



Impact of travel restrictions on Omicron in Italy and Finland

Oxera and Edge Health

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Summary: what has Omicron taught us about travel restrictions? (I)

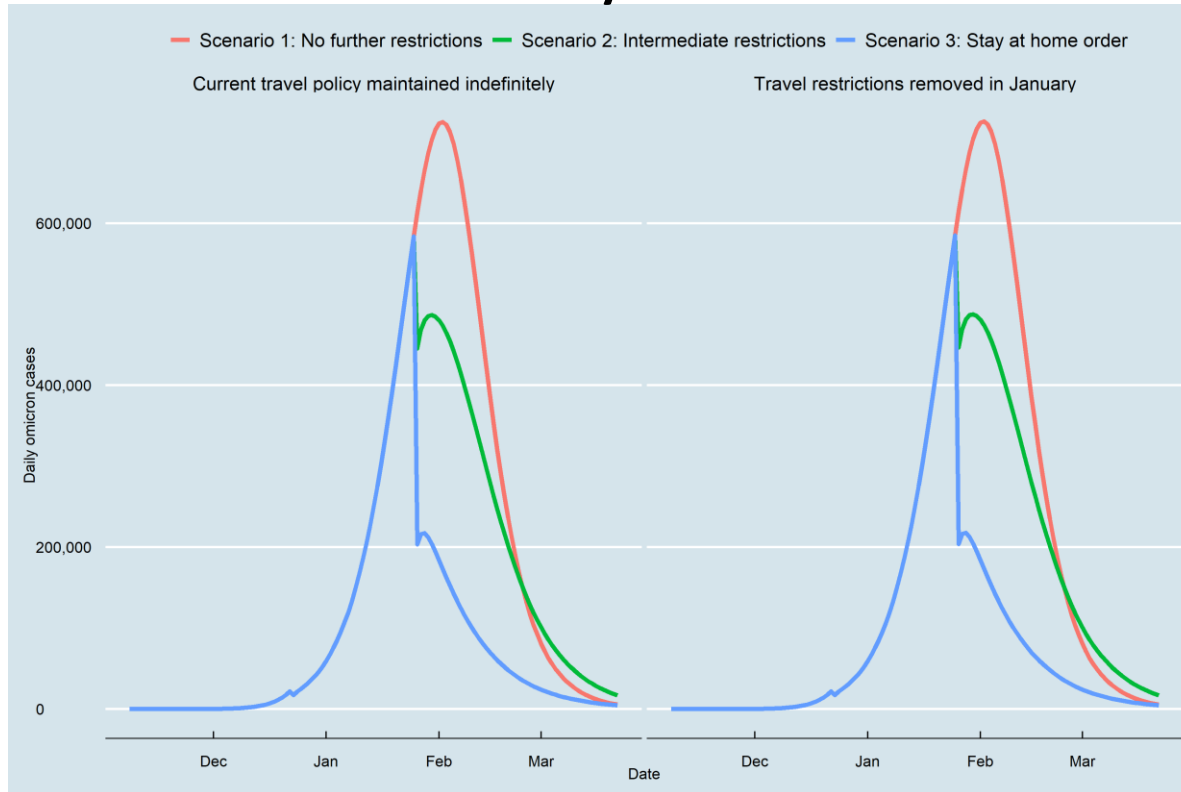
- Italy and Finland introduced pre-departure testing for air passengers in mid- and late-December respectively, in response to the Omicron variant.
- This was six to eight weeks after Omicron was first identified, meaning that the variant was likely being seeded in these countries for a number of weeks before travel restrictions were imposed.
- As a result, additional travel testing introduced in December was ineffective at preventing the spread of Omicron.
- If no travel testing had been introduced at all, Omicron's spread in Italy and Finland would not have been impacted.
- Even if more stringent travel testing requirements had been in place from the beginning of November—i.e. the day South Africa reported Omicron to the WHO—they would not have had any meaningful impact on the spread of Omicron in Finland, and would have had a small impact on the spread of Omicron in Italy.



Summary: what has Omicron taught us about travel restrictions? (II)

- Now that Omicron is highly prevalent in Italy and Finland, removing all travel testing requirements would not impact domestic Omicron spread. However, continuing to impose travel restrictions would impose a significant economic cost on the Italian and Finnish economies.

