Review of case studies of effectiveness of testing schemes

Prepared for
Virgin Atlantic, IAG, TUI, Heathrow, MAG, Collinson, Airlines UK and IATA

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1 Introduction and summary of key findings

Oxera, Edge Health, and Dr Kit Yates[1] have been commissioned by Virgin Atlantic, IAG, TUI, Heathrow, MAG, Collinson, Airlines UK and IATA to undertake an independent review of real-world evidence on the effectiveness of testing schemes for international travellers. Our review focuses on four case studies in different jurisdictions where testing regimes are in place and for which data is available, as follows: Jersey, Canada (Toronto-Pearson Airport), France (Paris-Charles de Gaulle Airport) and Iceland.

This note follows our report on the review of the effectiveness of testing on arrival schemes, which considered the Public Health England (PHE), London School of Hygiene & Tropical Medicine (LSHTM), and Animal and Plant Health Agency (APHA) papers.[2] Following this note, we will be updating the modelling completed to date with more recent data that can be aligned with the real-world evidence discussed in this note. The outputs of our analysis are intended to feed into the work of the recently established Global Travel Taskforce as it considers how a testing regime for international arrivals could be implemented to boost safe travel to and from the UK.

We have reviewed the travel policies currently in place in a number of jurisdictions. While the UK currently has a 14-day quarantine policy for all travellers except those arriving from travel corridors, a number of countries have introduced testing schemes for travellers in order to reduce, or instead of, quarantine requirements. For example, Germany, France, Belgium, Portugal, Cyprus and Italy all have testing schemes in place. In some cases, there are tests before departure or on arrival (e.g. France, Portugal) with no requirement to quarantine on arrival if individuals can show a negative test result from a period of 72 hours before boarding the plane. In other cases, travellers from high-risk countries are required to take a test a certain number of days after arrival, and can then be released from quarantine subject to a negative test result.

We have reviewed the effectiveness of four testing schemes in place around the world, based on data availability. The key findings are included in Table 1.1 below. Overall, we find that the effectiveness of a testing on arrival scheme is between 54% and 76% based on four case studies as follows: 54% to 63% in Jersey; 67% to 72% at Toronto-Pearson Airport; 76% at Paris-Charles de Gaulle (CDG) and 64% to 69% in Iceland. We note that the effectiveness of a testing on arrival scheme is likely to depend on several factors, including the country of origin of travellers (and therefore prevalence rates).

These results, based on real-world testing schemes, are significantly higher than the 7% estimated by PHE. Indeed, these results are more in line with the effectiveness we found in our report 'Review of evidence on testing on arrival schemes'. The analysis presented in this note provides further evidence that the UK government is significantly understating the effectiveness of testing on arrival schemes.

Our analysis of these testing schemes also shows that testing after five days is between 83% and 90% effective, with testing after seven days showing nearly identical results of between 84% and 90%. This indicates that testing after five

1 Dr Kit Yates is a Senior Lecturer in mathematical biology and Co-director of the Centre for Mathematical Biology at the University of Bath.
2 Oxera and Edge Health (2020), 'Review of evidence on testing on arrival schemes', 22 October.

days may be as effective as testing after seven days based on the examples considered.

Table 1.1 Summary of effectiveness of testing schemes

	Description of testing scheme	Effectiveness of testing scheme
Jersey	Test on arrival for green (low-risk) countries[1]	54–63% on arrival
Toronto-Pearson Airport	Three tests: one on arrival, one after seven days of quarantine, and one after 14 days of quarantine	67–72% on arrival and 84% to 90% after seven days
Paris-CDG Airport	Two groups: one group with an on-arrival test only; one group with a pre-departure test and a second test after seven days of quarantine	76% on arrival and 90% after seven days
Iceland	Two tests: one on arrival and one after five days of quarantine	64–69% on arrival and 83–90% after five days

Note: [1] We note that the Jersey testing scheme also includes testing on arrival for individuals travelling from amber and red countries, with five- and 14-day quarantine periods respectively. However, we have not included the results for individuals travelling from these countries in our analysis due to data availability.

Source: Oxera and Edge Health.

It is important to place these figures in the context of an understanding of the level of risk associated with alternative policies. For example, the PHE paper that the UK government has been relying on for developing travel policy considers that the risk of travellers spreading the virus is zero with a mandatory 14-day quarantine requirement.[3] However, there is evidence from SAGE that indicates that compliance with quarantine may be as low as 20%, and therefore in reality the risk is unlikely to be close to zero.[4]

We note that in some cases only interim data or data from a period of a few months is available for the testing schemes considered, and there is no data available on the pre-departure schemes that are in place. In addition, in some cases we have had to make assumptions in order to determine the effectiveness of the testing schemes. Where we have made assumptions, we have based these on the most recent empirical evidence and undertaken sensitivity analysis. However, for these reasons, the results should only be considered as indicative. We are therefore currently updating the modelling completed to date with more recent data, which can then be compared with the real-world evidence included in this note, in order to determine the effectiveness of different testing regimes.

