Witness Name: Adam Kucharski
Statement No.: 1
Exhibits: [AK/01 – 104]
Dated: [30 April 2025]

UK COVID-19 INQUIRY

WITNESS STATEMENT OF ADAM KUCHARSKI

I, Adam Kucharski, will say as follows: -

1. I make this statement in response to a request from the UK COVID-19 Inquiry dated 28 November 2024 under Rule 9 of the Inquiry Rules 2006, asking for a witness statement relating to Module 7 of the Inquiry, which I understand will examine the approach to testing, tracing and isolation (TTI) adopted during the pandemic in England, Wales, Scotland and Northern Ireland from 1 January 2020 to 28 June 2022.

Introduction

2. I am currently a Professor of Infectious Disease Epidemiology (2021–) and Co-Director of the Centre for Epidemic Preparedness and Response (2022–) at the London School of Hygiene & Tropical Medicine (LSHTM). From 2013–17, I held a Medical Research Council Strategic Skills Fellowship at LSHTM, and from 2017–23, a Wellcome Sir Henry Dale Fellowship. I have a MMath from the University of Warwick and a PhD in Applied Mathematics from the University of Cambridge. During 2012-13 I was a research associate in the Department of Infectious Disease Epidemiology at Imperial College London.

3. Pre-COVID, I was involved in several research studies relating to TTI. These included: measuring social contact patterns **(AK/01 - INQ000562900; AK/02 - INQ000562990)** and their relation to infection status **(AK/03 - INQ000562963)**; prospective analysis of the effectiveness of isolation **(AK/04 - INQ000562894)** and contact tracing **(AK/05 -**

INQ000562896) for Ebola; retrospective analysis of isolation strategies for Ebola **(AK/06 - INQ000562895; AK/07 - INQ000562898)**, as well as ring vaccination using an adapted contact tracing protocol **(AK/08 - INQ000562899)** for Ebola; and analysis of travel screening measures for emerging pathogens **(AK/09 - INQ000562893)**. I contributed evidence on contact tracing and vaccination to the Working Group on Ebola Vaccines and Vaccination for the WHO Strategic Advisory Group of Experts on Immunization (SAGE), as well as collaborating on epidemic response research relating to isolation strategies with organisations including Save the Children, Medecins Sans Frontières and UNICEF. I also published several papers related to TTI during the COVID-19 pandemic **(AK/10 - INQ000255418; AK/11 - INQ000562975; AK/12 - INQ000562942; AK/13 - INQ000562957; AK/14 - INQ000255419; AK/15 - INQ000562962; AK/16 - INQ000562968; AK/17 - INQ000562974)**, which have been cited thousands of times. This included analysis of TTI in the UK and Singapore.

Membership of groups during the period of January 2020 to 28 June 2022

4. During the period of January 2020 to 28 June 2022 I was a member of several scientific groups.

Scientific Pandemic Influenza Group on Modelling, Operational sub-group (SPI-M-O)

5. My initial involvement in SPI-M-O was via colleagues at LSHTM, who had pre-COVID involvement in the Scientific Pandemic Infections group on Modelling (SPI-M) as well as with SPI-M-O/SAGE for COVID. I attended SPI-M-O meetings on 26 February 2020, 16 March 2020 and 20 April 2020. As the scope of my contributions grew, I participated in meetings more regularly from June 2020 to February 2022. I was on parental leave for all of November and December 2021, and did not attend any meetings during this period. Overall I attended 69 main meetings between Feb 2020 and February 2022, as well as a number of ad-hoc discussions and subgroup meetings.

6. I made three main types of contributions as a participant:

   6.1. Submitted reports in response to specific questions from the Secretariat;

6.2. Submitted reports or preliminary results detailing broader epidemiological insights about COVID-19 my colleagues and I thought were noteworthy; and

6.3. Contributed to discussions during meetings, including sharing recent insights and literature from wider sources.

7. I contributed a number of reports for SPI-M-O relating to TTI **(AK/18 - INQ000148836; AK/19 - INQ000562907; AK/20 - INQ000206672; AK/21 - INQ000206673; AK/22 - INQ000562913; AK/23 - INQ000422073; AK/24 - INQ000562918; AK/25 - INQ000562925; AK/26 - INQ000562931; AK/27 - INQ000562932; AK/28 - INQ000422266; AK/29 - INQ000562985)**.

8. I also contributed two specific reports for SPI-M-O/SAGE relating to TTI **(AK/30 INQ000092694; AK/31 - INQ000562945)**.

SAGE

9. I attended SAGE on 18 June 2020 and 13 May 2021. The first invitation to participate came via my membership of the International Best Practice Advisory Group, in the context of presenting discussion of superspreading analysis I had been involved with **(AK/32 – INQ000562988)**. The second invitation was to present my analysis of the Delta variant, following my presentation at the SPI-M-O meeting the previous day **(AK/33 - INQ000387144)**.

Other SAGE subgroups

10. I was invited to join the Task and Finish Group on Mass Testing by the SAGE Secretariat. I attended around three meetings and coordinated the drafting of the epidemiological component of the report to SAGE in August 2020 **(AK/34 - INQ000371699)**.

11. I was invited by the SAGE Secretariat to join a group convened to work on a Department for Culture, Media and Sport commission during February to March 2021

for a science framework for opening up group events. I attended one meeting and contributed a number of comments on the draft report **(AK/35 - INQ000137650)**.

Other UK advisory groups

12. I was invited to join the International Best Practice Advisory Group (IBPAG) by the Cabinet Office and attended at least 30 meetings between May 2020 and Jan 2022 (**AK/36 - INQ000562989)**.

13. Unlike SPI-M-O. I did not produce new analysis for consideration at IBPAG meetings. Instead, I provided scientific feedback on draft reports shared by the International Comparators Joint Unit (ICJU), as well as highlighting new publicly available sources of evidence – both from our group and others – in meetings and on email chains. This included analysis and discussion of mass testing, contact tracing, and backwards tracing in locations such as Iceland, Japan, South Korea, and Slovakia.

Testing technologies

14. During a pandemic, testing is most meaningful when it informs action. There were three main applications of testing technologies in the UK during the COVID pandemic:

Understanding infection dynamics within the population to inform planning and control

14.1. This included: testing of all symptomatic cases in the community from May 2020; the Office for National Statistics and Real-time Assessment of Community Transmission infection surveys from May 2020 onwards (which tested a random sample of individuals regardless of symptoms); COVID-19 Genomics UK that sequenced and analysed SARS-CoV-2 genomes from the early stages of the pandemic; and analysis of contact tracing data. These datasets were used for several purposes, including estimating changes in transmission (i.e. the R number) and understanding the population-level spread of variants of concern **(AK/37 - INQ000562941)** and differences in individual-level transmission risk **(AK/38 - INQ000562981; AK/39 - INQ000120626)**.

Understanding individual infection status to inform individual treatment

14.2. During the pandemic, diagnostic testing was used in healthcare to enable identification of SARS-CoV-2 infections in symptomatic individuals, and hence guide treatment. This testing also enabled large numbers of patients to be enrolled in platform trials such as RECOVERY, to evaluate potential therapeutics **(AK/40 - INQ000562920)**.