Italy



Finland

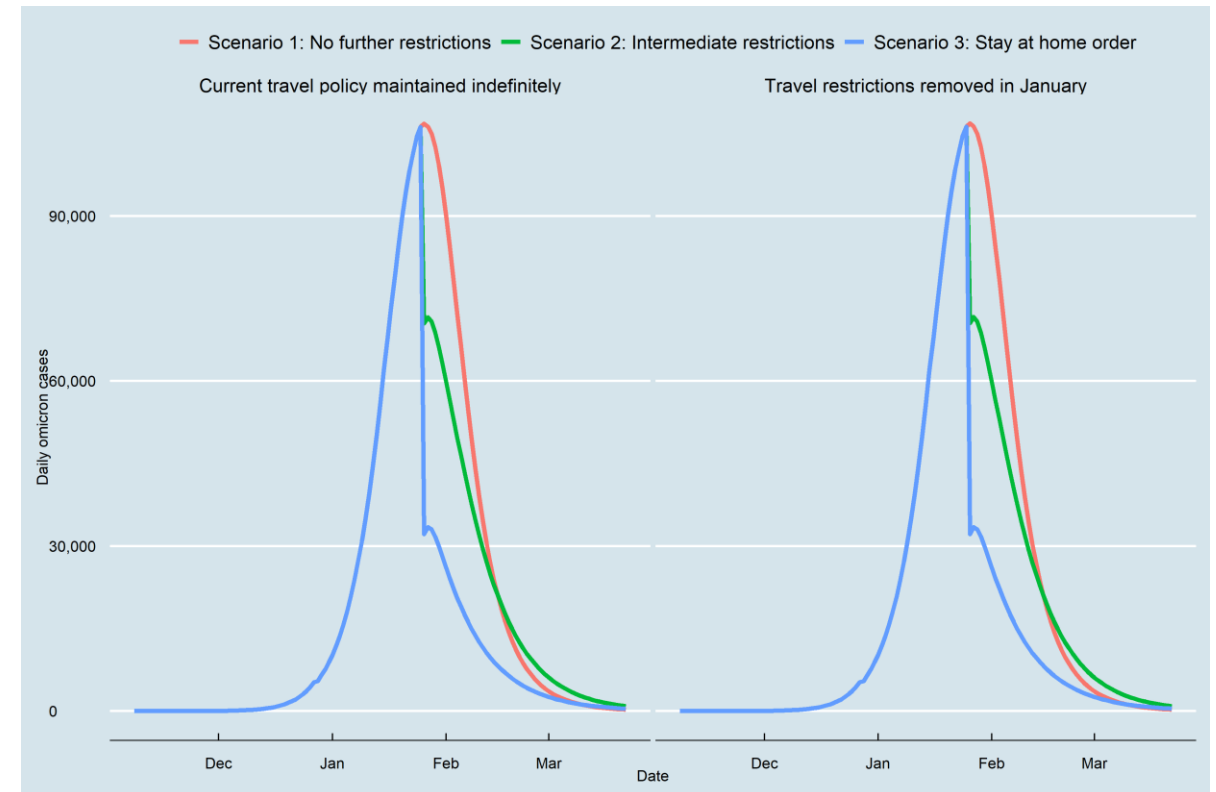




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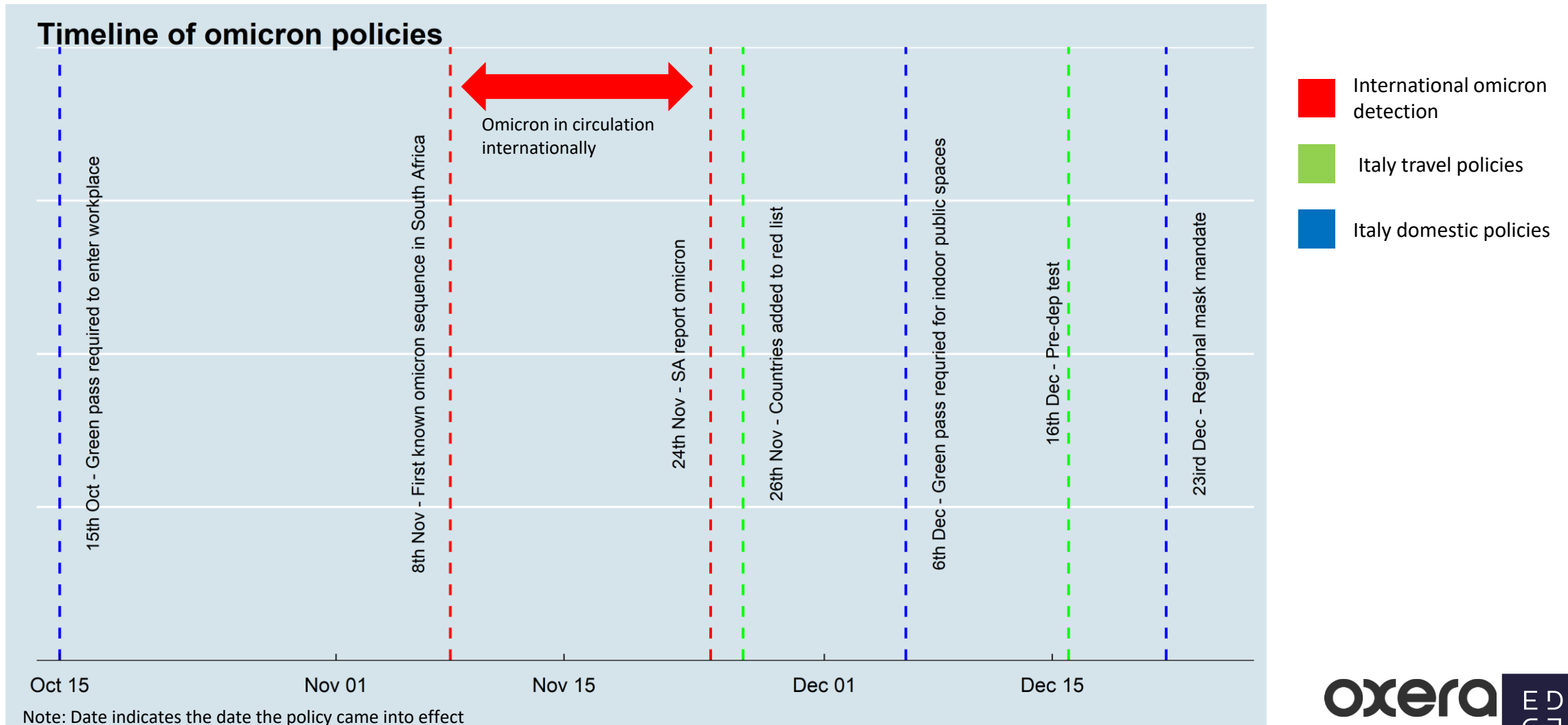
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1. Impact of travel restrictions on Omicron in Italy

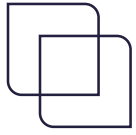
1.1 Background – the Omicron response in Italy