This note is structured as follows:

- section 2 sets out an overview of the testing schemes in place in a number of countries;
- sections 3 to 6 contain more detailed reviews of the Jersey, Toronto-Pearson Airport, Paris-CDG Airport and Iceland case studies in turn;

[3] Public Health England (2020), 'Investigation into the effectiveness of 'double testing' travellers incoming to the UK for signs of COVID-19 infection', 17 June.
[4] For example, SAGE has cited that only 'around 20% of those reporting symptoms of Covid-19 in England report fully self-isolating by staying at home.' See Scientific Advisory Group for Emergencies (2020), 'Multidisciplinary Task and Finish Group on Mass Testing', 11 September, para. 9.

- section 7 concludes.

2 Overview of testing schemes

While most countries have opened their borders to international travel, many have accompanied this with additional rules and requirements for international travellers.

For example, the UK has established travel corridors with a number of countries that it considers not to pose an unacceptably high risk to UK travellers, based on the latest assessment of COVID-19 risks.[5] The threshold for a travel corridor is considered to be 20 cases per 100,000 travellers. If a traveller arrives from a country with which there is a travel corridor in place, they are not required to quarantine. Travellers from all other countries are required to quarantine for 14 days.[6] The Netherlands has a similar system, whereby travellers arriving from certain countries need to quarantine for ten days.[7]

As indicated in Table 2.1, a number of other countries have introduced testing schemes for travellers arriving from abroad in addition to, or instead of, quarantine requirements in order to contain the spread of COVID-19.[8]

[5] Travel corridors are established separately for England, Wales, Scotland and Northern Ireland.
[6] There are certain exemptions, for example individuals with certain jobs. UK Government (2020), 'Coronavirus (COVID-19): jobs that qualify for travel exemptions', updated 25 October. See https://www.gov.uk/government/publications/coronavirus-covid-19-travellers-exempt-from-uk-border-rules/coronavirus-covid-19-travellers-exempt-from-uk-border-rules, accessed 28 October 2020.
[7] Government of the Netherlands (2020), 'Self-quarantine upon arrival in the Netherlands.' See https://www.government.nl/topics/coronavirus-covid-19/tackling-new-coronavirus-in-the-netherlands/travel-and-holidays/self-quarantine, accessed 28 October 2020.
[8] Most countries have different policies in place depending on the classification of the traveller's country of origin. These policies can change over time depending on prevalence rates, and the thresholds for placing countries in different categories are often not explicit. As such, we do not include this detail for most of the countries reviewed. Furthermore, testing regimes themselves are rapidly changing. What we report here refers to the situation as of 29 October 2020.

Table 2.1 Overview of quarantine and testing regimes for travellers

	Testing scheme?	Description of quarantine/testing regime
UK	No	Travellers are required to quarantine for 14 days unless there is a travel corridor in place (generally based on a threshold of fewer than 20 cases per 100,000 people)
Netherlands	No	Travellers arriving from certain countries need to quarantine for ten days
Spain	No	Health check (e.g. temperature check on arrival), with no testing or quarantine requirements
Belgium	Yes	No quarantine or testing requirements for individuals from orange and green countries. Travellers from red countries may be required to comply with a 10-day quarantine
France	Yes	Travellers from a number of countries do not have to quarantine or take a test. Individuals from other countries have to either take a test 72 hours before travelling to be allowed to board or take a test on arrival
Portugal	Yes	Travellers from a number of countries do not have to quarantine or take a test. Most individuals from other countries have to take a test 72 hours before travelling to be allowed to board, others can take a test on arrival and quarantine until the results are received
Germany	Yes	Any international traveller who has stayed in a 'risk area' in the previous 14 days needs to be tested upon entry into Germany and isolate until a negative test result is obtained. Alternatively, a traveller can present a negative result from a test taken pre-departure. Risk areas are defined based on 50 cases per 100,000 people
Italy	Yes	Testing is required for all passengers arriving from certain countries within 48 hours of arrival (at the airport or elsewhere). There have been several trials of testing—e.g. testing on departure on the Milan–Rome route.

Source: Oxera and Edge Health based on the sources below.

In Belgium, the approach for returning travellers depends on the country an individual is returning from. Countries are classified as red, orange or green. For orange (moderately elevated risk of infection) and green (low risk of infection) countries, there are no quarantine or testing requirements. People returning from red zones between 21 October and 15 November are not required to be tested. There are exceptions in the case of obvious symptoms, and individuals may be required to comply with a 10-day quarantine depending on their answers to a self-assessment questionnaire.[9]

In France, travellers arriving from a number of countries (e.g. Canada, Australia) do not have to self-isolate. Travellers arriving from other countries are subject to one of two protocols depending on the country categorisation:[10]

- category 1 countries: travellers need to provide a negative PCR test taken less than 72 hours before departure in order to be allowed on the plane;
- category 2 countries: travellers are strongly recommended to take a test within the 72 hours prior to travelling but can take a test on arrival instead.[11]

[9] Kingdom of Belgium (2020), 'Covid map & travel advice.' See: https://diplomatie.belgium.be/en, accessed 29 October 2020.
[10] UK Government (2020), 'Foreign travel advice: France'. See https://www.gov.uk/foreign-travel-advice/france/entry-requirements, accessed 23 October 2020.
[11] If a test on arrival is refused, the individual must quarantine for 14 days.