Understanding individual infection status to inform population control

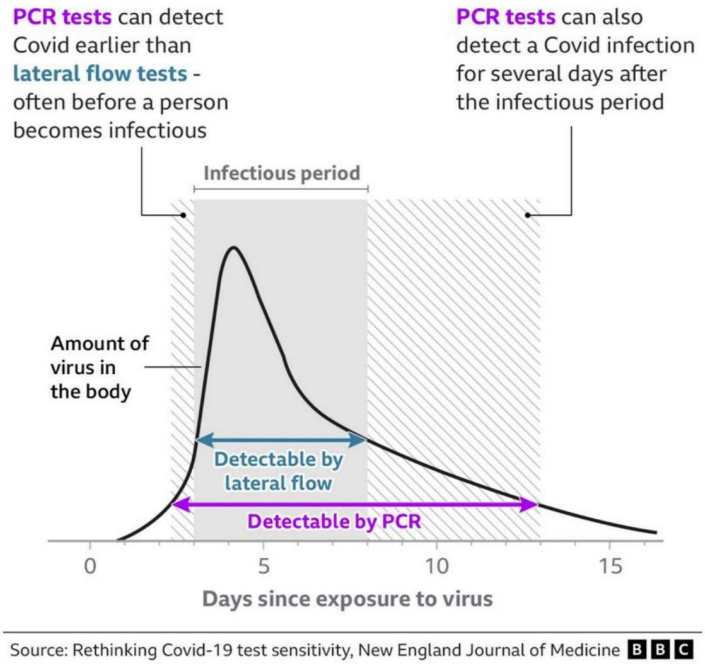
14.3. During the pandemic, testing was linked with isolation, contact tracing, and quarantine in an effort to reduce transmission in the population. Specific strategies used will be discussed in more detail in the following sections.

15. Two main types of tests were used in the UK during the pandemic: molecular tests, which detect the genetic material of the SARS-CoV-2 virus; and antigen tests, which detect protein(s) in the virus. The most used molecular test in the UK was the reverse transcription polymerase chain reaction (PCR) test. Depending on the amount of virus genetic material in the body, PCR could detect the virus from a couple of days post infection to several weeks afterwards **(AK/17 - INQ000562974; AK/12 - INQ000562942)**. Our analysis suggested not all infections were detectable with PCR, even with frequent testing. We estimated that among individuals with evidence of SARS-CoV-2 infection based on an increase in antibodies, there was just under an 80% probability of testing PCR positive by a self-test at the point where viral shedding was on average highest post-infection **(AK/12 - INQ000562942)**.

16. As well as detecting the virus, over 2 million PCR samples were sequenced in the UK to identify the infecting variant up to March 2022 **(AK/41 - INQ000562956)**. By chance, one of the key mutations in the Alpha variant, and the later Omicron variant, resulted in commonly used UK PCRs tests being unable to recognize one of the three 'target' genes used to identify SARS-CoV-2. These 'S-gene target failures' allowed faster analysis of variant dynamics in real-time, because samples did not have to be sequenced to distinguish between old and new variants; instead, the test results that only recognized two out of the three targets could be used as a proxy for Alpha infections **(AK/37 - INQ000562941)**.

17. Because PCR testing requires laboratory equipment, results in the UK took hours, if not days: in June 2020, hospital-based testing in National Health Service (NHS) pathology laboratories – which was at the fastest end of the scale – had an average turnaround time of 14 hours **(AK/42 - INQ000562977)**. Alternative molecular testing methods such as loop-mediated isothermal amplification (LAMP), which offered faster results, were piloted for NHS staff and asymptomatic testing **(AK/43 - INQ000562935)** but ultimately not deployed as widely as the more established PCR.

Figure 1: Comparison of PCR and LFT detection **(AK/44 - INQ000562952)**. *BBC adaptation shown for conceptual clarity*



18. The most used antigen test in the UK was a lateral flow test (LFT). Unlike PCR, which can detect lower amounts of virus, LFTs are more likely to detect individuals shedding higher amounts of virus, and hence more likely to be infectious. Comparisons of LFT results with detection of infectious virus found that LFTs identified over 90% of positive samples with viable virus **(AK/45 - INQ000562955)**, indicating the LFTs were likely to detect the most infectious individuals. Around 1.7 billion LFTs were distributed in the UK up to January 2022 **(AK/46 - INQ000562953)**. Because LFTs could be self-administered, with results in around 15 minutes, they offered a faster and cheaper

alternative to PCR, making strategies involving repeat testing more feasible **(AK/47 - INQ000562928)**.

19. A key conceptual challenge throughout the pandemic was that test performance was often framed around detection relative to PCR. For example, single values were quoted for the 'clinical sensitivity' **(AK/48 - INQ000562950)** of an LFT. However, this framing assumes individual tests are being used to inform individual outcomes, i.e. [14.2] above, rather than population-level control, i.e. [14.3] above. As Michael Mina et al stated: 'The key question is not how well molecules can be detected in a single sample but how effectively infections can be detected in a population by the repeated use of a given test as part of an overall testing strategy' **(AK/49 - INQ000268293)**.

TTI Strategies

20. During the pandemic, 'self-isolation' was used to refer to keeping both cases and their contacts away from other individuals. I understand the desire for simplicity in public messaging, but throughout this statement I will use the epidemiological definitions for clarity: 'isolation' refers to someone known to be infected and 'quarantine' refers to someone suspected to be infected (who may later be isolated if infection is confirmed).

21. A TTI system involves identifying infected individuals (i.e. 'cases') so they can be isolated, then identifying others who they have potentially infected (i.e. 'contacts') so these individuals can be quarantined. If cases are isolated later in their infectious period, or infected contacts are quarantined later in their infectious period, the TTI system will have less impact on reducing onwards transmission in the population. We can therefore think of TTI as a 'leaky pipe': each step that is missed, or delayed, reduces its impact on transmission. A combined intervention is therefore crucial to ensure as few 'leaks' (i.e. transmission events outside isolation and quarantine) as possible.

