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ROYAL STATISTICAL SOCIETY SUBMISSION TO THE JOINT HEALTH AND SOCIAL CARE COMMITTEE AND SCIENCE AND TECHNOLOGY COMMITTEE INQUIRY: 'CORONAVIRUS: LESSONS LEARNT"

4 December 2020

This is the Royal Statistical Society's (RSS) response to the joint inquiry held by the Health and Social Care Select Committee and the Science and Technology Select Committee into lessons to be learned from the response to the coronavirus pandemic so far.

Introduction: Covid-19 – a crisis of data collection and analysis

Statisticians and data scientists have played a vital role in the response to the Covid-19 epidemic. From the earliest attempts to understand the disease and track its progress, to the trials of the vaccines that we hope will put things right, statistics and data have been at the core of the fight against Covid-19.

But when we look back at the debate surrounding how the UK could have handled the Covid-19 epidemic better, in terms of limiting loss of life and economic damage, we find that many of the underlying issues raised relate to collection, analysis or interpretation of data. At the heart of many of the systems or communication that did not meet expectations, from Test-and-Trace to "Moonshot" as well as the Number 10 briefings, there were inadequate data systems, poorly handled data, or problems of statistical understanding.

The crisis has required the government to make decisions swiftly on the basis of data-informed forecasts, but the surveillance systems that were needed to provide these data could not be set up as quickly as necessary due to existing data architecture that was not fit for purpose and fine-grained real-time surveillance tools that were not ready for a pandemic. This has contributed to a sense that the UK was often on the back foot and making decisions based on sparse or suboptimal information.

On top of this, there are clear signs of a lack of statistical literacy in both the decision-making process and government communication of data, which has meant that apparently poor decisions were made (for example in the design of testing regimes and the procurement of tests), and data-informed decisions have been explained in a way that has not been conducive to maintaining public confidence.

The UK should have been better placed to manage the issues around the collection and analysis of data that would emerge throughout the pandemic. We lead the world in many (non-health) areas of data including the advantage of the NHS's centralised records and a strong academic base. Had robust systems for the real-time analysis of UK-wide, precisely geo-referenced NHS data been in place at the start of the pandemic, the UK's response could have been genuinely world leading. Some countries, either through more efficient testing and surveillance programmes – such as Singapore – or linking data sets to assess economic impact – such as Australia – would seem to have more effectively used statistics and data to manage their response to the pandemic.

The RSS has identified five key lessons from the pandemic:

Lesson 1: Two essentials for policy-setting and decision-making - especially during a pandemic – are: data architecture that is able to produce accurate, fine-grained data rapidly; well tested analytical tools that transform data into information.

Lesson 2: More and better integration of statistical expertise in the decision-making process could have led to better policy outcomes.

Lesson 3: When referring to data, transparency and clarity in Government communication are vital for maintaining public confidence – these are worth investing time, money and political capital in.

Lesson 4: The epidemic has underlined the importance of improving statistical literacy among politicians, journalists and the public.

Lesson 5: Data analysis and data-informed modelling is essential in managing epidemics – but the way in which government has used models to support decisions has not promoted public confidence as well as it might have done.

Our submission explains why we have drawn these conclusions and makes a series of recommendations, which are summarised at the end of the document.

Lesson 1: Two essentials for policy-setting and decision-making – especially during a pandemic – are: data architecture that is able to produce accurate, fine-grained data rapidly; and, well tested analytical tools that transform data into information

1.1. The UK's response to the pandemic has been hampered by a data-architecture that is not fit for purpose. Consequently, the UK was too slow to set up the scale of surveillance needed to gather and analyse data to enable real-time forecasting to be delivered with the required accuracy and granularity.

1.2. "Modelling'" has been much-used, typically without qualification, in communications about the present and possible future states of the epidemic. However, an important distinction is between *mathematical* and *statistical* models.

1.3. Mathematical models are informed by data, but also incorporate biologically informed assumptions about the disease transmission process that allow them to estimate non-observable transmission characteristics such as the R-number and to make predictions even when data are sparse. Statistical models are data-driven, avoid mechanistic assumptions and, given sufficient volume and quality of data, are able to make predictions that take account of less tangible features of an epidemic such as the vagaries of human behaviour in response to government advice or directives.