Similarly, in Portugal there are a number of EU and non-EU countries for which no test or quarantine is required. For other countries, most individuals must present a negative PCR test performed 72 hours before the flight in order to be allowed to board the plane. However, there are certain exemptions (e.g. citizens, foreigners who reside in Portugal) who can instead take a test on arrival at the airport at their own expense. These individuals must then remain in quarantine until a negative result is received.[12]

In Germany, the individual federal states are responsible for setting the specific quarantine regulations. According to current regulations, which have been in place since August (but are due to change on 8 November 2020), any international traveller who has stayed in a risk area during the previous 14 days needs to get tested upon entry into Germany and isolate until a negative test result is obtained. Alternatively, a traveller can present a negative result from a test taken pre-departure. Germany defines a country as a risk area if infection rates in a country are 50 per 100,000 people.

A negative test result from a molecular test conducted no more than 48 hours prior to entry in a EU member state or a country with comparable quality standards is considered an alternative to an on-arrival test. However, certain federal states require that international travellers take another test after a few days.[13] Tests taken within ten days after arrival in Germany are free for travellers from risk areas.[14] Tests are usually administered by health professionals at airports, testing stations or medical practices. A mix of molecular PCR tests and antigen tests are available at most international airports (e.g. Berlin,[15] Frankfurt,[16] Düsseldorf,[17] Munich,[18] and Cologne[19]) and test results can be expected between six and 72 hours after the test is taken. Some airports, such as Frankfurt and Munich, offer voluntary departure testing as well. As at September 2020, around 150,000 travellers had been tested for COVID-19 at the testing facilities at Frankfurt Airport. Between mid-July and September, around 1% of test results were positive.[20]

Finally, in Italy, testing is mandatory within 48 hours of arrival for individuals arriving from certain countries. There have also been a number of trials of pre-departure testing schemes, including on the route between Rome Fiumicino and Milan Linate airports (in both directions). Passengers on this route had the option of presenting a test taken in the 72 hours before their flight, which 15% of passengers made use of. The remaining 85% took a test at the airport on arrival. Tests taken at the airport were free and results were obtained within 30

[12] Serviço de Estrangeiros e Fronteiras (2020), 'COVID-19: Frequently Asked Questions'. See https://imigrante.sef.pt/covid-19/faqs/#1596230552441-6d9c2833-a5bd, accessed 23 October 2020.
[13] Federal Foreign Office (2020), 'Information on entry restrictions and quarantine regulations in Germany', 21 October. See https://www.auswaertiges-amt.de/en/einreiseundaufenthalt/coronavirus, accessed 23 October 2020.
[14] Bundesministerium fur Gesundheit (2020), 'FAQ regarding corona testing when traveling to Germany'. See https://www.bundesgesundheitsministerium.de/coronavirus-infos-reisende/faq-tests-einreisende-englisch.html#c18640, accessed 23 October 2020.
[15] FBB (2020), 'Flying safely under corona conditions', 13 October. See https://www.berlin-airport.de/en/company/latest-news/news/2020/2020-06-10-fliegen-corona/index.php, accessed 25 October 2020.
[16] Frankfurt Airport (2020), 'Coronavirus Testing at the Airport'. See https://www.frankfurt-airport.com/en/transfer-at-frankfurt-airport/covid-19/coronavirus-testing-at-the-airport.html, accessed 25 October 2020.
[17] Dusseldorf Airport (2020), 'Corona Testcenter'. See https://www2.dus.com/en/inform/for-a-safe-journey/corona-testcenter, accessed 25 October 2020.
[18] Munich Airport (2020), 'Corona-Tests am Flughafen'. See https://www.munich-airport.de/corona-tests-am-flughafen-9494091, accessed 25 October 2020.
[19] Cologne Bonn Airport (2020), 'Reach your destination healthy.' See https://www.cologne-bonn-airport.com/en/flights/travel-healthy.html, accessed 25 October 2020.
[20] Cirium (2020), 'Lufthansa makes case for expanding airport Covid testing scheme', 8 September. See https://www.flightglobal.com/strategy/lufthansa-makes-case-for-expanding-airport-covid-testing-scheme/140078.article, accessed 25 October 2020.

to 40 minutes. Between 16 September 2020 and 16 October 2020, on the route from Milan–Rome 0.76% of individuals tested positive, while on the route from Rome–Milan the figure was 0.83%.[21]

The examples outlined above demonstrate that there are a variety of different testing schemes in place in different countries. Table 2.1 below sets out the key dimensions according to which testing schemes may vary. In part, this variation in approaches could be a result of a lack of evidence about the effectiveness of different types of testing regimes. More evidence could help harmonise the approaches.