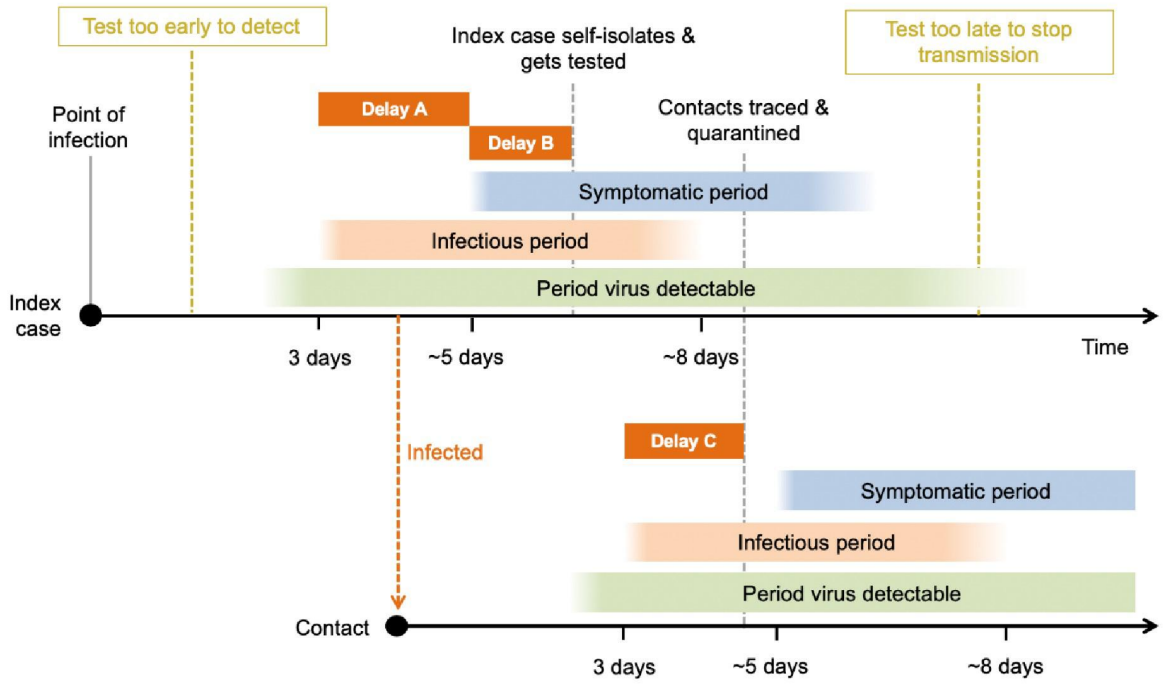
22. The effectiveness of a TTI system depends strongly on three key steps (illustrated in Figure 1):

22.1. delay between a case becoming infectious and becoming symptomatic (or otherwise showing evidence of infection), as well as the proportion of infected individuals that become symptomatic;

22.2. delay between a case becoming symptomatic and entering isolation, as well as the proportion that isolate;

22.3. delay between an infected contact becoming infectious and entering quarantine, as well as proportion that quarantine

Figure 2: Timeline of transmission and key delays in a test and trace system, with average epidemiological timeline for COVID-19 **(AK/25 - INQ000562925)**

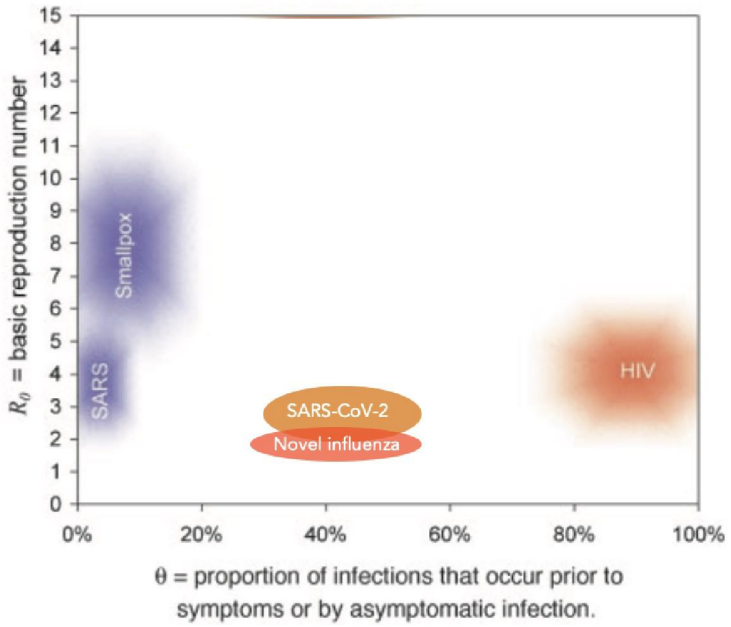


23. The size of these windows for action, and hence effort required for control, will depend on the characteristics of a pathogen. For infections where most transmission happens after the appearance of symptoms, such as SARS-CoV-1 and Ebola, case identification and contact tracing can have a large impact on control because it can, in theory, reduce delay C to zero, with all infected contacts in quarantine by the time they

become infectious **(AK/50 - INQ000562973)**. Conversely, during the COVID-19 pandemic, substantial presymptomatic transmission meant that an effective TTI strategy required reduction in delays A and B as well.

24. The effect required for control will also depend on the transmissibility of the infection (i.e. the basic reproduction number, R_0, defined as the average number of secondary infections caused by a typical case in a fully susceptible population). Specifically, R_0 depends on the number of contacts a typically infectious individual makes and the probability of transmission per-contact. Figure 3 shows the relationship between R_0 and transmission before symptoms for different infections. It is notable that, based on these two characteristics, SARS-CoV-2 is epidemiologically closer to pandemic influenza than SARS-CoV-1. However, a key difference is that time from infection to onset of infectiousness and symptoms is shorter for influenza than for SARS-CoV-2 **(AK/51 - INQ000562969)**, which would compress the timeline in Figure 2.

Figure 3: Schematic of the relationship between the magnitude of transmission and proportion of transmission that occurs prior to symptomatic or by asymptomatic infection. Adapted from Fraser et al and additional sources to illustrate characteristics of SARS-CoV-2 and novel pandemic influenza in the community **(AK/52 - INQ000562891; AK/53 - INQ000562892; AK/54 - dhsc006:08589667; AK/55 - INQ000231538)**

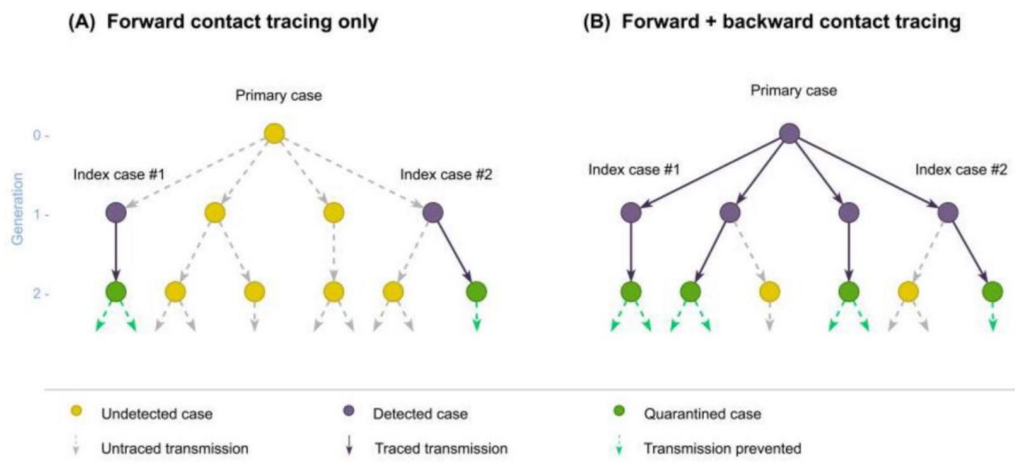


25. There are several strategies that can reduce the three TTI delays and hence the number of infectious individuals in the community:

