed once delta and omicron were declared to be variants of concern, they still came too late to prevent or even meaningfully delay these variants arriving in the UK. At no stage during the pandemic did I get the impression that ministers fully understood the limitations of travel restrictions as a means of protecting public health.

192. As restrictions were relaxed, I was surprised that senior ministers in both Westminster and Holyrood were openly engaged with questions such as whether a scotch egg was a substantial meal, how many people could meet outdoors, when pubs should close, or how many people could queue for a takeaway. These fine-grained decisions would, taken in isolation, have minimal impact on the course of the epidemic and, in my view, could have been left to the public health agencies.

193. I am concerned that a tendency of government to micro-manage led to a suboptimal pandemic response by deflecting attention from much bigger issues that were never addressed; for example, building up capacity to implement interventions other than social distancing measures (case finding, contact tracing, self-testing, Covid safety) in advance of the anticipated second wave. For other kinds of crisis I would not expect this kind of issue to arise. For example, during military conflicts I would expect politicians to set the objectives but to leave the conduct of the campaign to their military commanders.

194. I am not able to comment directly on the Institute for Government's finding that there was a lack of joined up thinking regarding the lifting of restrictions in summer 2020. However, in Scotland I was concerned when Scottish Government was actively promoting the idea of eliminating the virus while at the same time overseeing a gradual relaxation of restrictions. I could not see how those two policies could be compatible.

195. The apparent intention to return to normal during the summer 2020 by a gradual relaxation of restrictions signalled to me that the government did not accept the epidemiological assessment that there would be as a second wave if too many restrictions were lifted, an assessment dating back to early March.

196. Scottish Government put great emphasis on the importance of a cautious exit from lockdown and I am concerned that there was not a clear understanding that a second wave would occur once the R number rose above one regardless of the length of time it took to reach that point. Any threat to public health would come from unlocking too far not too fast.

197. Across the UK, the sequencing of relaxations was difficult to align with the objective of keeping the R number low because there was no way of estimating how much transmission was occurring in diverse settings such as gyms, hairdressers or churches,

so there was no objective way of ranking them in terms of their anticipated contribution to the R number. We had a limited degree of knowledge of the risks associated with different settings from a patchy collection of empirical studies, but these data could not be incorporated in the models since features such as gyms, hairdressers and churches were not explicitly represented.

198. The introduction of the Eat Out to Help Out (EOHO) scheme in August 2020 was just one element of this relaxation strategy, alongside others such as the re-opening of universities and overseas travel during the holiday season. Against that background, there is no suggestion that EOHO, by itself, was responsible for the second wave, though one retrospective study from the University of Warwick (provided as Exhibit **MWO/057** {INQ000220382}) suggests that it made a detectable contribution. The extent of that contribution depends on what individuals would have done instead of eating out and, as many restrictions were being relaxed at the time, there was a range of options.

199. Moreover, changes to people's behaviour are not just driven by the government-imposed restrictions in place, they are driven by their own assessment of the risk to themselves and others, and it is worth noting that levels of infection were generally low in August 2020. EOHO allowed people to meet in a controlled environment with mandated Covid-safety measures, as such it was likely less risky than people meeting in their own homes. Overall, I doubt that the UK's Covid-19 epidemic in late 2020 would have unfolded that differently without EOHO.

200. The UK's Covid-19 epidemic was clearly growing in mid-September 2020. However, the R number was not as high as it had been in March. This immediately indicated that we did not need such a drastic response as was felt necessary in March to bring the epidemic under control again; in other words, we did not need another lockdown. From discussions at SPI-M-O and from hearing SAGE members speaking in the media I did not get the impression that this was the interpretation being communicated to government.

201. I am concerned that repeated calls for another lockdown by advisors were motivated by a desire not to be seen to make the same perceived mistake of delaying calls for lockdown in March, ignoring the fact that the epidemiological situation was different in September. The lower R number in September – and correspondingly longer doubling time – indicated that measures well short of lockdown would have slowed or stopped the growth of the epidemic. Therefore, I was concerned when the Chief Scientific Advisor (CSA) advised "going hard and early" (see Exhibit **MWO/058** {INQ000220367}). I did not agree with that advice: based on evidence going back to March 2020, a better maxim is that earlier action can be less drastic action. Yet I never heard that view expressed by any member of SAGE.

202. At the time I was particularly concerned that approximately 50% of cases were not being reported (with the implication that self-isolation of cases or contacts may not have been happening), and studies were indicating that self-isolation rules were being broken when imposed. I was also concerned that, as the epidemic grew, extra measures were not put in place to protect those most vulnerable to severe disease. Even if these measures proved insufficient to keep the second wave manageable, had they been implemented early enough then there would have been time to establish this and introduce additional measures as needed. I did not, however, present a formal analysis of under-reporting of cases until January 2021. My report is provided as Exhibit **MWO/059** {INQ000220378}.

203. I note that, to the best of my knowledge, the advice from SPI-M-O at the time took no account at all of the possibility of voluntary behaviour change influencing the course of the wave, though in practice it is likely to have had a significant role, thereby reducing the need for government intervention.