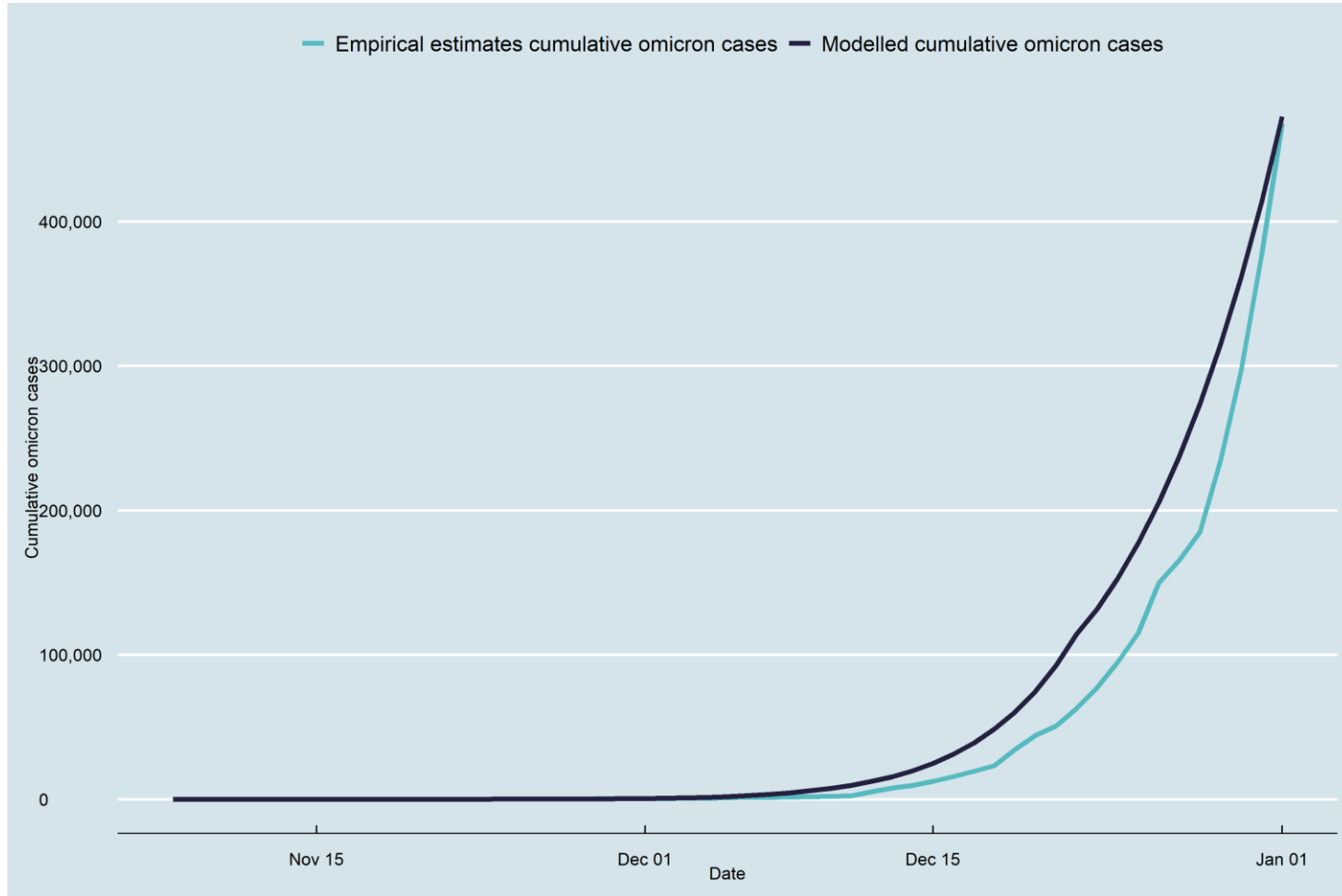
Testing of air travellers was introduced on 16 December, a few weeks after South Africa reported Omicron. The variant was likely in circulation internationally for a month prior to being reported, meaning that it was **being seeded for at least six weeks** before the travel restrictions were introduced.



1.2 Travel testing and quarantine policy - what we can learn from the Omicron response in Italy



Our model predictions closely match empirical estimates of Omicron cases in Italy. Both suggest that cases are growing exponentially.



- Based on the Italian government's travel testing policy in November / December* and estimates of Omicron prevalence among passengers,** our modelled cumulative Omicron cases closely match empirical estimates of Omicron cases in Italy.***
- We estimate Omicron cases in Italy based on recorded cases and domestic sequencing data.

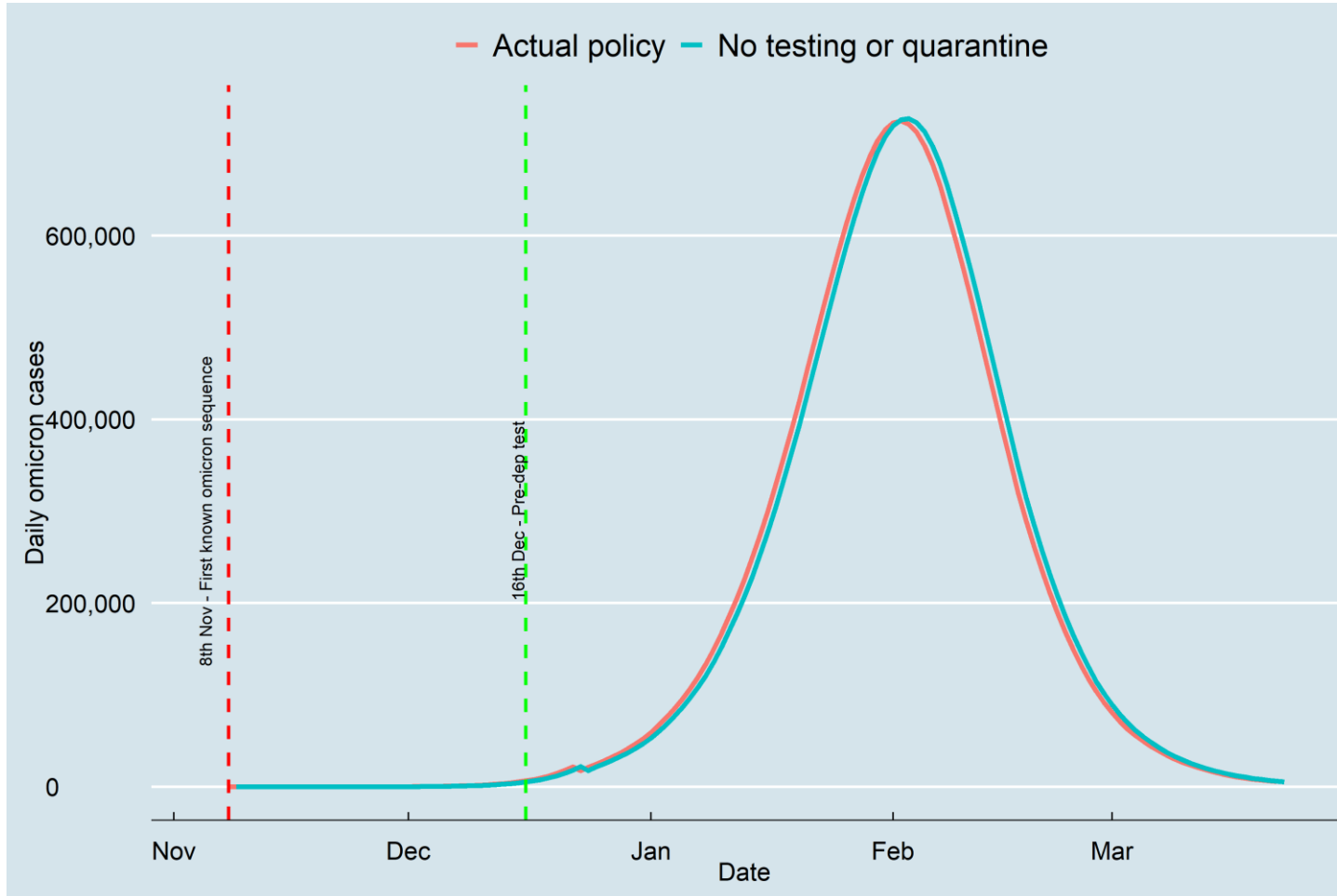
*The Italian government introduced pre-departure PCR testing on 16 December.