Reduce delay A (onset of infectiousness in case to onset of symptoms) and increase proportion with evidence of infection

25.1. Asymptomatic testing can detect infections before onset of symptoms (or in absence of symptoms), and hence prompt earlier isolation. This can include routine mass testing programs and surge testing in response to rising infections. If access to events, venues or travel is dependent on a negative test, it can further enhance ability to detect infections early **(AK/13 - INQ000562957)**. Because SARS-CoV-2 transmission is clustered (i.e. some cases infect many, and most few or none) **(AK/23 - INQ000422073)**, 'backwards tracing' can also enable detection of additional cases beyond standard contract tracing methods. When a new case is detected, backwards tracing involves identifying where that case was originally infected, rather than just tracking their subsequent contacts (Figure 4). The clustered nature of SARS-CoV-2 transmission means that more likely than not, the newly detected case will have been infected within a transmission cluster where other cases have also been infected. Hence backwards tracing can identify these other infections sooner than they otherwise would have **(AK/11 - INQ000562975)**. Specifically, we would expect standard 'forward tracing' to detect R additional secondary cases, where R is the reproduction number, and backward tracing to detect R(1+1/k), where k is the dispersion parameter (estimated to be 0.1–0.4 for COVID). Hence backwards tracing would be expected to identify a transmission event three to 10 times larger than that caused by a randomly chosen case.

Figure 4: Illustration of infections identified through forward and backward tracing **(AK/11 - INQ000562975)**



Reduce delay B (onset of symptoms in case to entering isolation) and increase proportion isolating

25.2. The delay between a case showing symptoms and isolating can be reduced if the trigger for isolation is onset of symptoms rather than requiring a positive test. Several factors can increase the probability an infected individual isolates and remains in isolation: (i) proactive provision of information and social and clinical support, (ii) sufficient supplies of food, (iii) employment protection, (iv) financial assistance and (v) accommodation where necessary **(AK/34 - INQ000371699; AK/56 - INQ000562965)**. Accessibility of testing with multiple low-friction points for access, e.g. walk-in centres or home tests can also increase test uptake. Strategies like 'cocooning' or 'shielding', which reduce contacts between vulnerable groups and the wider population, in effect act to isolate these disproportionality susceptible individuals from potentially infectious contacts in the community.

Reduce delay C (onset of infectiousness in contact to entering quarantine) and increase proportion that quarantine

25.3. Infected contacts will spend less time infectious in the community if the delay from the initial case isolating to contacts being identified and quarantined can be reduced. If a positive test is required to trigger contact tracing, then the delay between that case becoming symptomatic and getting a positive test result is

a key driver of success for TTI **(AK/20 - INQ000206672)**. 'Test-to-release' strategies, where contacts who test negative are released from quarantine for a period of time (e.g. until a follow-up test) can reduce the number of people quarantined **(AK/21 - INQ000206673; AK/57 - INQ000197178)**. Having pre-defined 'bubbles' of high-risk contacts can also reduce the time required to identify and quarantine those most likely to be infected once a case is detected **(AK/58 - INQ000562976)**. The factors that can encourage individuals to remain in quarantine are similar to those listed to encourage isolation above. Measures like quarantine of arriving travellers in effect work by broadening the definition of a contact to be anyone arriving, and hence ensure a larger proportion of infected travellers are already in quarantine when they later test positive **(AK/59 - INQ000562951)**.

26. In practice, the ability to increase the effectiveness of TTI will also depend on wider interventions in place. For example, if there are more imported infections in the early stages of an outbreak, or more infections as a result of a growing domestic epidemic, more resources will be required to detect cases and trace and quarantine their contacts **(AK/15 - INQ000562962)**.

27. The below is a high-level assessment of how different strategies were used for TTI in the UK, adapted from and building on the testing strategies itemised in Littlecott et al **(AK/60 - INQ000376641)**. My assessment is based on analysis and discussion I was part of in my capacity as a contributor to SPI-M-O, IBPAG and other SAGE subgroups, as well as public policy announcements, and published reports and papers.

Focused testing of symptomatic and high-risk individuals to contain spread and prevent transmission among the wider population, especially during the early phase of an in-country outbreak, when infection is rare

27.1. During January and February 2020, individuals who were symptomatic and met specific travel or contact-based criteria were tested with manual contact tracing performed. There were two major limitations to this approach for control: the narrow criteria for testing meant large numbers of infections were going undetected **(AK/61 - INQ000562914)**, and a manual TTI process would always

be outpaced by an exponentially growing outbreak. Even if resources had been quadrupled once TTI reached capacity, the early COVID epidemic was doubling around every 3 days in the UK, so this additional capacity would have again been exceeded within 6 days. This initial containment strategy was discontinued in mid-March 2020.

Community quarantine (i.e. stay-at-home order)

27.2. Ideally, only individuals with a high probability of being infected would be defined as contacts and quarantined, to reduce wider disruption to those not infected. However, against a background of limited understanding of the growing COVID epidemic in mid-March 2020, the UK imposed a stay-at-home order, which is equivalent to a quarantine definition of 'anyone could be infected'. From July 2020 onwards, 'local lockdowns' would be used in a similar way **(AK/62 - INQ000052785)**, imposing quarantine in geographic areas where the infection risk was higher. Other countries made this link between TTI and lockdowns explicit: the Philippines, for example, called lockdown-type measures 'enhanced community quarantine'. Although this broad approach ensured all infected individuals fell under the quarantine definition, its untargeted nature also incurred large economic, social and wider health costs.

Mass PCR testing of those with symptomatic respiratory disease to identify SARS-CoV-2 infection, so individuals could take appropriate action, including home isolation and authorities could organize contact tracing

27.3. This was introduced from May 2020 onwards, replacing the blanket guidance that had been in place since March 2020 for all symptomatic individuals to isolate **(AK/63 - INQ000562970)**. An advantage was that it provided individual-level confirmation of infection, reducing the potential for a large number of 'false positive' quarantines that a blanket symptom-based-only isolation policy would create. However, the value of this system was reduced because test results were often not followed by action (i.e. isolation) **(AK/64 - INQ000262568)**.

Mass testing of those entering healthcare or other vulnerable settings such as care homes

27.4. This aimed to prevent infected individuals coming into contact with – and hence potentially transmitting to – groups more at risk of severe COVID outcomes. An advantage is that this disproportionately targeted the transmission events that contributed most to severe disease burden, but preventing such events was also sensitive to the timing of the test – too early before a visit and the infection would be more likely to be missed.

The requirement of a negative test result to undertake particular activities or enter particular settings

27.5. Similar to [27.4 – mass testing], this requirement aimed to prevent transmission from infectious individuals to others. However, rather than focus on the susceptibility of the contacts, this approach typically focused on volume, i.e. larger events where an infectious individual was more likely to transmit to several others **(AK/65 - INQ000498474)**. During the pandemic, travel testing was also implemented with the aim of reducing imported cases. However, this measure was most impactful when domestic transmission was low. Once an epidemic was growing within the UK, the relative contribution to transmission from these domestic cases was exponentially larger than that from imported cases, and hence the amount of 'time bought' by such travel testing reduced dramatically.