204. I was concerned when, at a briefing on 21st September 2020, the CSA showed a projection of an epidemic doubling every seven days. The SPI-M-O estimate at the time was that the epidemic was doubling every 10-11 days. I could not see any reason to expect the epidemic growth rate to suddenly accelerate. I therefore expected the projection to turn out to be too pessimistic, as it did. A longer doubling time corresponds to a lower R number and therefore less drastic interventions are needed to bring the epidemic under control.

205. I made my concerns public through a comment posted by the Science Media Centre. The next day I received four e-mails from Graham Medley (SPI-M-O Co-Chair) culminating in a request he passed on from an unspecified source that my views be "corrected". My reply indicated that I was surprised to receive such a request and the conversation ended. The e-mail trail is provided as **MWO/060** {INQ000103400}, **MWO/061** {INQ000103394} **MWO/062** {INQ000103395}, **MWO/063** {INQ000103396}, **MWO/064** {INQ000103397} **MWO/065** {INQ000103398}- **MWO/066** {INQ000103194}

206. On 16th October 2020 I wrote to the SPI-M-O Co-Chairs and DHSC lead to let them know that I had been asked to give evidence to a House of Commons Select Committee five days later. I took the opportunity to state that I was concerned that some of the short-term projections and long-term scenarios coming from SPI-M-O were unduly alarmist and say that I did not see any need to exaggerate the serious of the threat in order to stimulate action. This led to an e-mail exchange over the next two days with Deputy CSA Angela McLean and CSA Patrick Vallance. The exchange was mainly to do with whether the seven day doubling time presented by the CSA in his September briefing could be viewed as reasonable worst case scenario. The e-mail trail is provided

as MWO/06 {INQ000103258}, MWO/06 {INQ000103272}, MWO/069 {INQ000103267}, MWO/070

207. {INQ000103271}, MWO/07 {INQ000103273}, MWO/07 {INQ000103276}, MWO/073 {INQ000103277}, MWO/074 {INQ000103278}, MWO/075 {INQ000103279}, MWO/076 {INQ000103264}, MWO/07 {INQ000103280}, MWO/078 {INQ000103259}, MWO/079 {INQ000103262},

208. In the e-mail that I sent to the SPI-M-O co-chairs on 16th October 2020 I included a graphical comparison of the inaccurate case number projection for England with a much more accurate projection for Scotland based on a lower and more realistic estimate of the doubling time. I note that while a lockdown was imposed in England in early November, lockdown was not reintroduced in Scotland at that time, the epidemic in Scotland was brought under control through a tier system.

209. A tier system of local restrictions introduced in England on October 14th 2020 and was a reasonable attempt to tailor the severity of restrictions to the local epidemiological situation. This was always an appropriate way of responding to a heterogeneous epidemic. The main question raised at the time was whether the highest level of restrictions would be sufficient to keep the R number below one and so prevent a second wave.

210. My view was that this concern was exaggerated because it did not take into account voluntary changes to people's behaviour beyond enforced restrictions. I would expect behaviour to change as case numbers rose.

211. Two lines of evidence support this view. First, the second wave in England began to peak even before a national lockdown was imposed on November 5th (though noting that the lockdown was pre-announced on October 31st). Second, the Scottish Government introduced its own tier system of restrictions on November 2nd rather than a full lockdown and Scotland's second wave peaked at much the same as England's.

212. The detection of the alpha variant in December 2020 was a grave concern, particularly given its increased transmissibility. However, I did not agree with the argument that, of the levers available to respond to the imminent new wave, school closures were the most important. As far back as April 2020 we had good evidence that Covid-19 does not transmit particularly well between children or in a school environment. Schools were not driving the epidemic in 2020 and early 2021 in the UK or anywhere else in Europe (I shared an analysis of this issue with SPI-M-O in a briefing dated 11/11/20 provided here as MWO/080 {INQ000220381} wouldn't be until the autumn of 2021 that schools would make a major contribution to spread and that was only because the delta variant was even more transmissible.

213. I did agree, and this was the general view within SPI-M-O, that additional measures would be required to tackle the alpha wave, but my preference was to focus on case detection aided by self-testing, supported self-isolation, Covid-safety measures and protecting the vulnerable. In practice, because there had been no concerted effort to build up capacity to deliver these interventions in the autumn of 2020, we were left (as back in March 2020) with social distancing as the only practical option on the table.

Protecting the vulnerable

214. Though one of the UK government's stated policy objectives was to save lives, SPI-M-O paid less attention (but not none) to interventions that would protect those at greatest risk than it did to designing intervention strategies based on social distancing.

215. We knew from early on in the pandemic that the risk of severe illness or death from Covid-19 rose dramatically with age, such that an individual aged 75 years was ten thousand times more likely to die than a 15-year old. The risk profile was quickly refined to account for a range of co-morbidities and other risk factors as well. These are crucial observations and their obvious implication is that we need to do all we can to protect those at highest risk. Some interventions – such as measures to protect care homes or shielding in the community – were of this kind but the monetary investment in these measures was dwarfed by the costs of lockdown.