**Based on an average of sequencing data across European countries (ECDC).

***Based on data from the ECDC.



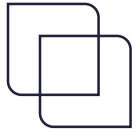
Additional travel testing introduced in mid-December was ineffective at preventing the spread of Omicron in Italy



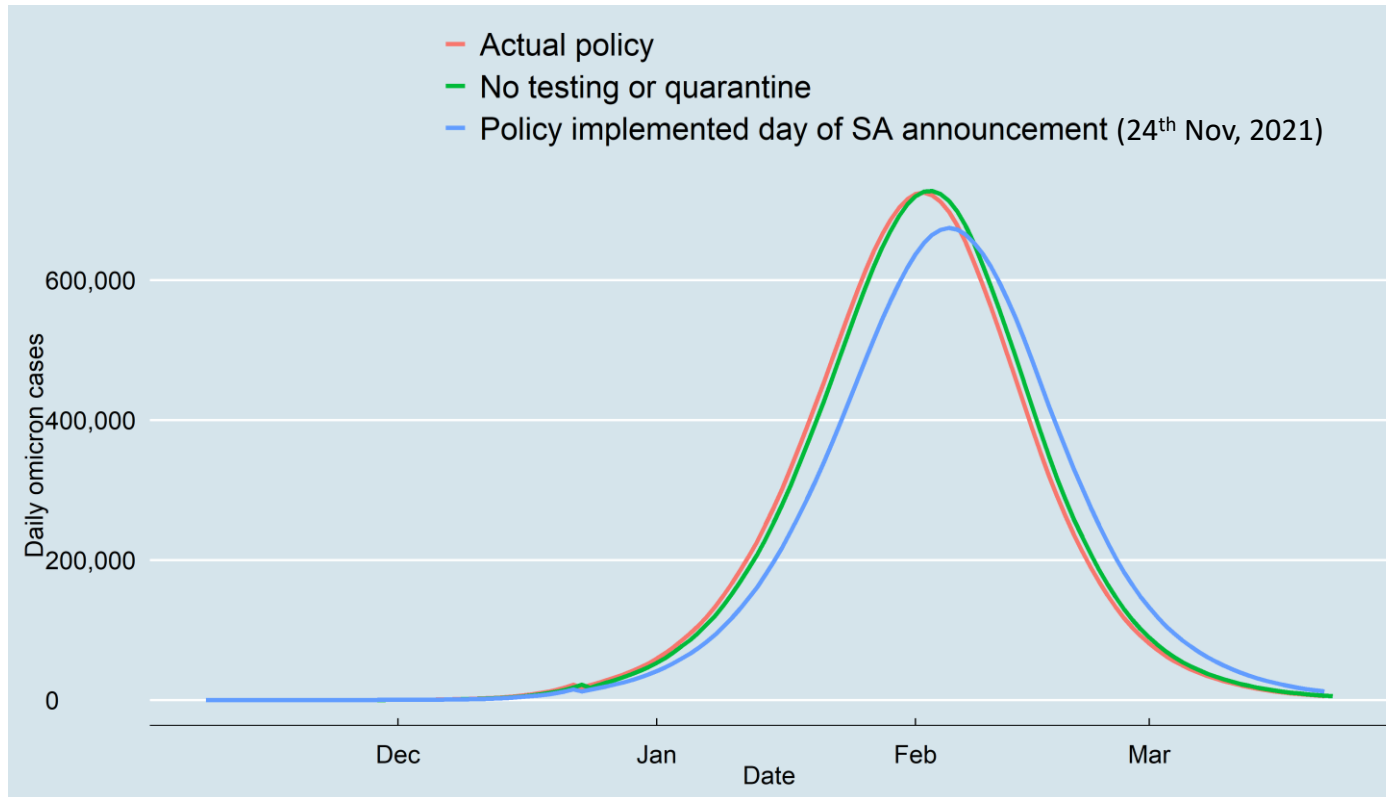
- We model Italy’s actual travel testing policy* (red line) and compare it to what would have happened had the government made no changes to travel testing policy—i.e. no testing or quarantine (blue line)
- The modelled trajectories of Omicron cases in Italy are **virtually indistinguishable**, suggesting that **introducing further travel restrictions on 16 December was ineffective.**

* The Italian government introduced pre-departure PCR testing on 16 December.

Note: We assume that domestic policies continue as-is for all of the above scenarios. We have also lagged the position of the lines for illustrative purposes, however, the raw modelling results in two perfectly overlapping curves.



Even if travel testing had been in place in November (i.e. the day Omicron was identified as an issue by the WHO), Omicron's spread in Italy would have only been minimally impacted