Mass antigen testing regardless of symptoms, in an attempt to identify both symptomatic and asymptomatic infections and hence reduce the amount of circulating infection

27.6. This was first piloted in the UK in Liverpool in November 2020 **(AK/66 - INQ000488660)**, with LFTs made universally available for free at point-of-use from April 2021 **(AK/63 - INQ000562970)**. Such tests had the advantage of being fast and easily accessible; people could access them proactively rather than needing to wait for a symptom trigger. However, adherence to such testing was not tracked in any detail, and it was unclear to me how equitable the use

of such testing was in reality (i.e. how much it was benefitting the groups most at risk from COVID).

Regular asymptomatic testing to identify all infectious individuals in workplace and educational settings

27.7. This included specific populations such as healthcare workers, care home workers, secondary school children and laboratory staff. Early on, this involved frequent PCR testing and later LFTs. This had the advantage of identifying individuals before they displayed symptoms, but required frequent testing with high uptake to ensure that infections were detected sufficiently early.

Report-based tracing of contacts via NHS Test and Trace (NHSTT)

27.8. The central 'manual tracing' component of the TTI system identified contacts of new cases, so these individuals could be asked to quarantine. From what I could tell, the tracing component system was too slow and too leaky to have a large impact of transmission (see below for assessment of effectiveness), but there was insufficient data available to reliably evaluate this effectiveness with any confidence in real-time.

App-based tracing of contacts via the COVID-19 app

27.9. The NHS COVID-19 App was developed from May 2020 onwards, with national introduction in September 2020. This had the advantage of being much faster at notifying contacts than the NHSTT system, and, in theory, able to reach a large number of contacts. However, the anonymous nature of the app (a specific design decision) meant there was a limit to the amount of epidemiological understanding that could be gained; although it was possible to evaluate how many notified cases became infected **(AK/67 - INQ000562944)**, it was not possible to reconstruct the full network of interactions, as with apps like the Singapore TraceTogether system. Because users could not be identified, there was also nothing to stop people deleting the app to avoid quarantine notices, which was a particular risk during times of high infection levels and more social interactions (e.g. the July 2021 reopening),

which meant an increasing number of app notifications to quarantine (i.e. the 'pingdemic) **(AK/29 - INQ000562985)**. The app also only sent contacts quarantine notifications once the case had been confirmed by PCR, which meant its effectiveness could be limited if this preceding step was too slow.

Venue-based tracing of contacts via NHS Test and Trace

27.10. The UK also operated a venue 'check-in' system, whereby visitors could scan a QR code on the COVID app to log their attendance and hence speed up contact tracing. In theory this could have helped accelerate both standard contact tracing and backwards tracing, but as I understood it, the outbreak identification process involved a manual step with NHSTT, which slowed the system down and hence was likely to substantially reduce its effectiveness **(AK/68 - INQ000562924)**.

Quarantine of pre-defined contact bubbles

27.11. In well-defined settings such as schools, contact 'bubbles' were used to pre-define those most at risk, and hence speed up the quarantine process if a case was identified. This approach had the advantage of reducing the reactive data collection required, but it also had the challenge that the size of the bubble had to be balanced with risk: too small and infected contacts may not be quarantined; too large and several individuals with a low risk of infection would have to quarantine.

Testing of contacts of cases

27.12. Standard COVID quarantine was a blanket measure that, in effect, assumed all contacts had the same infectiousness profile. 'Test-to-release' approaches were therefore used to reduce quarantine burden, by only restricting those with a higher risk of being infected. Initially these used PCR tests (e.g. for incoming travellers) and later repeat LFTs. This strategy has the advantage of making use of individual biological information to avoid blanket measures. In theory, a test-to-release approach can potentially lead to more transmission risk than a strict lengthy quarantine, because some people may test negative but still be

infectious, but in practice such testing may increase engagement with a contact tracing system by reducing the burden of being identified as a contact.

28. The challenge that an exponentially growing outbreak can outpace targeted approaches such as case isolation was well-known pre-COVID for other epidemics **(AK/06 - INQ000562895)**, as was the challenge of encouraging at-risk groups to access testing promptly **(AK/69 - INQ000562897)**. There had also been mathematical modelling work showing that the success of a contact tracing strategy depends critically on the proportion of transmission that occurs prior to the onset of clinical symptoms, as well as the inherent transmissibility of an infection **(AK/52 - INQ000562891)**.

29. The need for rapid and effective data linkage to identify and quarantine contacts for coronaviruses was anticipated by several countries and territories pre-COVID **(AK/70 - INQ000562960)**. After the 2003 severe acute respiratory syndrome outbreak, Taiwan established the National Health Command Center, which rapidly mobilized against COVID-19 in early 2020 using data-driven measures ranging from a location-based 'electronic fence' for those in quarantine to triangulation of patient travel and contact history **(AK/71 - INQ000562904)**. After the 2015 Middle Eastern respiratory syndrome outbreak, South Korea amended legislation to allow health agencies to access and analyse data, including mobile-phone location and credit card transactions, when faced with a serious outbreak **(AK/72 - INQ000562908)**.

30. During COVID, a key early learning was that transmission tended to cluster in 'superspreading events', and that reducing these events could have a considerable impact on the epidemic. For example, in early March 2020, my colleagues and I compiled reported superspreading events globally and noted that they all occurred among close contacts, such as guests at a meal. We suggested that targeting such events could therefore have a disproportionate effect on reducing overall transmission **(AK/73 - INQ000562902)**. In Japan, closed environments were identified early as a source of secondary transmission in more detailed outbreak investigations **(AK/74 - INQ000562978)**. Public messaging therefore suggested people should avoid the 'three C's': closed spaces, crowded places and close-contact settings **(AK/75 - INQ000562954)**. Once a cluster was detected, backwards tracing was used to identify

others linked to the transmission event **(AK/76 - INQ000562916)**. In South Korea, mobile-phone and credit-card data linked individuals to COVID-19 hotspots: 57,000 people who had been near a nightclub outbreak received text messages telling them to get tested **(AK/77 - INQ000562930)**. In my view, the UK did not make particularly good use of this evidence overall, both in terms of reducing venue risk and increasing ability to link people to transmission events. 'Eat Out to Help Out' in summer 2020 was a notable example of a policy that encouraged close contact in closed spaces, going against two key pillars of the targeted strategy used in places like Japan. It was never entirely clear to me whether the UK could not do the things East Asian countries had done, or just would not do these things, and I would have liked to see more (re)consideration of these perceived constraints.