216. I was puzzled by the focus on population-wide measures to reduce the R number at the apparent expense of targeted measures to protect those most vulnerable to Covid-19. Regardless of what other measures were in place, the better we protected the vulnerable the lower the toll of severe disease and death. Over the short term (such as the first wave) there is a substantial payoff: if we had been able to halve the risk to the most vulnerable 20% then we would have reduced the death toll between March and August by more than 40%. In my view, this should have been the primary focus of our response, but it was not.

217. My understanding is that SPI-M-O models did capture the fact that the elderly were far more at risk of severe disease than the young and healthy. However, I am unable to say whether risk factors other than age were ever incorporated. Model outputs presented at SPI-M-O meetings were almost always in the form of numbers of cases, hospitalisations and deaths that were not broken down by age or other risk factors. This made it difficult to evaluate how well the models were capturing risk heterogeneity.

218. The models did not, to my knowledge, include shielding the vulnerable. It may be that the demographic inputs into the models did not distinguish the risk groups given shielding advice. Nor, to my knowledge, did the models include any distinct behavioural

characteristics of the most vulnerable groups, including the need for close contacts with carers.

219. Care homes and hospitals were not explicitly represented in the early models, even though 30-40% of deaths in the first wave were linked to infections acquired in these settings and though the spread of infection in both settings is at least partly independent of transmission in the wider community. Schools were explicitly represented in at least some models even though they made negligible contribution to the burden of severe illness.

220. I agree with the view that modellers did not pay sufficient attention to the roles of care homes and hospitals. However, this criticism could equally well be applied to public health advisors more generally.

221. I do not believe that the public health response was adequately targeted at those individuals who were most vulnerable to Covid-19, nor at settings such as care homes and hospitals with large numbers of vulnerable people at high risk. My team did do some modelling of the potential impact of interventions to reduce the risk in the vulnerable population (described below) but I am not aware that any other models considered – or were able to consider – this kind of strategy. There was no concerted effort by advisors to persuade policy makers that targeted interventions would be beneficial, though in my opinion it is self-evident that they could have had considerable benefit in reducing the burden on the NHS.

222. In March and April 2020 my team developed a proposal for a strategy referred to as 'segmentation and shielding' as a means of both reducing the public health burden of Covid-19 and accelerating the exit from lockdown. Between April 1st and August 5th 2020 we submitted a series of briefings on this topic to SPI-M-O. Our August 4th briefing (Exhibit **MWO/08** {INQ000220368}) and our peer-reviewed publication – published on-line by the Royal Society in May 2020 and provided here as Exhibit **MWO/082** {INQ000220376} were discussed at the fiftieth SAGE meeting on August 6th 2020. According to the minutes SAGE requested further work, but the topic was not discussed again until October, and then in the distinct context of the Great Barrington Declaration. I am not aware that it was discussed at all after that.

223. We posted a preprint setting out our segmentation and shielding strategy on May 8th 2020. The preprint is provided as Exhibit **MWO/083** {INQ000103508}. The unique feature of our approach was to protect the vulnerable by interventions directed at those in contact with the vulnerable. This would include health care workers, social care workers, informal carers and household members – the 'shielders'. Regular testing of shielders was a key element of this strategy.

224. The impact of this intervention could not be studied with the models being used by SPI-M-O because they did not include representation of contacts between vulnerable individuals and their shielders. Our analysis suggested that if this delivered a high enough – but, in our view, achievable – level of protection to the vulnerable then the epidemic in the vulnerable and non-vulnerable segments could be partially decoupled, sufficiently so as to reduce the numbers of vulnerable people infected (over a single wave) even if transmission rates were higher in the general population (implying a partial relaxation of population-wide social distancing measures).

225. In our work we used age as a proxy for vulnerability. This is justified as age is – as was known at the time – by far the most important risk factor for severe Covid-19. However, as our knowledge of risk developed over time – through initiatives such as the QCOVID study – other risk factors could, in principle, easily have been included in the strategy. This should make segmentation and shielding even more effective as more of the total risk is carried by an even smaller segment of the population.

226. We used a standard 'SIR' compartment model extended to represent different population segments and heterogeneous rates of contact between them. The model was parameterised using data available at the time, noting that – as with all epidemiological models in the early stages of the pandemic – there was little or no information on some parameters. Where that was the case, we carried out extensive sensitivity analyses to better understand the impact of uncertain parameters on our conclusions. As such, this was a similar kind of modelling exercise to all those we and others carried out early in the pandemic.

227. Our analysis indicated a possible quicker and safer route out of lockdown and so attracted widespread interest. I discussed our findings with SPI-M-O, with Cabinet Office and with Scottish Government among others in April and May 2020 but I was not asked to present them to SAGE. Discussions with SPI-M-O took place on April 27th 2020 (mentioned in the consensus statement from that meeting which is provided here as Exhibit **MWO/084**{INQ000220360}) and by e-mail (Exhibit **MWO/08**{INQ000220372}). Discussions with Cabinet Office took place on May 1st 2020 but I have no report of that meeting. Discussions with Scottish Government (First Minister's briefing) took place on May 15th 2020. The briefing is provided here as Exhibit **MWO/086**{INQ000220366}.