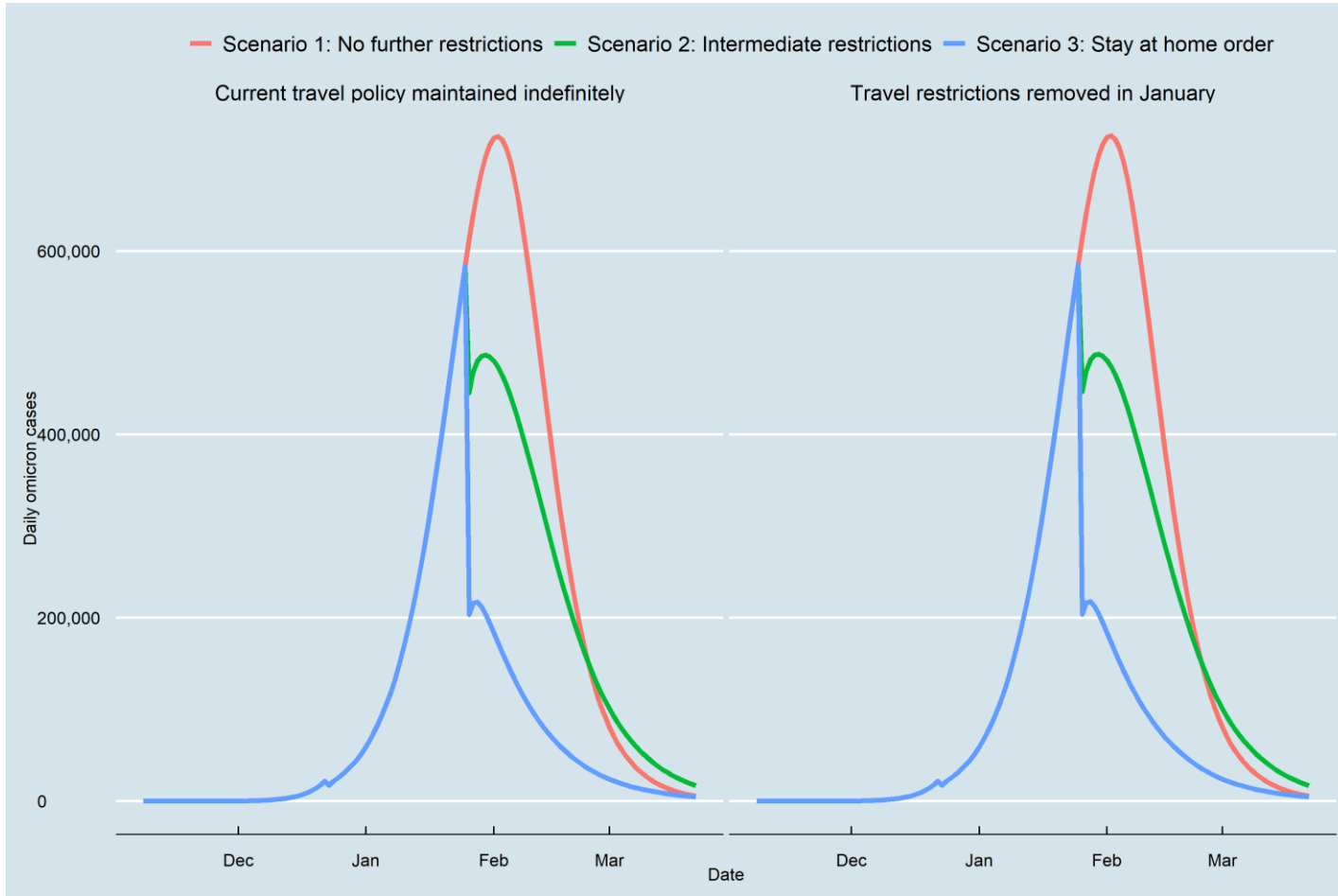
- If the government had not had any travel restrictions in place in November/December (green line), cases would have peaked only **three days** sooner compared to a scenario where travel restrictions were put in place on the same day that Omicron was flagged as an issue to the WHO on 24 November (blue line).
- The peak would have been 8% higher without any travel testing compared to a scenario where travel restrictions were introduced on the same day that Omicron was flagged as an issue to the WHO in November (blue line).
- This is in large part due to the ongoing vaccination campaigns for children aged 5-12 and the booster dose campaign.

Note: We assume that domestic policies continue as-is for all of the above scenarios. We assume that pre-departure antigen (24h) or PCR (48h) testing policy was put in place either on 24 November, the day South Africa reported Omicron to the WHO (Policy implemented day of SA announcement) or on the 16th of December (Actual policy).

1.3 Current response to the Omicron variant – weighing the impact of travel and domestic responses going forward in Italy



Now that Omicron is highly prevalent in Italy, removing all travel testing would not impact domestic Omicron spread. Domestic restrictions would now have a more significant impact on Omicron cases in Italy than travel testing.



- Removing all travel testing would not impact the spread of Omicron in Italy.
 - We consider a scenario where travel tests were lifted on 1 January 2022. Peaks are 0.11%-0.23% higher when travel restrictions are removed.
- On the other hand, retaining travel testing could impose a significant cost on the Italian economy.
- This is consistent across scenarios where different domestic restrictions (e.g. limits on gathering, work from home orders) are applied on 26 January 2022.

See appendix A.3 for assumptions on the impact of domestic restrictions.

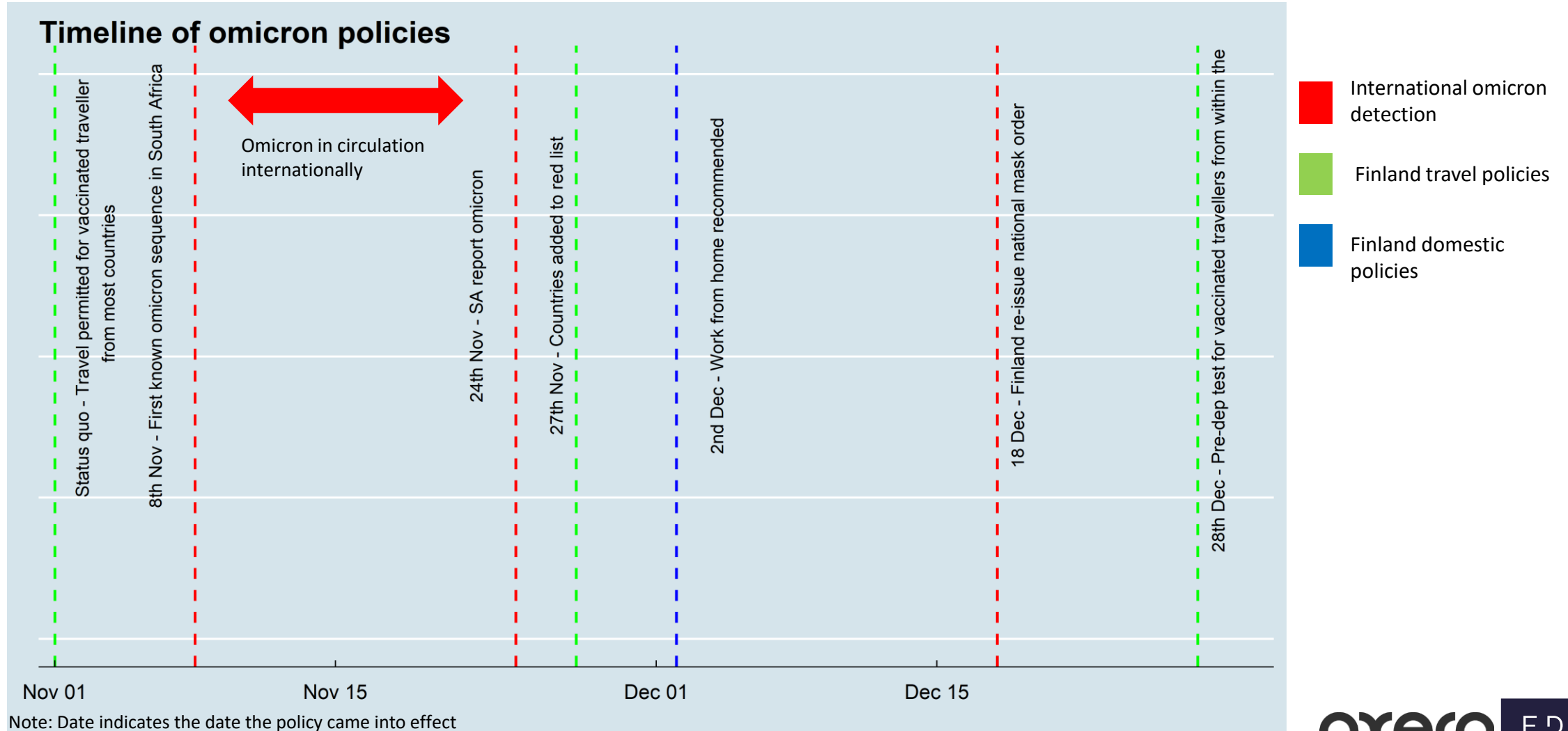
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2. Impact of travel restrictions on Omicron in Finland