Table 2.2 Classification of testing schemes for international travellers

Dimension	Consideration(s)
Existence of testing scheme	Is a testing scheme in place? Is it mandatory or voluntary?
Type of test	What type of test is administered (antigen or molecular)?
Tested travellers	Is the testing scheme available to (national/international) arriving or departing passengers, or both?
Quarantine obligation	Are any quarantine periods required for international travellers? How many days?
Number of tests	How many tests are required?
Timing of tests	When are tests administered?
Test administration	Who administers the tests?
Funding	Who funds the testing schemes? Do travellers need to pay for the test(s)?
Time until results	How long does it take for the test result to arrive?
Procedure in case of positive result	Which procedure is followed in case of a positive test result?

Source: Oxera and Edge Health.

In the following sections we provide more detailed reviews of four case studies where testing schemes are in place for international travellers. The selection of case studies was determined by data availability. We note that the results cannot be directly compared given the different nature of the testing regimes in place. However, the results from the case studies all point to similar results in terms of the effectiveness of testing regimes.

[21] Berberi, L. (2020), 'Voli <<Covid free>> Roma-Milano, in un mese fermata 25 passeggeri positivi', *Corriere Della Sera*, 24 October.

3 Jersey Safer Travel Testing Programme

On 3 July 2020, Jersey started its Safer Travel Testing Programme to minimise the spread of COVID-19 on the island while opening its borders to unrestricted travel.[22] The programme offered COVID-19 testing to all passengers arriving in Jersey free of charge. We have analysed the Jersey Safer Travel Testing Programme over the months of July and August.

The countries that travellers arrive from are categorised as green, amber or red, based on the prevalence of COVID-19 in the country.[23] Passengers are allocated to the highest colour classification of all the countries they have stayed in overnight during the 14 days prior to their arrival in Jersey.[24] Depending on the colour a passenger is assigned to, they are required to:[25]

- *green*: get tested on arrival and isolate until the negative PCR test result is returned, usually on the day after the test is administered. (We note that this was the system in place until 29 September, and therefore the relevant scheme for the purposes of our analysis. Since this date, a second test has been required on day five);[26]
- *amber*: get tested on arrival and on day five after arrival, then isolate until the second negative PCR test result is returned (usually on day six of their stay in Jersey);
- *red*: get tested on arrival and isolate for 14 days.

Instead of getting tested on arrival, prior to their departure passengers can present approved documentary evidence of a negative COVID-19 PCR test conducted within 72 hours of their arrival in Jersey.[27] For passengers from green countries, this replaces the need for an arrival test and the need to isolate on arrival until the results of the test are provided. For travellers from amber and red countries, this replaces the need to be tested on arrival, although passengers must still isolate for the required period.[28] Travellers can also choose to opt out of the Safer Travel Testing Programme and isolate for 14 days instead.

Data on the Safer Travel Testing Programme that is publicly available includes:

- the number of travellers per month and their departure country;
- the aggregate number of COVID-19 tests administered to travellers from all country groups as well as positive test results by green, amber and red country groups.

[22] Government of Jersey (2020), 'Testing programme for opening Jersey's borders', 1 July. See https://www.gov.je/News/2020/Pages/BordersTesting.aspx, accessed 28 October 2020.
[23] Day trip passengers travelling from and returning to Jersey without an overnight stay off-island were classified as having a green travel history regardless of the classification of the country or region visited.
[24] Government of Jersey (2020), 'Travelling to Jersey (safer travel guidance)'. See https://www.gov.je/Health/Coronavirus/Travel/Pages/CoronavirusTravelAdvice.aspx#anchor-0, accessed 28 October 2020 .
[25] Children under the age of 11 at the time of their arrival in Jersey were not required to undergo testing.
[26] Morel, J. (2020), 'FOCUS: Why the covid travel map is changing', *Bailiwick Express*, 25 September. See https://www.bailiwickexpress.com/jsy/news/focus-why-covid-travel-map-changing/#.X5cIV9D7RnI, accessed 28 October 2020.
[27] Data on the number of travellers that opted for the pre-departure test is not available. We therefore cannot take into account travellers that were filtered out by a pre-departure test and never travelled to Jersey. Our modelling approach in this respect is conservative, as those travellers with a positive pre-departure test may have been picked up by the on arrival test as well, and would have increased the effectiveness of such a test.
[28] Government of Jersey (2020), 'Travelling to Jersey (safer travel guidance)'. See https://www.gov.je/Health/Coronavirus/Travel/Pages/CoronavirusTravelAdvice.aspx#anchor-0.