Effectiveness of rollout of TTI systems

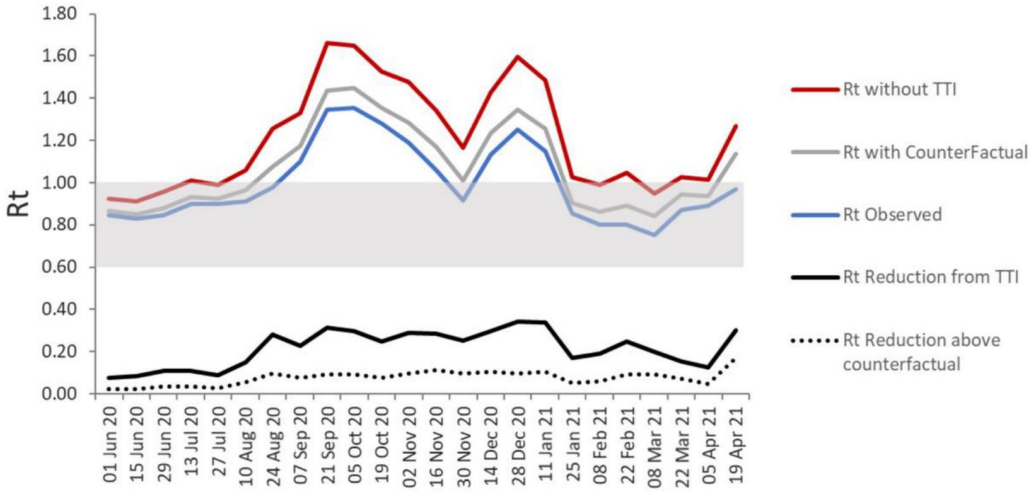
31. In the absence of designed experiments like randomised controlled trials – which were not conducted for TTI in the UK, but for one exception described below – there are two main ways to evaluate the effectiveness of a TTI system from observational data. One is to use a bottom-up approach, which involves calculating the proportion of infected individuals who enter and advance through each stage of the TTI process, and hence estimate how much onwards transmission was likely prevented. The other option is a top-down approach, using data on infections in the population alongside timing of the introduction of TTI measures to estimate the effect TTI had on the epidemic.

Bottom-up analysis

32. The Canna model published by UKHSA in September 2021 assessed the impact of TTI on COVID-19 transmission in England from June 2020 to April 2021 using a reproduction number-based model **(AK/64 - INQ000262568)** (details on the model provided in the next section). This built on the earlier Rùm model, which focused on an October 2020 type situation, and had estimated the overall impact of TTI (including self-isolation when symptomatic) as a reduction in R of 18-33% (corresponding to an absolute reduction of 0.3-0.6 in R), with contact tracing reducing R by 1.7-4.6%.

33. I was a member of the advisory panel for the Canna project in mid-2021. Given time constraints, the panel regarded the core assumptions and structure of the model as appropriate for determining the impact on transmission of TTI. The model included contacts identified in the NHSTT Contact Tracing and Advisory Service (CTAS), as well as the COVID-19 app and school-age contacts. Combining the characteristics of the infection and transmission with estimates of adherence, the analysis estimated that TTI reduced R by around 0.2-0.4 during the second half of 2020. This corresponds to around a 15-20% reduction in overall transmission, and may have made the difference between R being above and below the crucial value of 1 overall during winter 2020/21 (Figure 5). The analysis also compared the estimated impact of TTI with an imagined counterfactual in which all individuals who tested with COVID-like-symptoms self-isolated, without ever taking a test, together with their household contacts. This counterfactual was similar to the reality (blue and grey lines in Figure 5). To me, this suggests that most of the impact of TTI in England came from the testing and isolation of cases, and quarantine of their households, rather than the tracing and quarantining of their wider social contacts.

Figure 5: Estimation of the reproduction number over time (Rt) with and without TTI in the Canna model, as well as overall reduction in Rt



34. Early statistics from the NHSTT system support the conclusion that contact tracing was insufficiently fast or extensive to have a large impact on the epidemic. 73% of

referred index cases could be contacted (78% of these within 24 hours) and 90% of their contacts could be contacted (86% within 24 hours). This implied that less than half of contacts were being contacted within 48 hours of the index case being referred to NHSTT **(AK/78 - INQ000562980)**.

35. The effectiveness of the NHS COVID-19 app for England and Wales was also evaluated from its launch on 24 September 2020 to the end of December 2020 using a reproduction number-based approach **(AK/67 - INQ000562944)**. The app had around 16.5 million regular users (28% of population). The analysis suggested that the app averted around 284,000 cases (central 95% range of sensitivity analyses 108,000–450,000). For every 1% increase in app uptake, it was estimated that the number of cases could be reduced by 0.8%. A subsequent analysis using similar methodology estimated around 1 million cases (sensitivity analysis 450,000–1,400,000) averted during the first year of the app, corresponding to 44,000 hospital cases (SA 20,000–60,000) and 9,600 deaths (SA 4600–13,000) **(AK/79 - INQ000561521)**.

36. To my knowledge, it has not been possible to evaluate the impact of mass LFT usage in the same way because the required data were not available. I suspect that the use of LFTs was, in reality, strongly inequitable, with high usage amongst lower risk groups and relatively low usage amongst high-risk groups who would not be able to isolate following a positive result (e.g. for financial reasons).

Top-down analysis

37. The simplest metric to assess the effectiveness of the UK TTI system is to note that it did not stop a resurgent epidemic in the second half of 2020, even with additional social distancing measures in place. Put simply, if we define the measure of success of a TTI system as preventing a second UK wave, then it failed.

38. We can gain further insight into the effectiveness of TTI by comparing observed transmission during this period with what we'd expect from social distancing measures alone (i.e. not including the relatively small proportion of the population isolating and quarantining as a result of TTI). The SAGE consensus estimate for the observed value

of R in the UK peaked at 1.3–1.6 in autumn 2020 **(AK/80 - INQ000562984)**. In contrast, the estimate of R - derived from average population social mixing data - peaked at around 1.8 during this period **(AK/37 - INQ000562941)** (noting that social contacts are a leading indicator of transmission, so we would not necessarily expect the peaks to occur at the same point). As a very rough estimate, this would imply TTI systems potentially reduced R by 0.2–0.5.

39. Analysis of the COVID-19 app pilot on the Isle of Wight found that R declined from 1.3 before the COVID-19 app launch to 0.5 after. This did not necessarily mean the app was responsible for all this drop; other factors may have contributed to the decline. However, it was notable that the Isle of Wight went from having the third highest R before the launch compared with other Upper Tier Local Authorities (UTLAs), to the twelfth lowest afterwards.

40. There have also been studies of infection dynamics following the introduction of TTI measures in specific settings and locations **(AK/81 - INQ000496282; AK/82 - INQ000562961; AK/83 - INQ000496292; AK/84 - INQ000562949; AK/85 - INQ000562688; AK/86 - INQ000562937)**. For example, analysis of Liverpool's community testing pilot in late 2020, which involved asymptomatic LFT testing and confirmatory and symptom-based testing via PCR, estimated a 21% (12% to 27%) reduction in cases up to mid-December 2020 versus control areas **(AK/87 - INQ000562949)**.