1.4. Elements of mathematical and statistical modelling can and should be used in combination. Mathematical modelling plays a particularly crucial role at the beginning of an epidemic episode in providing a range of future scenarios to government. As surveillance data from multiple sources (eg, hospital presentations, test results, randomised surveys) become more abundant, the outputs from empirical statistical models become increasingly informative. Good data architecture and well tested analysis tools enables statistical models to be made operational at pace, providing a data driven evaluation of the changing state of the epidemic to policy makers.

1.5. At the start of the pandemic in early February 2020 the UK Government had epidemiological evidence coming from China of sustained person-to-person transmission of SARS-CoV-2. Evidence on main transmission routes – on characteristics of the transmission dynamics and on case fatality ratios, informed by data mostly coming from China – were presented to Government by its Scientific Advisory Group in Emergencies (SAGE) during February. As soon as it was known that some of the characteristics of the transmission dynamics were markedly different from previous viruses, such as the probability of pre-symptomatic and asymptomatic transmission, it was clear that large-scale active surveillance and data collection programmes were necessary to inform about the spread of the virus. This is made clear in the SPI-M-O Consensus Statement on Covid-19 from 2 March.

1.6. There are structural challenges for statisticians working with the UK's data architecture. First, because health and social care data in the UK is devolved and a variety of organisations produce data – each of the four nations of the UK has data collection split between its government, NHS, civil registration agency and public health body – coherent UK-wide data requires a level of collaboration and communication which is difficult at the best of times, and harder still in the pressure of an epidemic. In addition, the different demands of each devolved administration mean that data and analytics tend to be focussed on their own needs rather than on the UK as a whole.

1.7. Second, in England, NHS England and its data collection function have been fragmented into multiple agencies. The Office for Statistics Regulation (OSR) published a systemic review of health and social care statistics in England in 2015 and concluded that "there was no single individual or organisation with clear leadership responsibility and this had led to problems with the coherence and accessibility of these statistics". Despite some improvement, we believe problems still exist.

1.8. Because of this fragmentation in England, statisticians and data analysts are spread throughout the health system and there is a shortage of statisticians centrally in the Department for Health and Social Care (DHSC), where they were needed to pull together data from this disparate array of sources. The situation has been better in

Scotland, where the vast majority of health statistics relating to COVID-19 are produced by Public Health Scotland (formerly ISD (Information Services Division) Scotland and Health Protection Scotland).

1.9. Government statisticians have worked intensely and under pressure during the pandemic – but this work has been made harder by these structural problems with the UK's data architecture. In 2016, the Bean Review of economic statistics recommended that the Office for National Statistics (ONS) should "move away from focusing largely on the production of statistics and become more of a service provider, helping users answer their questions about the economy" (p.10). While this review focused on economic statistics, many of its findings could equally have been applied to health statistics. We believe that a similar review into health statistics, building on the OSR's review of English health data, is essential and urgent.

1.10. In addition to these challenges with the large-scale data infrastructure, there are specific data issues that are worth highlighting:

1.10.1. *Delay in death registration* when cases are referred to the Coroner. In Scotland, fact-of-death must be registered within 8 days of death having been ascertained, whereas in the remainder of the UK when deaths are referred to the Coroner for the fact of death is not registered with the Office for National Statistics (ONS) until cause of death has been determined – in some cases, months later than they have occurred. This has prevented a timely count of the occurrence of deaths caused by Covid-19. The problem was particularly acute for health and social care workers, especially in the first wave of the virus, who were on the frontline of responding to the disease and were, therefore, more likely to have been exposed to it unknowingly.

1.10.2. *Record-linkage* (the process of joining-up data relating to an individual) in the context of health data is important to ensure that the best possible data is used in modelling. It prevents double-counting, helps identify under-reporting and is a vital part of a functioning surveillance system. Pre-epidemic, record-linkage permissions had not been established and this has played a role in slowing the establishment of a suitable surveillance system.

1.11. These issues with the UK's health data, combined with a lack of preparedness in having an operational blue print for pandemic surveillance ready to be implemented, meant that when the SARS-CoV-2 pandemic came, the government was not in a position to swiftly roll out or even establish a well-functioning surveillance system. This in turn delayed the availability of data to build statistical models with accurate estimates on the spread of the virus, making it difficult for the Government to adapt its policy in good time.