For the purposes of our analysis of the effectiveness of the scheme, we have considered travellers who arrived in Jersey between 1 July and 1 September 2020.

According to Jersey passenger arrival statistics, 58,139 individuals arrived in Jersey by air or sea in the period from 1 July to 1 September 2020.[29] A significant majority of these (52,122, approximately 90%) arrived from the UK.[30] The individuals who did not come from the UK arrived from France (St Malo and Granville), Spain (La Palma) and Portugal (Madeira). There was also a total of 296 travelling yachtsmen who had a stopover in Jersey. For the time period considered, Table 3.1 shows the categorisation of countries into green, amber and red applied by Jersey.

Table 3.1 Categorisation of countries into green, amber and red

Green	Amber	Red
La Palma, Madeira, UK (1 July– 2 September 2020) France (1 July–8 August 2020)	France (9 August– 1 September 2020)	n/a

Note: No travellers arrived from red countries.

Source: The Jersey government reports only current and future country status. Previous status has therefore been collected by Edge Health and Oxera from public sources. France: ITV News (2020), 'People returning to Jersey from France must isolate', 10 August. Fromhttps://www.itv.com/news/channel/2020-08-09/people-returning-from-france-to-jersey-must-isolate, accessed 29 October 2020; UK: Channel 103 (2020), 'Travel 'Traffic Light' List Published', 9 July. From https://www.channel103.com/news/jersey-news/travel-traffic-light-list-published/, accessed 29 October 2020; Madeira: Government of Jersey (2020), 'Regional Covid traffic light system for UK, France and Republic of Ireland', 28 August. From https://www.gov.je/News/2020/Pages/CovidTrafficLight.aspx, accessed 29 October 2020; La Palma: Government of Jersey (2020), 'Update: countries reclassified', 27 August. From https://twitter.com/govjersey/status/1298927142051381248, accessed 29 October 2020.

In our analysis we have only considered travellers arriving from green countries. This is because there are multiple tests for individuals arriving from amber and red countries, but the data does not indicate which of the tests the results relate to (e.g. if there is a positive and a negative test result we do not know which relates to the on-arrival test and which relates to the test on day five). Therefore, we have focused on individuals from green countries, who are required to take only one test, and it is therefore clear that the result relates to the on-arrival test.

In order to analyse the effectiveness of Jersey's testing scheme, we needed to determine the number of likely infected travellers depending on the country of origin. Given data availability, we also needed to make some other assumptions. These are outlined in Table 3.2 below. We have undertaken sensitivity analysis for the key assumptions (e.g. regarding the prevalence of COVID-19 among travellers) and found that the results did not significantly

[29] Jersey, Jersey Statistics. See https://business.jersey.com/index.php/jersey-statistics, accessed 26 October 2020.

[30] There is the potential that a share of travellers used the UK (or one of the other departure countries) as a transfer location and actually travelled from a different origin country. However, according to Jersey travel statistics, 89% of travellers to Jersey are UK residents and 90% of travellers in our sample were travelling from the UK. Similarly, 7% of travellers were French residents, and 9% of individuals in our sample were travelling from France. Hence, we do not consider that there was likely to have been a large proportion of transfer passengers. See Statistics Jersey (2020), 'Jersey Travel Survey January to March 2020)', https://business.jersey.com/sites/default/files/components/pdf_download_row/Q1%20Visitor%20Survey%20report.pdf for the resident statistics. 'Arriving passengers by route-month of July 2020' https://business.jersey.com/sites/default/files/components/pdf_download_row/July%202020%20%20-%20Passenger%20Arrivals%20%28002%29.pdf. 'Arriving passengers by route – month of August 2020.' https://business.jersey.com/sites/default/files/components/pdf_download_row/August%202020%20%20-%20Passenger%20Arrivals_0.pdf for departure country statistics.

change. In addition, where we made assumptions, these are conservative, and therefore may actually understate the effectiveness of the testing scheme.