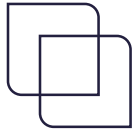
2.1 Background – the Omicron response in Finland



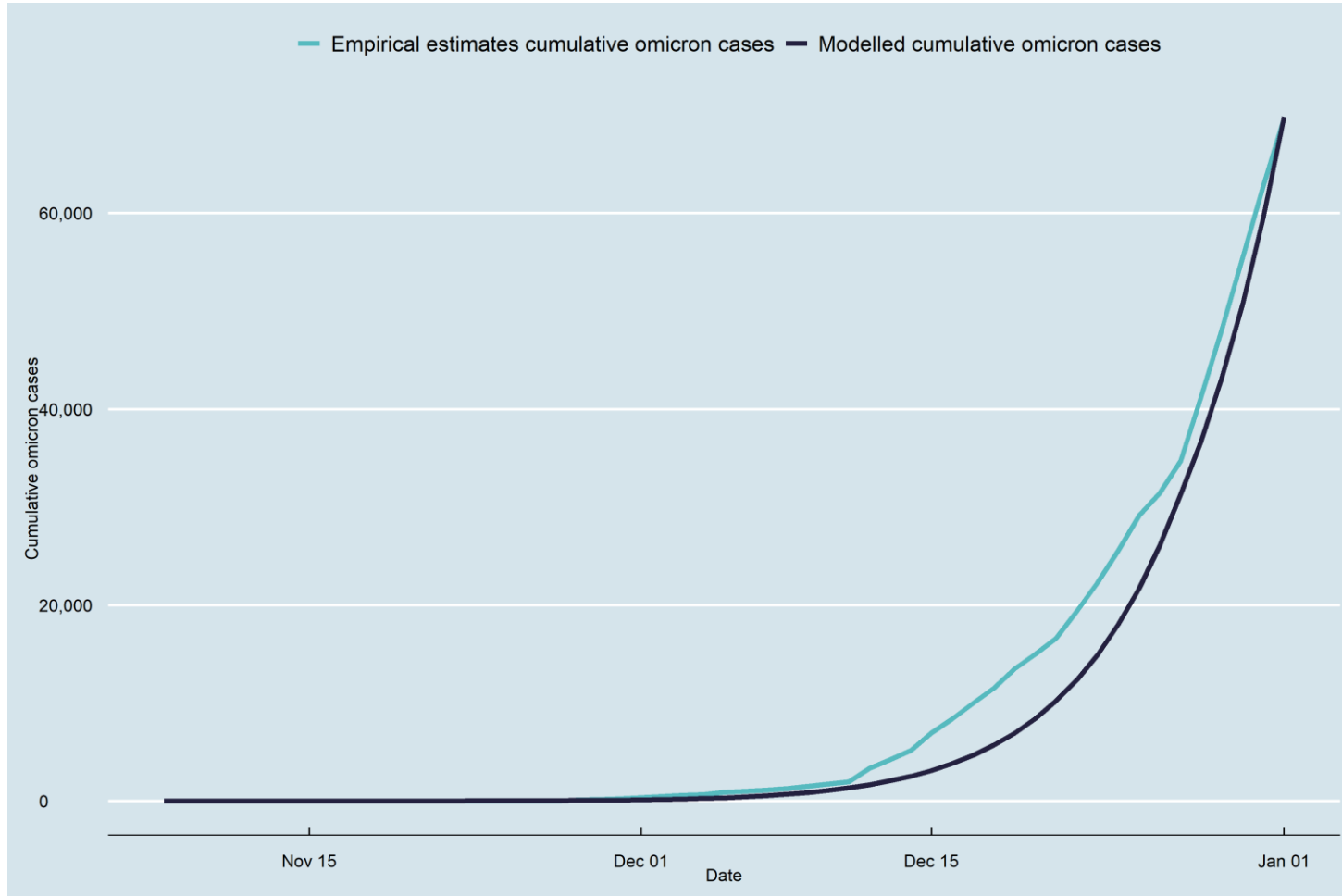
Testing of air travellers was introduced on 28 December, a month after South Africa reported Omicron. The variant was likely in circulation internationally for a month prior to being reported, meaning that it was **being seeded for at least eight weeks** before the travel restrictions were introduced.



2.2 Travel testing and quarantine policy - what we can learn from the Omicron response in Finland



Our model predictions closely match empirical estimates of Omicron cases in Finland. Both suggest that cases are growing exponentially.

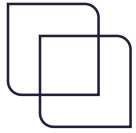


- Based on the Finnish government's travel testing policy over the course of November/December* and estimates of Omicron prevalence among passengers,** our modelled cumulative Omicron cases closely match empirical estimates of Omicron cases in Finland.***
- We estimate Omicron cases in Finland based on recorded cases and domestic sequencing data.