1.12. As it was, surveillance has ultimately been provided by The ONS Covid-19 Infection Survey and Imperial's REACT programme. Both were designed in remarkably quick time in the circumstances, with fieldwork begun in May and June 2020. However, had the UK's data infrastructure and surveillance analysis tools been ready at the start, integration of these programmes with other sources of data on the state of the epidemic would have been able to get up to speed more promptly and to inform decisions in a more timely manner. It is imperative that, after the epidemic has subsided, the Joint Biosecurity Centre will continue to improve the data pipeline and associated statistical tools to ensure that it is ready for any future pandemic.

Recommendation 1. A formal government review, analogous to the Bean review of economic statistics, should be conducted into the UK's health data to ensure that a well-functioning system is established at the earliest opportunity.

Recommendation 2. Adaptable surveillance-focused statistical models and analysis tools able to integrate different data feeds should be developed and robustly evaluated as part of a blueprint for epidemic preparedness.

Lesson 2: More and better integration of statistical expertise in the decision-making process could have led to better policy outcomes

2.1. There are two aspects of the pandemic where it seems that a lack of statistical expertise in the decision-making have particularly contributed towards poor policy outcomes: rapid testing and Test and Trace. This is not a case of being wise after the fact: statistical issues in these areas have been clear for many months and have been

consistently raised by the RSS. Better understanding of the collection and management of data could have significantly improved the UK's response to Covid-19.

Test and Trace

2.2. Given that Test and Trace was entirely rebuilt after it stopped functioning mid-March, the new system had the potential to be a great asset in tackling Covid-19: the programme gave the Department of Health and Social Care (DHSC) access to a rich source of information that, properly utilised, could have dramatically improved our understanding of how to reduce transmission of the virus.

2.3. The statistician team at DHSC who were charged with producing official statistics on Test and Trace, did not have sufficient input into the design or inter-operability of the data-collection systems used. There was little thought given as to how data could be used to help answer important infection control questions. Instead, a commercial-style operational design was favoured.

2.4. As a result, Test and Trace failed the most basic requirements of any infection control operation, namely to learn about: who is infected; how early they became antigen-positive; whether this is with or without symptoms; and whether quarantining asymptomatic close contacts of people who have tested antigen-positive is necessary and effective.

2.5. In July, the RSS released a statement suggesting ways that Test and Trace could use two key statistical methods – record-linkage and random sampling – to learn about transmission of the virus. In this context record-linkage means Test and Trace using its records to find out how many of the quarantined persons in each high-risk group tested positive for the virus during (or soon after) their quarantine period. Random sampling ensures that sub-samples are representative of the whole. These methods would have allowed the government to establish the proportion of high-risk individuals who developed symptoms and tested positive for the virus during or soon after the end of their quarantine period and to assess the level of infection, with or without prior symptoms, among those who are self-isolating, both of which would have provided vital information for controlling the virus. The record-linkage step was accomplished in September, yet results were unpublished by the end of November 2020.

Poor understanding of the regime for test validation has compromised "Operation Moonshot"

2.6. When news of "Operation Moonshot" was first briefed to the media, the RSS wrote a letter to the *Times* setting out some concerns with the plan to test millions of people daily for Covid-19. A particular concern was that the plan seemed to depend on the availability of tests that were extremely accurate – more accurate than those currently available for any other disease.

2.7. There are harms associated with testing when they miss or wrongly diagnose cases: false negatives risk infectious people spreading the virus – which is especially problematic given that we know the pandemic has been driven by super-spreading events – and false positives risk causing personal and economic harm as people needlessly self-isolate. Even if a test returns only 1-2% of false positive or false negatives – which would be very good by the standards of these tests – when millions of people a day are being tested that is potentially tens of thousands of people being misdiagnosed. At the time we called for transparency about the tests and their use to enable broad discussion with experts and reach consensus and understanding on the balance of risks. There are relatively simple ways to drive down the false positives by using repeated testing, which are rarely articulated when presenting plans for mass testing.

2.8. Over time, more information about the new rapid tests that would enable mass testing programmes has become available. The RSS has stressed the importance of ensuring that tests which are intended to be used on asymptomatic people are trialled on asymptomatic people before they are rolled-out widely. We remain concerned about whether this is happening.