Table 3.2 Overview of assumptions

Assumption	Explanation/source
Proportion of visiting yachtsmen are allocated to green and amber countries in line with the origin countries of the remaining travellers arriving by sea	There is no data available on the country of origin for visiting yachtsmen. Therefore, the proportion of yachtsmen in the green and amber categories have been calculated to be in line with the proportion in each category of travellers arriving by sea
Proportion of travellers from France in August that fall into the amber category: 75%	France was moved to the amber category in the second week of August. We have assumed an equal number of travellers from France in each week in August
All travellers arriving from a green country are tested once, while all travellers arriving from an amber country are tested twice	This is in line with the rules of the Jersey Safer Travel Testing Programme in place during the time period considered
Scenario 1: Travellers' probability of being infected with COVID-19 is adjusted depending on the country they come from. Travellers from France, Spain and Portugal are estimated to have a higher COVID-19 prevalence than England of 0.21%, 0.66% and 0.23%. To be conservative, travellers with an unknown departure country are assigned the Spanish COVID-19 prevalence. We have also assumed that all Jersey residents who are day-travelling have the same probability of being infected with COVID-19 as the residents in the country they travel to. This is conservative, as the prevalence in Jersey is lower than in any of the other jurisdictions considered	We have augmented the UK COVID-19 prevalence as reported by the Office for National Statistics by the ratio of positivity rates between the relevant country and the UK. For Spain, this factor was 9.1, for France it was 2.8 and for Portugal it was 3.2
Scenario 2: All travellers arriving from green countries have the same probability of being infected with COVID-19 as private households in England. As shown in Table 3.1, England was classified as a green country by the Jersey government throughout the relevant period. Based on data from the Office for National Statistics, we have estimated a COVID-19 prevalence of 0.07%.[31] We have also assumed that all Jersey residents who are day-travelling have the same probability of being infected with COVID-19 as the residents in the country they travelled to. This is a conservative assumption, as the prevalence in Jersey is lower than in any of the other jurisdictions considered.	

Source: Oxera and Edge Health.

Between July and August 2020, 55,672 PCR tests were administered to incoming travellers from abroad. Assuming that all travellers from green countries were tested once, in line with the requirements of the scheme at the time, we have calculated that 50,291 of those tests were administered to international travellers arriving from green countries. Twenty-three individuals arriving from one of the green countries tested positive on arrival.

[31] Office for National Statistics (2020), 'Coronavirus (COVID-19) Infection Survey', 23 October. See https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/datasets/coronaviruscovid19infectionsurveydata, accessed 27 October 2020.

Based on an estimate of actual prevalence rates in the departure countries as detailed in Scenario 1 in Table 3.2, we have estimated that the number of infected travellers from one of the green countries participating in the Safer Travel Testing Programme was 38. Hence, the percentage of infected travellers identified by an on-arrival test in Jersey is 54%. This is conservative, as it assumes that more remote areas such as Madeira and La Palma have COVID-19 prevalence rates in line with their countries' averages.

We have considered an alternative scenario where we modelled the probability of infection of all passengers to be aligned with the prevalence rate in England (see scenario 2). This is also likely to be a conservative assumption, as individuals taking day trips from Jersey and returning home are likely to have lower prevalence rates than in England. In this case, we have estimated that the number of infected travellers from the green countries that participated in the Safer Travel Testing Programme was 36. In this scenario, the effectiveness of on-arrival testing is estimated to be 63%.

4 Toronto-Pearson Airport study of international travellers

Canada implemented strict border restrictions in early March 2020. The Canadian government closed its international borders to foreign nationals on 16 March 2020 and, starting two days later, required international flights to be redirected to four airports: Toronto-Pearson, Vancouver International, Montréal Trudeau and Calgary International. Simultaneously, the government introduced a ban on non-essential travel across the Canada–US border.[32] While some of these restrictions were lifted over the summer, Canada still requires international travellers to quarantine for 14 days upon arrival.

From 3 September 2020, international travellers arriving at Toronto-Pearson Airport Terminal 1 have been invited to take a voluntary COVID-19 test. This is part of a COVID-19 study being undertaken by McMaster Health Labs (MHL), Air Canada and the Greater Toronto Airports Authority (GTAA) to consider the effectiveness of various quarantine periods for travellers.[33] The study is intending to determine if an airport-based COVID-19 test is feasible, whether self-collection of COVID-19 testing is effective, and to explore options regarding the 14-day quarantine for international travel.[34]

Participants undertake a PCR test on arrival followed by two additional tests that are self-administered seven and 14 days after arrival. Participants are notified electronically of the first results within 48 hours.

The results of the study are still being analysed, and we understand that an interim report will be available in November. However, at this stage there is some aggregate data available regarding the study and its results:[35]

- approximately 13,000 tests of returning international travellers were administered between 3 September and 1 October 2020;
- approximately 1% of these individuals returned positive test results (130 positive test results);
- of the individuals testing positive, more than 80% were detected by the on-arrival test, 20% at the second test, and 0% at the third test.

There is a wide range of estimates of the detectability of COVID-19 depending on whether an individual is symptomatic or asymptomatic, and the point during the infection at which the test is taken. Based on a review of the literature, we have assumed that 10% of travellers infected with COVID-19 cannot be detected because the illness is not yet detectable or because of test sensitivity.