228. I consider – and did at the time – that this work was policy relevant but not policy ready. To turn segmentation and shielding into policy would have required input from multiple other sources, including some bespoke confirmatory modelling by SPI-M-O, expert assessment of what levels of protection could be achieved, and logistics input regarding the rapid scaling up of the support – including access to testing – available to

shielders. Since, as far as I can tell, SAGE did not support the proposal, it was never pursued with any real intent.

229. In August 2020 we extended our concept of segmentation and shielding to the 'chain of trust', the notion that shielders need to protect themselves from infection to protect their vulnerable charges, and one way to help achieve that is for all the contacts of shielders to do as much as they can to ensure that those contacts are safe. Our briefing is provided here as Exhibit **MWO/081 {INQ000220368}**

230. Over that period, there was some discussion about the ethics of shielding in general. I discussed this issue with SAGE members Brooke Rogers and Mike Parker by e-mail in August and September 2020. The key advice I received was that "if we are ever to emerge fully from lock down there is inevitably going to be a phase during which responsibilities/burdens are going to be unevenly distributed". This seemed to me to be consistent with segmentation. The e-mail correspondence is provided here as Exhibit **MWO/087** {INQ000220371}.

231. I do not think that stressing the need to protect those at greatest risk should be controversial. Yet, there were suggestions that a Covid-19 response strategy that emphasizes protection of the vulnerable was "unethical". I regard any such suggestion as self-evidently absurd. Exhibit **MWO/088** {INQ000220370} is an October 2020 e-mail exchange with Professor Robert Lechler, outgoing President of the Academy of Medical Sciences. The exchange illustrates the scope for misunderstanding the ethical issues (and also how these can be resolved by open discussion).

232. I think there are three reasons why segmentation and shielding was not pursued to the point where it became policy.

233. The first was that I did not make the case well enough, failing to make it clear that shielding need not be about extreme isolation, which is how it had come to be perceived at the time. Our focus on shielders was explicitly intended to make contacts with vulnerable people safe, not least because for many vulnerable people (such as my own mother) those contacts are unavoidable. I fear this was not properly understood.

234. The second reason was that the strategy was misrepresented by some advisors as incompatible with suppressing the virus (reducing the R number). This was incorrect: the two are entirely compatible and the impact of doing both is self-evidently that fewer vulnerable people will die. If, instead, the policy objective is not letting the NHS become overwhelmed then, equally clearly, this is more easily achieved if vulnerable people are better protected.

235. The third reason was that the Great Barrington Declaration's "focussed protection" version of a segmentation and shielding strategy was widely criticised. Focussed protection involves unrestricted spread of infection in the non-vulnerable population,

whereas in our May 8th preprint we made it clear that, in our view, other measures would still be required to control transmission in the whole population. Our version of segmentation and shielding was potentially a route out of lockdown but not an escape from any Covid-19 countermeasures at all.

236. My impression is that the debate became ideological. At the time, I wrongly assumed that there was a common goal of exiting lockdown safely as quickly as possible. I failed to realise that this was not true of advocates of the now discredited 'Zero Covid' strategy. Zero Covid can only be achieved by the strongest possible suppression of transmission. In our May 8th preprint we were proposing a way to live with higher transmission rates – something I had recognised we would need to do since February 2020 – and that was not compatible with Zero Covid.

237. On October 15th SAGE summarized their advice that segmentation was not a viable strategy. It seems to me that SAGE failed to make a distinction between a specific (and, in my view, unworkable) "focussed protection" strategy proposed by the Great Barrington Declaration and the much wider range of quite distinct options set out in our paper.

238. On October 2nd 2020 I co-authored a report making the case that – based on our retrospective analysis of data from the first Covid-19 wave in Scotland – a new lockdown, if implemented, would not adequately protect the vulnerable. Our analysis indicated that up to 73% of fatalities during the first wave in Scotland had been the result of infections acquired after lockdown was implemented – clearly, lockdown alone was not providing adequate protection for the most vulnerable individuals. Our report is provided here as Exhibit **MWO/089** {INQ000220365}.

239. We now have a good understanding of why this was the case: the most vulnerable people require day-to-day care and cannot fully self-isolate; necessary interactions with health care workers, social care workers and informal carers put these people at risk. If we had done more to protect the vulnerable by protecting their contacts then the death toll could have been reduced.

240. Our October 2nd paper warned that if this omission was not rectified then this pattern was likely to be repeated in the autumn with many thousands of preventable life-threatening infections occurring even after lockdown. We recommended enhancing protection of the vulnerable immediately. The paper was tabled at the SAGE meeting on October 29th but not was not considered or discussed at the meeting.