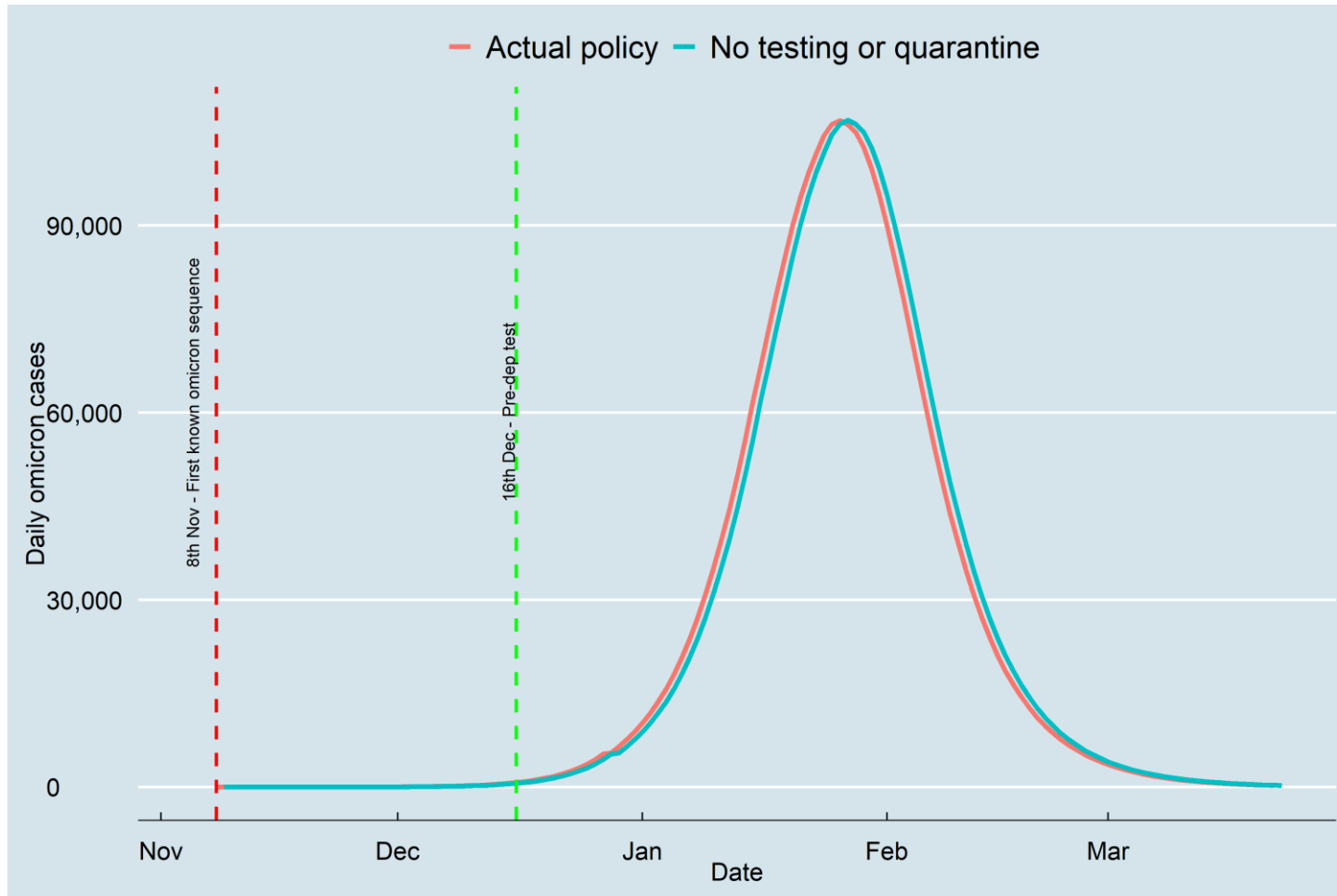
*The Finnish government introduced pre-departure PCR testing on 28 December.

**Based on an average of sequenced cases across European countries (ECDC).

***Based on data from the ECDC.



Additional travel testing introduced at the end of December was ineffective at preventing the spread of Omicron in Finland



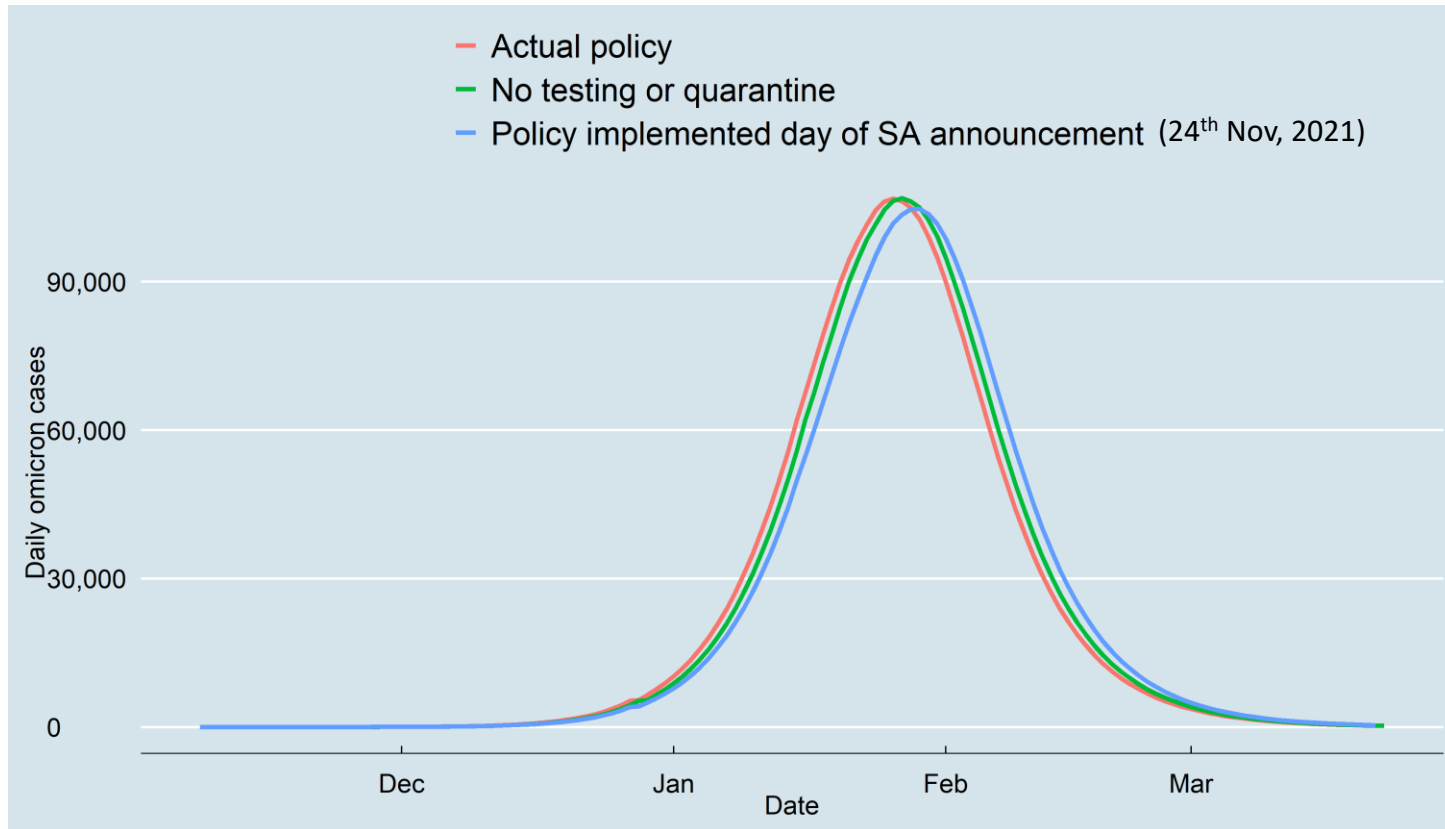
- We model Finland’s actual travel testing policy* (red line) and compare it to what would have happened had the government made no changes to travel testing policy—i.e. no testing or quarantine (blue line).
- The modelled trajectories of Omicron cases in Finland are **indistinguishable**, suggesting that **introducing travel restrictions on 28 December was ineffective**.