Therefore, based on a test sensitivity of 90% in all three tests, this would mean that 72% of infected passengers are detected at arrival, and an additional 18%

[32] Statistics Canada (2020), 'Leading indicator of international arrivals to Canada by air, second quarter 2020,' 14 July. See https://www150.statcan.gc.ca/n1/daily-quotidien/200714/dq200714c-eng.htm, accessed 27 October 2020.
[33] Air Canada (2020), 'McMaster HealthLabs, Air Canada and Greater Toronto Airports Authority to Conduct a Voluntary COVID-19 Study of Arriving International Travellers', News Releases. See https://aircanada.mediaroom.com/2020-09-03-McMaster-HealthLabs-Air-Canada-and-Greater-Toronto-Airports-Authority-to-Conduct-a-Voluntary-COVID-19-Study-of-Arriving-International-Travellers, accessed 23 October 2020.
[34] ibid.
[35] Air Canada (2020), 'Air Canada Finalising Initial Order for Newly Approved COVID-19 Rapid Testing Kits from Abbott', News Releases. See https://aircanada.mediaroom.com/2020-10-01-Air-Canada-Finalizing-Initial-Order-for-Newly-Approved-COVID-19-Rapid-Testing-Kits-from-Abbott, accessed 23 October 2020.

of passengers are detected after seven days. [36] Results from studies that compare the sensitivity of self-administered tests to those administered by healthcare professionals provide mixed results: one study shows that they have similar sensitivities,[37] while another demonstrates that self-administered tests are only 66% sensitive.[38] We have therefore also considered a scenario with a 90% test sensitivity in the first test and a 66% test sensitivity in the second and third tests (as these are self-administered and therefore potentially less reliable). This would mean that 67% of infected passengers are detected on arrival, and an additional 17% are detected after seven days.

[36] A recent study by Grassly, N.C., et al. states that PCR testing was assumed to be 100% on the basis of the performance of the majority of available tests reported by the Foundation for Innovative New Diagnostics (see Grassly, N.C., Pons-Salort, M., Parker, E.P.K., White, P.J. and Ferguson, N.M (2020), 'Comparison of molecular testing strategies for COVID-19 control: a mathematical modelling study', *The Lancet Infectious Diseases*, 18 August; and Foundation for Innovative New Diagnostics Interactive dashboard of SARS-CoV-2 diagnostic performance data, https://finddx.shinyapps.io/COVID19DxData/, accessed 3 June 2020). However, we have not specifically modelled detectability distributions and therefore cannot assume that all travellers were detectable at the time of arrival. A lower test sensitivity is supposed to encompass this effect.
[37] See Altamirano, J., Govindarajan, P., Blomkalns, A.L., Kushner, L.E., Stevens, B.A., Pinsky, B.A. and Maldonado, Y. (2020), 'Assessment of Sensitivity and Specificity of Patient-Collected Lower Nasal Specimens for Sudden Acute Respiratory Syndrome Coronavirus 2 Testing', *JAMA Network Open*, **3**:6, 14 June.
[38] See Kojima, N., Turner, F., Slepnev, V., Bacelar, A., Deming, L., Kodeboyina, S. and Klausner J.D. (2020), 'Self-Collected Oral Fluid and Nasal Swabs Demonstrate Comparable Sensitivity to Clinician Collected Nasopharyngeal Swabs for Covid-19 Detection', *MedRxiv,* 11 April [Preprint]. Available from: https://www.medrxiv.org/content/10.1101/2020.04.11.20062372v1

5 Paris-CDG Airport and French overseas territories testing scheme

France experimented with reducing the 14-day mandatory quarantine period for flights between Paris-CDG and La Réunion. After an initial trial phase, flights between Paris-CDG and Guadeloupe, Martinique, St Bart and St Martin were also included in the experimental scheme. The experiment took place between 9 June and 10 July 2020.[39]

The experiment separated travellers into two groups:

- Group A: one test on arrival and then a 14-day quarantine. There were 1,996 participants in this group;
- Group B: one test 72 hours prior to departure, a seven-day quarantine upon arrival, and then a test on day seven. If the test on day seven was negative, then the individual was allowed to end their quarantine. This group had 5,695 participants.

There is only aggregate data available for the results for the two groups, which is as follows:

- of the 1,996 participants in Group A, 13 tested positive (0.65%);
- of the 5,695 participants in Group B, seven tested positive (0.12%).

In contrast to the Toronto and Iceland case studies, the Paris-CDG case study consists of two separate cohorts. As their sample sizes are sufficiently large and we do not know of any systematic differences, we can assume that they are representative of any traveller. Therefore, we have assumed that, had the 1,996 travellers in Group A been tested after seven days in quarantine, 0.12% (or two travellers) of this group would have tested positive. Based on a 90% test sensitivity in both tests, the results would imply that 76% of infected travellers are detected by an on-arrival test, and an additional 14% are detected after the seven-day quarantine.

Some uncertainties remain around how the scheme was implemented in practice. For example, it is not clear whether quarantine was mandatory during the 72 hours between the pre-departure test and the flight. It is also not clear whether the tests were self-administered or administered by medical professionals. For these reasons, the results presented should be considered as indicative.

[39] ADP (2020), 'Feedback on the implementation of a corridor experiment: CDG-Overseas Territories', July.