Access to, Sharing and Quality of data

241. In the early stages of the pandemic (January and February 2020) our ability to advise policy makers was significantly hampered by lack of information. In part this was inevitable, as some necessary studies had still to be performed, but I share a general

concern that information was slow to emerge from China. Key (interrelated) information gaps at that stage were the fraction of cases that were asymptomatic, the case-fatality rate, and the way that both were related to age.

242. Though these numbers were integral to the analyses my team and others were doing at time, I do not think that this had immediate policy implications since numerous scientists – including myself – had recognised and communicated the threat. We were able to provide preliminary but useful indications of the expected course of the UK epidemic as early as mid-January.

243. An important question in those early stages was whether a Covid-19 epidemic would be more influenza-like or more SARS-like. The UK response initially assumed on an influenza-like event. This was not unreasonable but, in my view, it took too long to recognise that Covid-19 had many similarities to SARS: we knew from early January that Covid-19 was closely related to SARS. Compared with influenza, Covid-19 had a higher R number and had little impact on children while being highly dangerous to the elderly, frail and infirm.

244. If we had accepted these SARS-like features sooner it might have led to better policy advice: for example, that care homes would be far more important than schools. On the other hand, Covid-19 turned out to less severe than SARS and exhibited a higher proportion of asymptomatic cases; these features also had policy implications. So, though better information faster would certainly have helped, it was also important that the information we did have was correctly interpreted and acted upon.

245. The only real-time analyses that my team carried out during the pandemic was calculation of the weekly ratios of cases, hospitalisations and deaths in Scotland. Those data were obtained from Scottish Government twice a week in the early stages with a lag of a few days. This was adequate for our primary purpose of communicating the trajectory of the epidemic in Scotland after the first lockdown, informing decisions that were taken on the basis of trends over weeks rather than days. We did not use data from PHE, CO-CIN or NHS England.

246. I was also involved in the EAVE II data analysis study led by Aziz Sheikh at the University of Edinburgh. This study linked demographic and near real-time clinical data from almost the entire population of Scotland. Because of its scale, EAVE was able to make estimates of key quantities with unprecedented speed. Two high-profile examples from 2021 were rapid estimates of vaccine efficacy and the severity of omicron infections.

247. EAVE was conceived early in 2020 and activated in mid-March. However, it was unable to carry out large-scale analysis of linked databases until the requisite permissions had been obtained and implemented, which took until June. In my opinion,

had the administrative requirements been less onerous then EAVE could have started generating invaluable data - for example on risk factors – much earlier, thus making a better evidence base available to advisors and officials during those early months.

248. I note that I wrote an e-mail to the CMO Scotland in May 2018 warning that I feared the bureaucracy around access to health data in Scotland could cost lives during a pandemic. The e-mail trail is provided here as Exhibit **MWO/09** {INQ000149112}.

249. I think the CSA was right to raise for England the data access issues I have just commented on for Scotland. However, I have no information on which SPI-M-O modelling groups had access to what data and when. I do not know if the Imperial College group had privileged early access to data (or funding or other resources). However, I note that in the early stages of an emergency there may not be the permissions and arrangements in place to share real-time data between government departments and agencies and every academic research group offering assistance.

The Influence of Modelling on Policy Decisions during the Covid-19 Pandemic

250. I consider that there was an over-reliance on epidemiological modelling in 2020 and its influence on policy making was not appropriately tempered by an understanding of its limitations. Good practice guidance for the use of models in policy is that models should be one line of evidence (and can be a very useful line of evidence) but never the only one. I felt from early on that the (entirely warranted) intense focus on the public health impact of Covid-19 was not balanced by a similarly intense focus on the harms that lockdown and other countermeasures would do.

251. I note that epidemiologists and public health experts are rarely called upon to consider indirect harms to the economy, education or wider society because most public health interventions have little negative impact other than monetary cost and resource allocation, so this was an unrehearsed situation. As a result, my strong impression for much of 2020 was that policy was being driven much more by public health considerations than anything else.

252. As I explained earlier, the main focus of SPI-M-O's work was on the impact of social distancing on the course of the UK epidemic. The committee was well placed to answer questions about the impact of, say, another lockdown but less well placed to answer questions about the impact of improving Covid-safety, case detection or protection of the vulnerable.

253. At the same time, the questions being asked by government were narrow. For example, SPI-M-O was never asked to identify alternatives to lockdown. I believe that

this narrow focus had an impact on policy in that it led an overemphasis on social distancing measures at the expense of alternative interventions.

254. Since I was not present at discussions between SPI-M-O leads and officials, I cannot say whether this overemphasis was because the government didn't think to ask other questions or because SPI-M-O would have had difficulty answering them if it had, or both. My concern is that the policy options offered to government – or, at least, the ones given greatest weight – were influenced significantly by what SPI-M-O's models were set up to do, rather than a broader review of all policy options available whether 'modellable' or not.