2.9. The pilot programme of mass asymptomatic serial testing in Liverpool is being interpreted as successful in enabling the city to move from tier 3 to tier 2 – however, it remains vital that the evidence behind the efficacy of these rapid tests be considered before they are used to give people the sense that they do not still need to adhere to restrictions such as social distancing. There are several limitations in the evidence that we have seen for rapid tests that would make them unsuitable for screening asymptomatic people, e.g.: the test may have been validated on samples from patients in hospital, who have symptoms; the diagnosis of the sample may have first been

confirmed by at least one other test; the test may have been validated to use only on samples that were taken within a certain number of days of symptoms; a large quantity of samples may have been taken from a small number of patients; the sub-set of the population who presented for testing may not have been representative of the variation in risk and exposure for the complete population.

2.10. In the case of the tests used in Liverpool, a recent PHE study does not provide enough evidence to warrant confidence in the idea that negative results rule out infection. The test's instructions for use explicitly state: "Negative results do not rule out SARS-CoV-2 infection and should not be used as the sole basis for treatment or patient management decisions, including infection control decisions." Lateral flow tests, such as this test, only come back positive when viral levels are very high, they miss people who never have such high levels or only reach that level for a couple of days. While it is reasonable to hypothesis that detectability would correlate with infectiousness, we do not yet know how reliable this correlation is: so, any strategy for releasing people based on this type of test needs to be i) carefully designed, based on an understanding of viral dynamics and ii) tested rigorously in the intended context-of-use.

2.11. Indeed, the figures released so far in the Government's Community Testing guidance includes concerning information about the number of false positives: "In the field evaluation in Liverpool, compared to PCR tests, these tests picked up 5 out of 10 of the cases PCR detected and more than 7 out of 10 cases with higher viral loads, who are likely to be the most infectious". Meaning that around 50% of infections are missed, and around 30% in the case of high viral loads. It is difficult to fully interpret this information without access to the background data – but on the face of it, this raises important questions about whether the mass testing programme can work.

2.12. This is an area where it is essential to have statisticians involved in study-design, in analysis of the data and in the decision-making process: through transparently releasing studies and the lessons from the pilot in Liverpool so that they can be properly assessed; and by ensuring that the right expertise is involved in the decision-making process. Doing this correctly could lead to a screening programme that had a chance to bring benefits; not doing so could lead to the virus spreading again.

Linking data sets

2.13. The potential for improving decision-making also extends to the Government's economic response to the epidemic. Statistical innovations in Australia and New Zealand have helped their governments understand and manage the economy impact of Covid-19; the UK's lack of equivalent systems made it harder for the Government to understand and mitigate the effect of lockdown on the economy.

2.14. Both Australia and New Zealand made significant investments in linking enterprise data and employee data, which allowed them to rapidly understand the economic impact of lockdown, and the benefits of interventions like the Jobkeeper programme – the Australian analogue of the furlough scheme. Australia went so far as to amend their Tax Administration Act when they passed the Jobkeeper legislation, giving government emergency powers to link tax data and other economic data sets for analysis, leading to more informed decisions that took into account both health and economic factors.

The importance of statistics

2.15. These examples demonstrate the importance of involving people with statistical skills in the decision-making process and in the design of programmes that rely heavily on data. Programmes would then be more likely to achieve their aims and do so more cost-effectively. Statistical innovations that can improve the quality of information available are also more likely to be used if people with statistical skills, who understand the potential power of the information, are better represented in the most senior ranks of government.

Recommendation 3. Before new diagnostic tests are used as part of a public health strategy they need to be trialled for their intended purpose. Manufacturers should openly release the studies that support their marketing claims so that the accuracy of tests can be thoroughly quantified, and their utility assessed before they go into general use. Data should be published and decisions, including what money has been spent, should be explained.

Recommendation 4. Producers of official statistics and those with understanding of experimental design should have input into the design of data collection.

Recommendation 5. People with data and statistical skills should be given more support to move to leadership positions within the civil service – particularly to positions outside the Government Statistics Service.

Lesson 3: When referring to data, transparency and clarity in Government communication are vital for maintaining public confidence – these are worth investing time, money and political capital in

3.1. Throughout the epidemic there has been a steady decline in confidence in the government's handling of the crisis.[1] While this cannot solely be explained by a lack of transparency around statistics and how they have informed decision-making, we believe that this is an important part of the story.