6 Iceland testing scheme[40]

International travellers arriving in Iceland are subject to a testing regime or a mandatory 14-day quarantine period. The testing scheme in Iceland was introduced on 15 June 2020 and since then two different approaches have been applied: either one or two PCR tests in combination with various durations of quarantine. The tests are administered by trained personnel under the supervision of healthcare personnel, and results from the tests are available within 24–48 hours. More recently, Iceland has been applying one test on arrival and one after five days of quarantine to all passengers.[41]

Based on aggregate data available from 19 September, when the two-test regime was in place for all travellers:

- 29,411 individuals were tested in test 1 and 27,846 in test 2. Some individuals did not show up for the second test;
- 132 individuals were positive at the first test and 41 at the second test;

Based on a 90% test sensitivity, our results indicate that 69% of infected travellers are identified by an on-arrival test, and an additional 21% are detected after five days.[42]

We understand that the prevalence of COVID-19 among the population travelling to Iceland was around 1%. Assuming, therefore, that 1% of the travellers who failed to show up for the second test were also infected with COVID-19, the percentage of travellers identified by an on-arrival test reduces to 64% and the additional proportion of travellers detected after five days reduces to 20%.

[40] This case study is based on information provided by Thor Gudnason, chief epidemiologist of Iceland.
[41] We understand that it is currently being evaluated whether a rapid test should be used for the first screening.
[42] Grassly et al. (2020) states that PCR testing was assumed to be 100% on the basis of the performance of the majority of available tests reported by the Foundation for Innovative New Diagnostics (see Grassly et al. (2020), op. cit.; and Foundation for Innovative New Diagnostics Interactive dashboard of SARS-CoV-2 diagnostic performance data, https://finddx.shinyapps.io/COVID19DxData/, accessed 3 June 2020). However, we have not specifically modelled detectability distributions and therefore cannot assume that all travellers were detectable at the time of arrival. A lower test sensitivity is supposed to encompass this effect. Assuming 100% test sensitivity, this indicates that 76.3% of infected travellers are identified by an on-arrival test and 23.7% are detected at second test.

7 Conclusion

A number of countries have introduced testing schemes to accompany the opening of their borders to international travel. Based on a review of four testing schemes in place in four different jurisdictions, we find that the effectiveness of testing on arrival schemes is significantly higher than the 7% figure estimated by PHE, which has been relied on by the UK government in developing its travel policies.

We estimate that the effectiveness of on-arrival tests is between 54% and 63% in Jersey, between 67% and 72% at Toronto-Pearson Airport, 76% at Paris-CDG, and between 64% to 69% in Iceland. We also find that testing after five and seven days shows nearly identical effectiveness. Testing after five days is between 83% and 90% effective, and testing after seven days is between 84% and 90% effective, indicating that there is unlikely to be significant additional benefit from a seven-day quarantine compared with a five-day quarantine. This is therefore important evidence for the Global Travel Taskforce to consider in determining how to safely open up travel to and from the UK.

The case studies are based on different testing regimes and the extent of analysis that we were able to undertake based on the available data also differed. For example, in the Jersey case study we modelled prevalence rates in the traveller population, which we were not able to do in the other case studies. While there is limited data available in some instances, we have undertaken sensitivity analysis to consider the robustness of the estimates to changes in assumptions. Overall, the case studies all point to similar ranges for the effectiveness of on-arrival testing as well as testing after five and seven days.

While the testing regimes considered all include an on-arrival test, the schemes differ in terms of whether they also require a second test, and whether a second test is required for all travellers or just travellers from certain countries. In some cases pre-departure tests are also an option instead of an on-arrival test. It is also interesting that the testing schemes in some of the countries reviewed are trial schemes or have changed over time. In light of this, and the range of other factors that vary between the schemes (e.g. tests being self-administered vs administered by a healthcare professional), it appears that there is scope for further analysis of the effectiveness of different schemes. Our forthcoming modelling should help provide some consensus in this respect.

The results of the case studies also need to be viewed in the context of an understanding of the level of acceptable risk for travellers and how this would change with testing. Countries use different thresholds for considering acceptable levels of risk—for example, Germany uses a threshold of 50 cases per 100,000 people to identify a high-risk country while the UK generally relies on a lower threshold of 20 cases per 100,000 people. Germany has introduced a testing regime for individuals travelling from these high-risk countries while the UK imposes a mandatory 14-day quarantine regime. This is despite the fact that Germany has typically had (and continues to have) much lower prevalence rates than the UK, and despite the fact that a testing regime may be just as effective as a mandatory 14-day quarantine policy given low levels of compliance with quarantine.

The risk posed by travellers through the implementation of a testing scheme therefore needs to be assessed in the context of the risk that these infectious travellers pose to the UK population over and above the pre-existing

community transmission risk, the level of risk accepted by the implementation of other government policies, and the risks associated with the mandatory 14-day quarantine policy, such as levels of compliance.

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