255. In hindsight, I think that the modelling community should have done much more to communicate the limitations of the models to officials, minsters and the media, including limitations to the kinds of questions the models could answer. That said, advisors always faced a delicate and difficult balance between overstating the case and stimulating action when it was warranted – I had faced that dilemma myself when first sounding the alarm to the CMO Scotland in January 2020.

256. I agree with the Institute of Government that government priorities were not always clearly communicated to science advisors and that the absence of a clearly stated strategy for managing the pandemic was a significant shortcoming. As I pointed out at a SPI-M-O meeting in September 2020, if our job was to identify the public health interventions necessary to meet the policy objectives of minimizing the loss of life (or minimizing the pressure on the NHS) then we didn't need complex mathematical models to come up with an answer: the best approach would be to go into lockdown and stay there. The issue of defining policy objectives – referred to as the 'objective function' – is raised in a briefing to SPI-M-O authored by Steve Riley and Mike Tildesley and provided here as Exhibit **MWO/091** INQ000220364}.

257. Since that was clearly not the approach favoured by government it followed that they were – reasonably enough – trying to trade off public health harms against the indirect harms caused by lockdown. However, we were never given the terms of that trade off, nor a time scale, nor an indication of the final destination the government was aiming for. Clearer specification of the strategy would, in my view, have resulted in better quality advice.

258. The lack of a clear strategic framework within which to work did make my role as an advisor considerably more difficult. However, the development of those strategies has to be a two-way process between ministers and officials on the one hand and scientists and public health experts on the other. This is because ministers and officials may not have a full understanding of what strategies are and are not available to them.

259. This lack of understanding came to the fore in Scotland in late summer 2020 when – to my astonishment at the time – serious consideration was given to the idea that Scotland should adopt an elimination policy. As subsequent events around the world have made all too clear – and as I had pointed out repeatedly at Scottish C19AG – elimination was an unrealistic objective and we needed strategies that were consistent with the realisation that we would be living with Covid-19 for the foreseeable future.

260. A report by Sense About Science suggests that the UK government was not committed to transparency of evidence during the pandemic. I do agree that the information communicated to the public in 2020 was at best incomplete and at worst misleading; for example, the statement that "the virus does not discriminate". I am concerned that this lack of transparency stemmed from a lack of trust in the public to act sensibly on the basis of incomplete or changing information. Instead, there was a desire for clear and unequivocal public health messaging that was inevitably at odds with the growing and sometimes changing evidence base underpinning public health guidance.

261. I note that the SAGE subgroup SPI-B stated in a briefing dated March 22nd 2020 that "a substantial number of people still do not feel sufficiently personally threatened; it could be that they are reassured by the low death rate in their demographic group...the perceived level of personal threat needs to be increased among those who are complacent, using hard-hitting emotional messaging." The briefing is provided as Exhibit **MWO/092** {INQ000119485} I have previously described this recommendation as "unwise" on the grounds that it could be (and, I believe, was) interpreted as giving the Government licence to exaggerate the dangers of Covid-19 to low-risk segments of the population in order to assure compliance with lockdown.

262. From experience, I judge that the great majority of people will made sensible decisions about managing the risk to themselves and those around them based on whatever information is available (and noting that this comes from multiple sources, not just government and public health agencies). But they cannot make good decisions unless they have as complete and as accurate information as possible.

263. I agree with the Institute of Government that the government's communication of the risks associated with specific behaviours (and, I would add, to specific individuals) was inconsistent and confusing (and, I would add, sometimes actively misleading). And, with great regret, I agree with the suggestion that models were used to help create a climate of fear. I note the irony of widely publicised concerns about 'misinformation' circulating in the media and on social media whilst some of the government's own public health messaging was itself misleading, creating misperceptions about relative and absolute risk to individuals and communities that persist to this day.

264. I am not an expert in health ethics but I understand that there is an active discussion about whether instilling fear is appropriate as a public health messaging tool. However, emergencies are inherently alarming so I would re-frame the debate. I believe that the public has a right to accurate information – alarming or otherwise – on the basis of which they can modify their own behaviour if they so choose and also judge the appropriateness of government policy. This approach was taken later in the pandemic in discussions of vaccine safety, and the result was that uptake of vaccination was impressively high. My view is that if the public could be trusted with the full facts about vaccine safety then they could have been trusted with the full facts about the risks of Covid-19 itself.

265. In my view, the phrase 'following the science' gave the impression that policy was being driven more by advice from scientists than many people – including many scientific advisors – would be comfortable with. However, I note that while some advisors felt they were being held responsible for policy decisions that they were not theirs to make, other advisors were happy to advocate for policy options in the media; for example, during the build-up to the second lockdown in November 2020.

266. I never had any objection to advisors' names being made public and would have been content for my name to be made public as soon as I joined SPI-M-O in January 2020.

Lessons Learned

267. I have been asked by the Inquiry to address any lessons learned and how things might have been done differently from my perspective.

268. The most important area where my own contribution could have been improved was in communicating the need to protect those most vulnerable to Covid-19. With hindsight, I had failed to appreciate two impediments to recognising this need.