3.2. Several examples from the past year demonstrate how a lack of transparency can lead to a deterioration in trust:

3.2.1. At the start of the epidemic, too much prominence was given to daily figures which were artificially high or low on different days of the week and were either out of date – in the case of deaths – or biased by variable testing effort – in the case of incidence rates. There was little to no effort made in government communication to explain the uncertainties in this information or to be transparent around what information was missing from the figures.

3.2.2. Until 11 May, the government was insistent that face masks were ineffective for stopping the spread of the virus. In truth, masks were thought likely to be effective but there was some uncertainty about how effective they would be. This is an area where the evidence has strengthened throughout the epidemic, but government advice did not respond in a timely manner. By not being transparent about the evolving strength of evidence around face masks and expressing false confidence at an early stage that they were ineffective, the government made it harder at a later stage to persuade people who were reluctant to wear face masks.

3.2.3. The UK Government has only recently – on 26 November – explained which data will be considered when allocating local regions of England to a specific tier. The lack of a clear data-informed framework for assigning regions to tiers led to engagements with local decision-makers (notably in the case of Manchester) becoming more politicised than necessary. It is clear, in the case of Manchester, that public confidence in the handling of the crisis is especially low.[2]

3.2.4. When making the case for a second lockdown, a slide showing projections of deaths from different models was not only based on reports by SPI-M that were not available on October 31, but also used working analyses and scenarios dating from the week beginning October 9th without explaining their context and intended purpose. This was especially problematic since more recent data-driven forecasts were available to describe the upward trend supporting the decision of a second lockdown. This misleading presentation of modelling results was repeated in the briefing pack given to MPs ahead of the vote on new regulations on 4 November. By presenting the results in this way, the government left room for people who were sceptical of a second lockdown to – justifiably – criticise the models that were claimed to be informing its decision. This is one example of what has been a common problem: the use of poor-quality slides that have key information missing.

3.3. Public confidence is ultimately built on trust – and for the public to trust government communication of statistics, government spokespeople must demonstrate trustworthiness.[3] Key to this is that when the government announces new or changing rules, it should present information that is intended to inform rather than to persuade. This means, among other things:

3.3.1. Publishing all relevant data whenever a decision is made, clearly signposting this to the public and enabling people to explore it for themselves.

[1] The YouGov tracker has this falling from a high of 72% of people who think that the government is handling the crisis very or somewhat well on 27 March to a low of 30% on September 16.
[2] A YouGov survey on 4 November has only 21% of people in Manchester thinking that the government is managing the spread of the virus in Greater Manchester well or very well.
[3] This has been set out in detail by the co-chair of the RSS Covid-19 Task Force, David Spiegelhalter, and colleagues in an article for Nature, *Five rules for evidence communication*.

3.3.2. Presenting the balance of evidence and, crucially, avoiding partial presentation of evidence.
3.3.3. Being clear on the quality of evidence supporting a decision and open about its associated uncertainty.

3.4. The model of communication that Lord Krebs adopted when appointed as head of the Food Standards Agency was: say what you know; what you don't know; what you are doing to find out; what people can do in the meantime to be on the safe side; and that advice will change. Combined with publishing all the data and models that have been produced to enable government decision-making, this forms a sound basis for clearly and transparently communicating information in a manner that is likely to build trust.

3.5. Communicating in this way is difficult and requires a detailed understanding of the evidence and well-informed confidence in responding to questioning. It is difficult to expect politicians to be able to do this. We recommend that a mechanism is introduced to ensure independent and non-political communication of data – such as a weekly briefing to journalists by the national statistician, chief medical officer or chief scientific officer or their colleagues.

3.6. We also note that the OSR has played an important role in pressing for greater transparency around the data used to make decisions – including a recent statement in which they set out what the government should consistently do to promote transparency. We are strongly supportive of the OSR's work in this area and believe that the epidemic has shown the importance of having a strong statistics regulator to ensure that statistics are used for the public good. The OSR, however, remains a small team. We believe that their resources should be increased to allow them to be more proactive. We also believe that the OSR's ability to influence is limited by their lack of power – they can urge action but do little else. This also needs change.