41. In several settings, TTI measures were designed to enable an increase in the 'business as usual' activities that were possible, by detecting and isolating infected individuals rather than simply quarantining everyone at home. In other words, TTI was designed to offset the transmission risk from relaxation of other non-pharmaceutical interventions to allow specific services to continue. Analysis of TTI measures implemented within Cambridge college accommodation found a lower per-contact household transmission risk (7.8%) than that identified in domestic households (16.6–21.1%) as well as a lower-than-expected effective infectious period (3.0 days), suggesting earlier isolation **(AK/58 - INQ000562976)**. During 2020-21, the Francis Crick Institute also implemented an asymptomatic testing policy, with entry to the institute contingent on negative testing within the previous 8 days, and internal contact tracing following positive tests, alongside social distancing and face coverings. Mean

7-day occupancy was maintained at over 60% of peak attendance for 356/423 days and case levels were much lower than the surrounding borough of Camden **(AK/88 - INQ000562966)**. Analysis of the English Premier League (EPL) asymptomatic PCR testing program found that throughout late 2020 and early 2021, and during the early stages of the Omicron wave in late 2021, SARS-CoV-2 PCR positivity in the EPL broadly mirrored positivity in the UK Office for National Statistics Community Infection Survey. This was despite the large number of contacts made within and between football teams and their support staff **(AK/17 - INQ000562974)**.

Randomised controlled trial of daily testing

42. As well as observational TTI data, there was also a randomised controlled trial of daily testing of school-based contacts with LFTs for 7 days – with LFT-negative individuals remaining in school – to reduce the 10 day standard quarantine period **(AK/57 - INQ000197178)**. There were 657 symptomatic PCR-confirmed infections (59.1 per 100,000 per week) in the control group and 740 infections (61.8 per 100,000 per week) in the intervention group. This suggested that daily testing of school-based contacts was non-inferior to blanket quarantine of contacts for COVID control. However, there was also limited difference in measured absences: among students and staff, there were 59,422 (1.62%) COVID-19-related absences in the control group and 51,541 (1.34%) in the intervention group.

Modelling

43. Two main types of mathematical model were used by SPI-M-O contributors to explore the potential effectiveness of TTI strategies in the UK during the pandemic.

Individual-based outbreak models

44. These models simulated random transmission events from infected individuals to their contacts, incorporating knowledge about the biology of the infection (e.g. delay from exposure to showing symptoms), variation in social contact structure and/or transmission (e.g. superspreading) as well as comparing different TTI control measures **(AK/89 - INQ000191099; AK/24 - INQ000562918; AK/26 - INQ000562931;**

AK/90 - INQ000562986). Such models were well suited to exploring the effects of randomness in early outbreak control (i.e. when only a few cases had been introduced, or infection had been driven to low levels in a community), and showing how outbreaks could progress over time. Although some of these models assumed simple random mixing, these individual-based models could also incorporate more complex real-world network structures. Metrics such as the probability that an outbreak would exceed a particular size were used to compare the effectiveness of interventions. Because these models potentially needed to simulate a large number of transmission events in an outbreak, and simulate many outbreaks to understand the uncertainty around the effectiveness of an intervention, they could be quite slow and computationally intensive, making them less appealing in situations where questions needed to be answered rapidly and/or with a clear, intuitive explanation.

Reproduction number-based models

45. Rather than simulate a full outbreak, reproduction number-based models instead focused on the expected amount of onwards transmission from a single case **(AK/18 - INQ000148836; AK/91 - INQ000422237; AK/28 - INQ000422266; AK/30 - INQ000092694)**. For example, suppose hypothetically we expect a case to infect four others under normal behaviour patterns (i.e. the reproduction number, R, defined as the average number of people a typical case infects, is equal to 4). If the case fully isolates halfway through their infectious period, then we would expect two future infections to be prevented by this isolation, with two other contacts already infected. Now suppose one of these two infected contacts is traced, but they are only quarantined halfway through their infectious period. Hence contact tracing and quarantine will have cut the expected onwards transmission from those two contacts by only 0.5. Overall, the reproduction number from that first case will therefore be 4 minus 2 (from isolation) minus 0.5 (from tracing and quarantine), which gives R = 1.5 under this strategy. These models typically provided uncertainty in estimates by randomly generating individual contacts and randomly sampling the number of subsequent transmission events under different assumptions.

46. Reproduction number-based models focused on the expected level of transmission under certain strategies, particularly whether a particular strategy would result in

transmission above the crucial threshold for control given by R=1. These models were particularly well suited to situations where transmission was ongoing and hence R represented transmission in the population more accurately than for small outbreaks (specifically, because of the law of large numbers), and could provide a better predictor of future growth or decline.

47. Because this model structure involved a single calculation, rather than running a full outbreak simulation, it was also easier to rapidly test more complex contact-specific interventions (e.g. workplace closures) as well as incorporating complexity in individual viral shedding (e.g. to evaluate daily testing strategies) **(AK/92 - INQ000255426)**. The models were also much faster to run than full outbreak simulations. Variants of this approach were also used in population-level simulation models to approximate effects of TTI without implementing a full individual-based model **(AK/22 - INQ000562913)**.

Wider considerations and issues

48. Both types of models required the same broad parameters to be defined: the social contact structure of the population; the biological and transmission features of the infection; and the timescale and coverage of the TTI process. Early models had to rely on other documented coronaviruses (e.g. SARS-1 and MERS) for biological assumptions, and typically focused on symptom-based TTI (i.e. the dominant strategy at the time) and simpler contact assumptions (because TTI was not being combined with social distancing). In contrast, later models incorporated more detailed features such as viral shedding to allow repeat testing to be considered, and more detailed social contact structure to explore combined strategies involving social distancing or local targeting of measures.

49. A key barrier to success was the availability of data, and ability to infer the required parameters from these data. For example, to understand the impact of repeat testing, we first had to generate estimates of the probability of detection by PCR and LFT early in an infection **(AK/12 - INQ000562942)**; we were fortunate to have access to high quality healthcare working testing data from a collaboration with the Crick Institute and University College London Hospitals. A lack of routinely available metrics on the performance of the UK TTI system (i.e. distributions that could directly parameterise a

model, particularly around isolation adherence and how many new cases were already known contacts in quarantine) also meant that models instead had to explore a range of plausible assumptions **(AK/93 - INQ000562983; AK/94 - INQ000562987; AK/92 - INQ000255426)**.

50. One key challenge in communication was what seemed like a tendency of policymakers to focus on a single target, e.g. quarantining 80% of contacts within 48hr **(AK/95 - INQ000120511)**. Rather than 80% being good enough to ensure an effective system, our analysis suggested it was instead the absolute minimum value required. Because the TTI process involves several interlinked steps, even if such a target had been met, it would also have had little impact on transmission if cases were not being isolated and tested promptly (because some contacts would already have become infectious and infected others, starting the process afresh).

51. In my view, the scope of TTI modelling requests were often too narrow in the UK. There seemed to be a focus on using modelling to generate single metrics that could be targets for a 'successful' system, rather than ensuring all steps in the TTI process were working as well as possible, which would be essential to successfully reduce reliance on social distancing. There also seemed to be little consideration of how certain wider policies would interact with TTI. For example, some policies had the potential to substantially reduce the effectiveness of contact tracing, such as 'Eat Out to Help Out' and 'Rule of 6'. Advice on these was not sought from groups like SPI-M-O, who could have elaborated on these interdependencies.