269. First, I thought at the time that it was so obvious that it needed no discussion, and took the introduction of shielding to be a first, albeit crude, step down this path. Second, I assumed that there was a general desire to exit lockdown as quickly as it could be made safe to do so; I had not appreciated that there was a view that elimination of Covid-19 from the UK (and even global eradication) was feasible and should be the ultimate outcome of our response. I was certain that this outcome was not achievable but, for those that believed otherwise, lockdown was desirable as a means to that end (as it had been used originally in Wuhan, China).

270. Because I had not recognised that these debates needed to be won, I went too quickly to coupling protecting the vulnerable with exiting lockdown. I should instead have

emphasized that protecting the vulnerable has a clear and obvious public health benefit independent of whatever long term strategy is being pursued.

271. A second area for improvement concerns my advice on the timing of the introduction and lifting of social distancing measures. I failed to drive home the message that earlier action could be less drastic action and was arguably our best route to avoiding full lockdowns. I believe that taking this approach would have allowed us to avoid the November 2020 lockdown.

272. Equally, I failed to make the case that at least some restrictions could have been lifted sooner than they were: the threat to public health comes from relaxing too far not too fast. I am concerned that the mistaken belief that we had relaxed too fast (rather than too far) during the summer of 2020 led to an unnecessarily slow exit from the January 2021 lockdown.

273. In giving advice to government, I found it difficult to balance the dangers of under-reaction and over-reaction. In my view, there was a worrying lack of urgency and appreciation of the scale of the imminent crisis between mid-January and early March 2020. In contrast, I felt that the subsequent response – particularly lockdown – was disproportionate, unsustainable and not as effective as was being claimed. However, the emphasis on consensus and clear messaging, plus a sense of not wanting to 'rock the boat', made it difficult to discuss these issues openly at the time.

274. The problems faced by the UK in 2020-21 were replicated in many other countries around the world and so, as well as our national response, the international response was also relevant to how events unfolded – Covid-19 was undoubtedly a global problem. The most obvious route to achieving a co-ordinated international response is through the World Health Organization (WHO). Unfortunately, the WHO was too slow to respond to events in early 2020.

275. A specific issue was the WHO's delay before declaring a public health emergency of international concern (PHEIC), and again before declaring a pandemic. This badly undermined the case being made by me and others for early and effective action within the UK and elsewhere in January and February 2020.

276. Another issue was the WHO's (long-standing) reluctance to recommend travel restrictions when they could still have made a difference, at least in slowing the international spread. There was potentially a significant benefit to be gained from China closing its borders in early January. Failing that, worldwide restrictions might have been imposed by early February. Though these measures would have likely have been seen as extreme at the time, the disruption they would have caused was exceeded many fold over the next three years.

277. Given that WHO was not recommending travel restrictions in that early period I think that advice from me or any other advisor that the UK close its borders in January or February 2020 would not have been acted upon. Closing borders could have delayed the arrival of Covid-19 in the UK and elsewhere. However, I very much doubt that the pandemic could have been prevented by that means and expect that we would still have ended up living with Covid-19 as we are today,

278. I cannot comment for SAGE but I do not consider that either SPI-M-O or Scottish C19AG were made less effective by the (apparently unforeseen) need to work over a period of almost two years. In both cases, the chairs made conscious efforts to 'refresh' the committees at various points and there was a benefit to having access to the special Covid-19 expertise that the committees developed through their intense exposure to the subject.

279. I do think that in Scotland a positive working relationship of the scientific advisory committees with ministers and officials was maintained throughout, whereas this did not appear to be the case for SAGE and its subgroups. However, it is hard to argue that this disparity had any detectable impact of the course of the epidemics in England and Scotland.

280. I am concerned, however, about the quality of advice emanating from SAGE, despite the impressive expertise on that committee. The narrow focus on social distancing measures, the lack of emphasis on protecting the vulnerable in care homes and elsewhere, and the repeated advice to close schools all had a direct impact on policy, and thereby on millions of lives.

281. I am not familiar enough with the scientific advisory structures from other countries to point to better models. However, I do consider that SAGE and its subgroups put too much emphasis on consensus and too little on minority views. The most likely outcome – intended or otherwise – of only expressing a single view is that it presents policy makers with an overly limited set of options and so will channel policy decisions along a particular route.

282. For example, in the autumn of 2020 the majority view expressed by advisors was that urgent and drastic action was needed to avert a second wave. This led to an apparent stand-off between advisors calling for some kind of lockdown and government – for obvious reasons – being reluctant to impose one. Had the minority view that less drastic interventions would be sufficient if they were implemented early enough been communicated at the same time, this would have given government a more palatable option that they perhaps would have taken. That could have both saved lives and reduced the need for damaging restrictions. (I note that, in this instance, the minority view turned out to be correct, as it did with the early re-opening of schools).