3.7. We acknowledge that the Government has been improving the transparency of its communication throughout the epidemic. The recent move to indicate the data that will be used to inform decisions about tiers is welcome, although more of this data should be made easily available and the framework for decision-making should be explicit. There are also examples of good practice – such as Public Health England providing an API to allow easy access to its data.

Recommendation 6. A mechanism should be introduced to ensure independent and non-political communication of data – such as a weekly briefing to journalists by the national statistician, chief medical officer or chief scientific officer.
Recommendation 7. A considerable strengthening of the Office of Statistics Regulation is needed: increasing its resources to a level at which it can proactively identify issues with the production of statistics; and reviewing its powers to establish if there is a case for strengthening them.

Lesson 4: The epidemic has underlined the importance of improving statistical literacy among politicians, journalists and the public

4.1. For politicians, statistical literacy is important because it helps them to understand and interpret the advice they are given. An understanding of how mathematical and statistical models are generated, what is the difference between a random sample and observational data, what is meant by underlying prevalence, and how uncertainty is measured are important first steps before political judgement can be applied and decisions made. Similarly, a solid understanding of specific statistical concepts related to testing, for exampl – eg, the distinction between sensitivity and specificity and the notions of false positives, false negatives, predictive positive value, should inform specific decisions about procurement. Statistical literacy is also helpful, as suggested in §3, for politicians in allowing them to communicate a public health message clearly and confidently – especially when risk and uncertainty are at the heart of the message.

4.2. Statistically literate journalists have played an important role in the epidemic, helped hugely by the Science Media Centre. A number of RSS Fellows have engaged regularly and successfully with journalists, helping them to understand the data well enough to offer accurate explanations to the public. Specialist journalists – health or science and technology correspondents – have been generally very good at reporting data accurately, including graphically.

4.3. Political journalists, who tended to be the ones invited to ask questions at the daily briefings, often did not ask the sort of incisive question about data that could have been helpful (though the format of the briefings did not really lend itself to that in any case). This is, perhaps, in part because they are less comfortable in quickly identifying issues in the presentation of data but may also have been because they were more interested in political issues. For example, in the early stages of the pandemic the death figures that were being reported in the daily briefings were actually the number of deaths reported on a given day in a hospital setting. It would have been beneficial to have this clearly brought out through questioning.

4.4. For the public, the epidemic has demonstrated the importance of being able to engage with and understand data. Public understanding has been important both for navigating a sometimes-confusing mass of information about the pandemic, including misinformation on various topics, and for understanding how to manage personal risk. The importance of this is underlined by evidence that the greatest predictor of a person's resilience to fake news about Covid is their level of numeracy.[4]

4.5. Even for data-literate members of the public, it has not been straightforward to find information about the epidemic from official sources. It is difficult to say why this is the case – it could be a lack of political will, failure on behalf of aspects of the Government Statistical Service or a combination of the two. The cause of these problems should be identified, and improvement prioritised as part of our preparations for future pandemics.

4.6. Improving statistical literacy is fundamentally an educational issue. Statistics impacts on almost every subject and we believe statistical skills should be taught in a wide range of subjects at school level rather than restricted solely to mathematics. A similar problem is evident at university level, where students of, for example, social science subjects and journalism receive very little statistical training. In part, the problem is that teachers of non-science subject lack the confidence to teach statistical aspects of their courses. A potential intervention is to upskill these teachers at university and school level to enable statistical skills to be taught more widely.

4.7. Civil society data organisations have also come into their own in the pandemic. For example, the fact-checking charity Full Fact performed a vital service by clarifying and correcting a large number of misleading claims about statistics coming from both government and the media. The *Our World in Data* project provided valuable and timely international Covid data. Statistical mistakes are for the most part likely to be caused by journalists, civil servants and politicians lacking experience of critically engaging with data and having to operate at pace, rather than through any attempts to mislead. Until there is greater statistical literacy among their ranks – and OSR is substantially strengthened in order to perform more of this function – organisations that perform a fact-checking service and that provide accessible, accurate data to the general public should be encouraged and supported.

Recommendation 8. Statistics and data skills should be taught more widely, reaching beyond mathematics at school, college and university level – especially in social sciences and journalism.