Lessons learnt and recommendations

52. There are several roles that current emerging technologies could play in future testing and TTI strategies, alongside more general lessons learned during COVID-19. The below outlines some key areas for improvement in my view:

Reduce bottlenecks and manual input required in a TTI system

52.1. Delays in a TTI system can lead to a dramatic deterioration in its effectiveness. During COVID, two key TTI limitations were a lack of scalability – particularly

in the early stages of the pandemic – and a lack of speed. It is therefore important to consider how every step of the process could be improved. For example, proactively available LFTs can allow faster detection of infectiousness than waiting for symptoms and PCR. App-based tracing can allow near-instant identification of contacts and sending of notifications. Venue-based check-in can allow faster standard and backwards tracing. However, during COVID there were several missed opportunities: despite 1.7bn LFTs being dispensed, evaluation was limited and impact unclear; meanwhile, venue check-in required a manual NHSTT step, which reduced the speed of quarantining at-risk individuals, despite widespread roll-out.

Prepare data infrastructure and policies ahead of time, including decisions about feasibility and acceptability

52.2. When COVID emerged, places like South Korea and Taiwan had technological strategies in place following outbreaks of MERS and SARS. Even if these specific strategies are not feasible or desirable in the UK, and an alternative is preferred, I believe such a decision is better made before a pandemic. In particular, countries need to be clear what their hard constraints and red lines are when it comes to pandemic response. During COVID, governments were faced with trying to solve an extremely difficult constrained optimisation problem. In effect, they had to try to reach an optimal outcome in terms of balancing factors including direct and indirect health impacts and economic and social costs. They had to do this against a background of constraints, which included things that were impossible to change (e.g. they could not suddenly make the UK population younger with fewer comorbidities) as well as things that were deemed unacceptable to change even if theoretically possible (e.g. for ethical or privacy reasons). However, I do not think countries should wait until they are in a growing epidemic to define and debate what constitutes this set of constraints and red lines.

TTI strategies should build in routine evaluation of control outcomes, rather than focusing on metrics around process **(AK/96 - INQ000574821)**

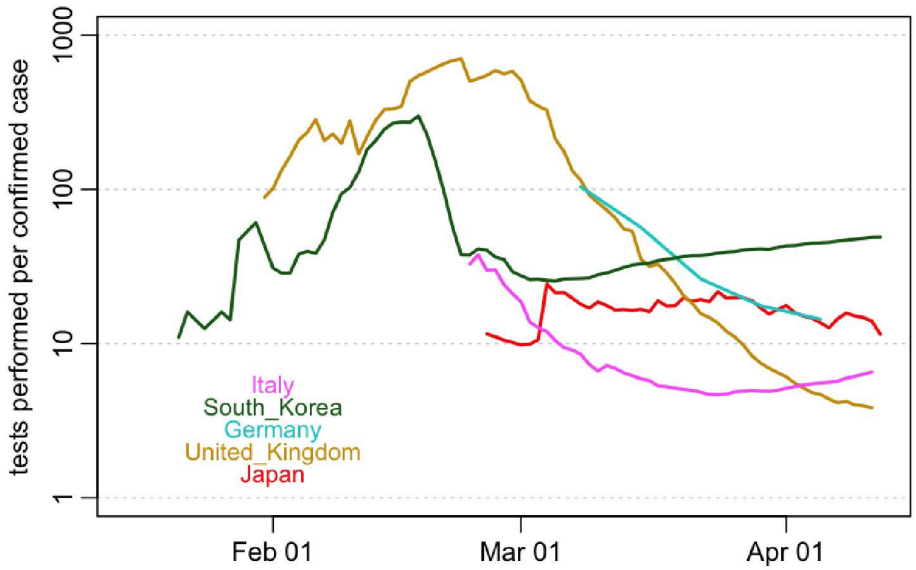
52.3. For example, the fact that a country is performing 100,000 tests per day tells us little about whether their epidemic is under control. It seemed to me that UK decision-makers tended to have a preference for simple process-orientated metrics that they could achieve (e.g. 80% of contacts traced or 100,000 tests per day) rather than getting a handle on the full complexities of control. This includes maximising adherence to isolation and quarantine, and the factors that influence whether people do this. Generally, performing rigorous evaluation of TTI will require additional data linkage. For example, the effectiveness of contact tracing can be evaluated by calculating the proportion of newly diagnosed cases that have already been contact traced and quarantined (i.e. what fraction are already 'in the system'), with the caveat that this can sometimes be an imperfect metric, particularly when an outbreak is growing rapidly **(AK/15 - INQ000562962)**. However, such metrics for NHS Test and Trace were to my knowledge not routinely available for analysis, making independent evaluation very difficult **(AK/97 - INQ000562922)**. In summer 2020, there were not publicly available statistics that could clearly show the poor performance of the UK TTI system, and hence the likelihood the UK would experience second wave with blanket reductions on social interactions as the only major control option available **(AK/98 - INQ000562923; AK/99 - INQ000562929)**. This meant it was not possible to fully understand or communicate the situation the UK was in until infections started rising. In contrast, countries like Iceland had public dashboards reporting the proportion of new cases that had been diagnosed while already in quarantine **(AK/100 - INQ000562919)**.

A testing system needs to identify growing domestic transmission as early as possible

52.4. During February 2020, the UK was performing more COVID tests per confirmed case than many other countries (Figure 6). However, because testing was focused on those with a history of travel to specific Asian countries or contact with a COVID case, many domestic infections were going undetected, and the true extent of the epidemic was not clear until additional reporting systems became active in mid-March 2020 **(AK/61 - INQ000562914)**. For example, on 6 March 2020, 48 new cases were reported, but subsequent estimates

suggested there were several hundred, and potentially as many as two thousand, new infections that day in reality **(AK/101 - INQ000562905)**. If more reliable leading indicators about epidemic growth had been available – as they were in autumn 2020 – it may have improved the quality of decision-making during this early period.

Figure 6: Tests performed per confirmed case in different countries in early 2020. Analysis originally generated on 13 April 2020 by myself **(AK/102 - INQ000562991; AK/103 - INQ000562992; AK/104 - INQ000562906)**



It is important to consider how the effectiveness and efficiency of TTI interacts with other non-pharmaceutical interventions (NPIs)

52.5. Resource demands on a TTI system will be lower if there are fewer new infections occurring within a population. In the early stages of an outbreak, the number of such infections will be influenced both by the number of imported infections, as well as the number of undetected transmission events in the domestic population, both of which are in turn shaped by population behaviour and wider NPIs in place. In particular, an exponentially growing epidemic can quickly outpace a finite set of TTI resources (see also 52.1 and bottlenecks above). The level of disruption from targeted strategies like TTI can also

increase as the outbreak grows. If effective contact tracing is in place when infection levels are high and individuals are making many risky social contacts, it would result in large number of individuals quarantining, and hence an outcome similar to a community stay-at-home order **(AK/14 - INQ000255419)**.

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: 30th April 2025