283. The first level of challenge to the scientific advisory process should be scientific challenge. For epidemiological modelling an important step is to ensure that the work done by evidence-generating committees such as SPI-M-O conforms to best practice. We therefore need to agree on and adhere to best practice for epidemiological modelling. There has been in-depth work on this in the past and much of that remains applicable, though a thorough review and re-evaluation would be timely. Best practice needs to cover all of: framing of the problem; implementation; communication of the outputs, especially uncertainty and limitations. An important specific point is that there need to be explicit recommendations regarding the role of worst case scenarios and best practice for generating them.

284. To ensure that issues such as the overly pessimistic model scenarios considered by SAGE in June 2021 and again in December 2021 are not repeated in the future, I think we need a reorganisation of the UK's scientific advisory system. We need to separate evidence generation – which is what SPI-M-O was doing – from evidence evaluation and synthesis – which should have been SAGE's role. During the Covid-19 pandemic this separation was not possible because the modelling expertise on SAGE came from within SPI-M-O. In future, we need to have proper independent scrutiny of evidence from modelling (or any other source).

285. Regarding political challenge, I do think that greater clarity regarding the respective roles of the advisory committees and government (was it that 'advisors advise and ministers decide' or more a case of ministers 'following the science'?) would have made a difference to the quality of decision-making. I stated earlier that I am particularly concerned there was no concerted effort to come up with policy options that would have kept us out of lockdown. It appears that government never thought to ask that question and the advisory committees did not take the initiative to suggest answers of their own accord.

286. From my own engagement with the public it is clear that modelling outputs were sometimes misleading, sometimes misunderstood and sometimes both. For example, many people's understanding of the rationale and justification for the March 23rd lockdown was based on three misconceptions: that if we didn't lock down immediately half a million people would die; that everyone was at equal and high risk; that after a lockdown of a few weeks the epidemic would be over. Epidemiologists and modellers inside and outside the advisory system knew that these notions were untrue at the time and they should have been challenged and corrected.

287. During 2020, my objections to what I perceived as an exaggeration of the public health threat by advisors in order to stimulate action by government were not well received, even though this was stoking fear among the public (which, according to one

briefing by SPI-B, was actually considered desirable). As the pandemic progressed it became ever more apparent that, given accurate information, the public were willing and able to manage the risks to themselves and those around them. During the omicron wave in late 2021 there was high uptake of free lateral flow tests, indicating that people were anxious to know their Covid status, allowing them to adjust their behaviour accordingly.

288. Yet the public was not given accurate information in the early stages, most notably in the much repeated phrases "we are all at risk" and "the virus does not discriminate" when we already knew that the risk of Covid-19 fatality was ten thousand times higher in the over 75s than the under 15s. In the media, the BBC television news repeatedly reported rare deaths or illnesses among healthy adults as if they were the norm, again creating a misleading impression of who was at greater or lesser risk. Neither the public nor policy makers on the public's behalf can make good decisions if they do not understand or have been misinformed about where the risks truly lie.

289. The way information was communicated about the risk of vaccination was much better. The possibility of adverse outcomes from vaccination was not understated but it was put in context. The result was that vaccine uptake was in the high ninety percents for vulnerable adults, well above initial expectation. If the public could be trusted with accurate information about vaccination then surely they could have been trusted with accurate information about Covid-19.

290. From the public's perspective, I believe that modelling was viewed as forecasting. In that context the tendency by many, particularly in the media, to focus on the worst case scenario presented is understandable but misleading. One possible remedy is for all scenarios to be labelled with some assessment of their likelihood. If the worst case scenario is given a likelihood of, say, 1% it becomes considerably less alarming. Incidentally, this would also give the modellers some protection from unwarranted criticism when, as is likely, reality turns out more favourably.

291. One of the main barriers to integration of epidemiology and economics is the absence of a critical mass of scientists with experience of such collaborations. Building this critical mass would take time but the tools are well-understood: co-creation of research projects; jointly held grants; co-supervised PhD students; and co-authored publications. An adequately resourced UKRI initiative in this area would be a good start, but momentum would need to be kept up for many years.

292. A second barrier to joint working is the absence of any accepted metrics that allow loss of life, impact on health, loss of livelihoods, reduction of GDP etc. to be considered in unified framework. During the Covid-19 epidemic, the exercise that came nearest to achieving this was a report for SAGE published in July 2020 that quantified the indirect

harms of lockdown in terms of quality adjusted life years (QALYs) and included the impact of damage to the economy on this metric, e.g. through reduced future funding to the NHS. The report is provided here as Exhibit **MWO/093** **INQ000280128** This is a challenging field and it is vitally important that whatever metrics are used prove to be acceptable to policy makers. Indeed, discussions about a suitable metric with policy makers might have helped clarify the government's strategic objectives in 2020.

293. A practical lesson from the pandemic is that preparedness planning needs to involve not just DHSC and PHE but multiple other ministries and agencies, particularly the Treasury and the Department of Education. In the same vein, planning needs to recognise that we must aim to minimise not only the public health impact of the next pandemic but also the indirect harms. The possibility that our response might cause damage on a similar scale to the pandemic itself was not one explicitly acknowledged in preparedness plans prior to 2020.

Statement of Truth

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

Signed: Personal Data

Dated: 15/08/2023