Recommendation 9. Charities, fact-checkers and others providing a valuable service by collating good data and challenging misuse of data by government and the media should be supported.

Lesson 5: Data analysis and data-informed modelling is essential in managing epidemics – but the way in which government has used models to support decisions has not promoted public confidence

5.1. Data analysis and data-informed mathematical modelling has been central to the response to the pandemic and has generally been used to good effect. As explained in section 1, mathematical modelling of transmission is important because it enables evidence-informed decisions at an early stage, whereas empirical statistical models have more to offer when surveillance provides more abundant data and there is a need to integrate multiple data sources. The accuracy of any of the models, of course, depends on having good data as an input – which is why, as detailed in §1, a well-established surveillance programme could have improved the performance of predictions made from mathematical models.

5.2. Faced in the early phase with sparse information and data on the essential characteristics of Covid-19 infection, the SPI-M subgroup of Scientific Advisory Group in Emergencies (SAGE) was nevertheless able to quickly adapt its infectious disease modelling, which was based on modelling flu, to apply it to the SARS-Cov2

[4] Rozenbeek et al, *Susceptibility to misinformation about COVID-19 around the world*

virus and provide the government with timely projection scenarios for hospitalisations and fatalities were available in early March 2020 to the government.

5.3. During an epidemic, both mathematical and statistical models can be best used for short-term forecasting (of the order of 2-4 weeks): for longer lead-times, they struggle to account for how people react behaviourally to the changing situation and policy recommendations on, for example, social distancing. Teams of academics will typically generate a range of models whose outputs, including short term forecasts, are subsequently synthesised by SAGE. Models on their own do not tell government what should be done. For example, government cannot make a lockdown decision by looking solely at the scientific advice based on mathematical models of Covid-19 outcomes – any decision that affects the whole of society has to take into account much broader criteria, which is why it is the job of politicians, not scientists, to make those decisions.

5.4. Particularly in the early stage of the epidemic the government's rhetoric of "following the science" was not helpful in clarifying the distinction between scientific advice and government decision-making. This is another area where transparency is important: it should be made clear what advice the government is receiving and what other considerations are being brought into the decision-making process. It is perfectly reasonable for government to act in a manner that is not determined by scientific advice, but the reason for this should be explained.

5.5. There has also been a problem throughout this epidemic – as there was during swine-flu – with the use of reasonable worst-case scenarios for public communication. These scenarios should be used for operational planning: that is, things like how many body bags may be needed in the worst-case scenario. Yet, the worst-case scenario may have been already ruled out (as in swine-flu) but continues to be used to paint a bleak picture. It is difficult to ascribe motive, but they seem to have been used as if to make what has actually happened seem less negative, or to justify unpalatable policies.

5.6. For example, at the start of the pandemic the public was repeatedly told that up to 500,000 deaths could occur and the government spokespeople would regularly compare current death figures to the reasonable worst case, despite the fact that the mathematical models on which that figure was based assumed that the government took no action whatsoever. Later, in the briefing ahead of the second national lockdown, it was claimed that deaths could reach 4,000 per day – which again was based on the idea that the government took no action. When extreme scenarios are used, there needs to be a clear distinction between such scenarios and forecasts of plausible futures – scenarios should only be presented as an ensemble and the full range should be commented on.

Recommendation 10. Worst case scenarios should not be used in public communication unless as part of a range of scenarios. Scenarios and short-term forecasts should be clearly distinguished in public communication.

Recommendations

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Recommendation 6.	A mechanism should be introduced to ensure independent and non-political communication of data – such as a weekly briefing to journalists by the national statistician, chief medical officer or chief scientific officer.
Recommendation 7.	A considerable strengthening of the Office of Statistics Regulation is needed: increasing its resources to a level at which it can proactively identify issues with the production of statistics; and reviewing its powers to establish if there is a case for strengthening them.
Recommendation 8.	Statistics and data skills should be taught more widely, reaching beyond mathematics at school, college and university level – especially in social sciences and journalism.
Recommendation 9.	Charities, fact-checkers and others providing a valuable service by collating good data and challenging misuse of data by government and the media should be supported.
Recommendation 10.	Worst case scenarios should not be used in public communication unless as part of a range of scenarios. Scenarios and short-term forecasts should be clearly distinguished in public communication.