*The Finnish government introduced pre-departure PCR testing on 28 December.

Note: We assume that domestic policies continue as-is for all of the above scenarios. We have also lagged the position of the lines for illustrative purposes, however, the raw modelling results in two perfectly overlapping curves.



Even if travel testing had been in place in November (i.e. the day Omicron was identified as an issue by the WHO), Omicron's spread in Finland would not have been impacted



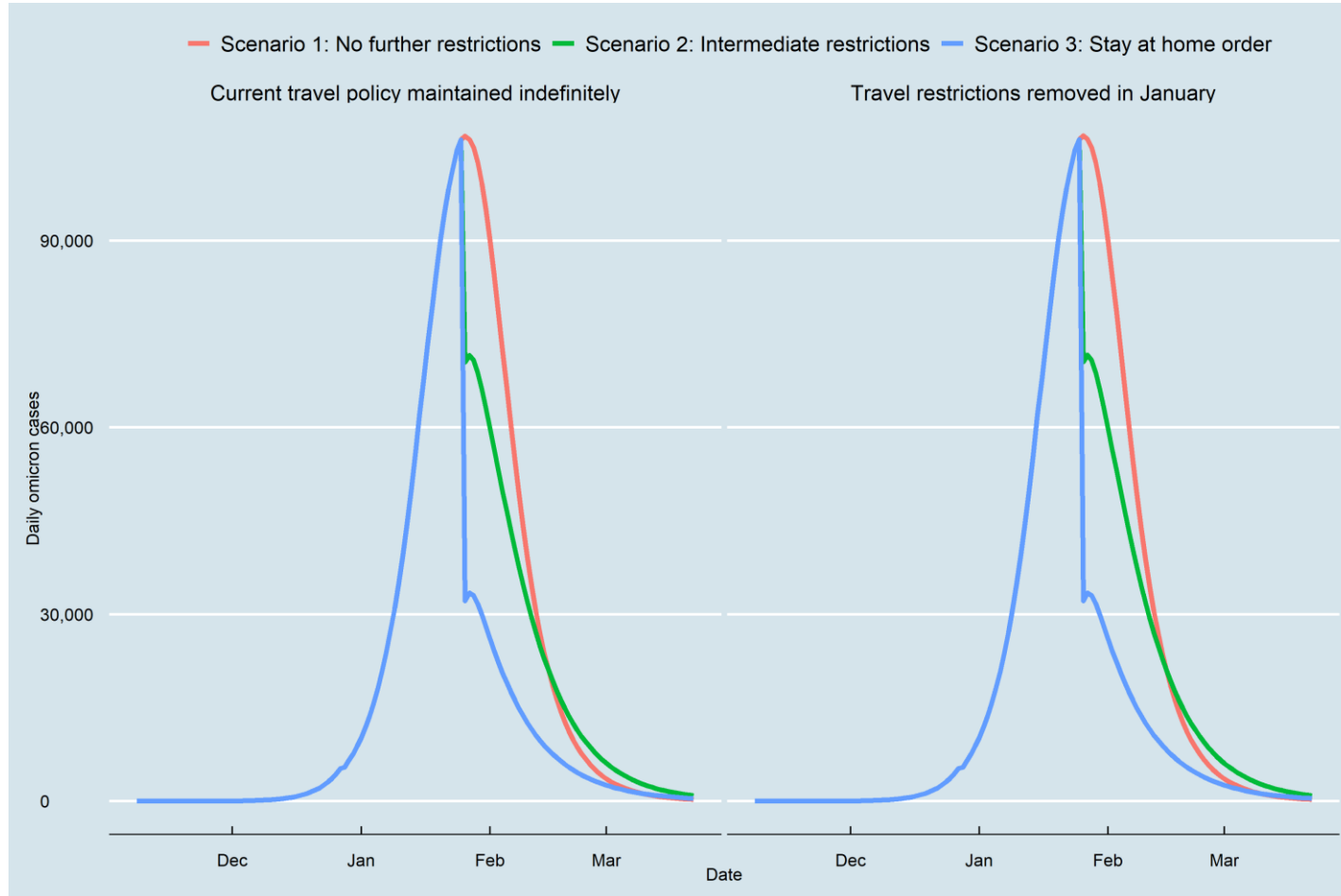
- If the government had not had any travel restrictions in place in November/December (green line), cases would have peaked only **three days** sooner compared to a scenario where travel restrictions were put in place on the same day that Omicron was flagged as an issue to the WHO on 24 November (blue line).
- The peak would have been 2% higher without any travel testing compared to a scenario where travel restrictions were put in place immediately once Omicron was flagged as an issue to the WHO in November (blue line).

Note: We assume that domestic policies continue as-is for all of the above scenarios. We assume that pre-departure antigen (48h) or PCR (48h) testing policy was put in place either on 24 November, the day South Africa reported omicron to the WHO (Policy implemented day of SA announcement) or on 28 December (Actual policy).

2.3 Current response to the Omicron variant – weighing the impact of travel and domestic responses going forward in Finland



Now that Omicron is highly prevalent in Finland, removing all travel testing would not impact domestic Omicron spread. Domestic restrictions would now have a more significant impact on Omicron cases in Finland than travel restrictions.



- Removing all travel testing in January would not impact the spread of Omicron in Finland.
 - We consider a scenario where travel testing was lifted on 1 January 2022. Peaks are 0.06%-0.07% higher when travel testing is removed.
- On the other hand, retaining travel testing could have a significant cost on the Finnish economy.
- This is consistent across scenarios where different domestic restrictions (e.g. limits on gathering, work from home orders) are applied on 26 January 2022.

See appendix A.3 for assumptions on the impact of domestic restrictions.

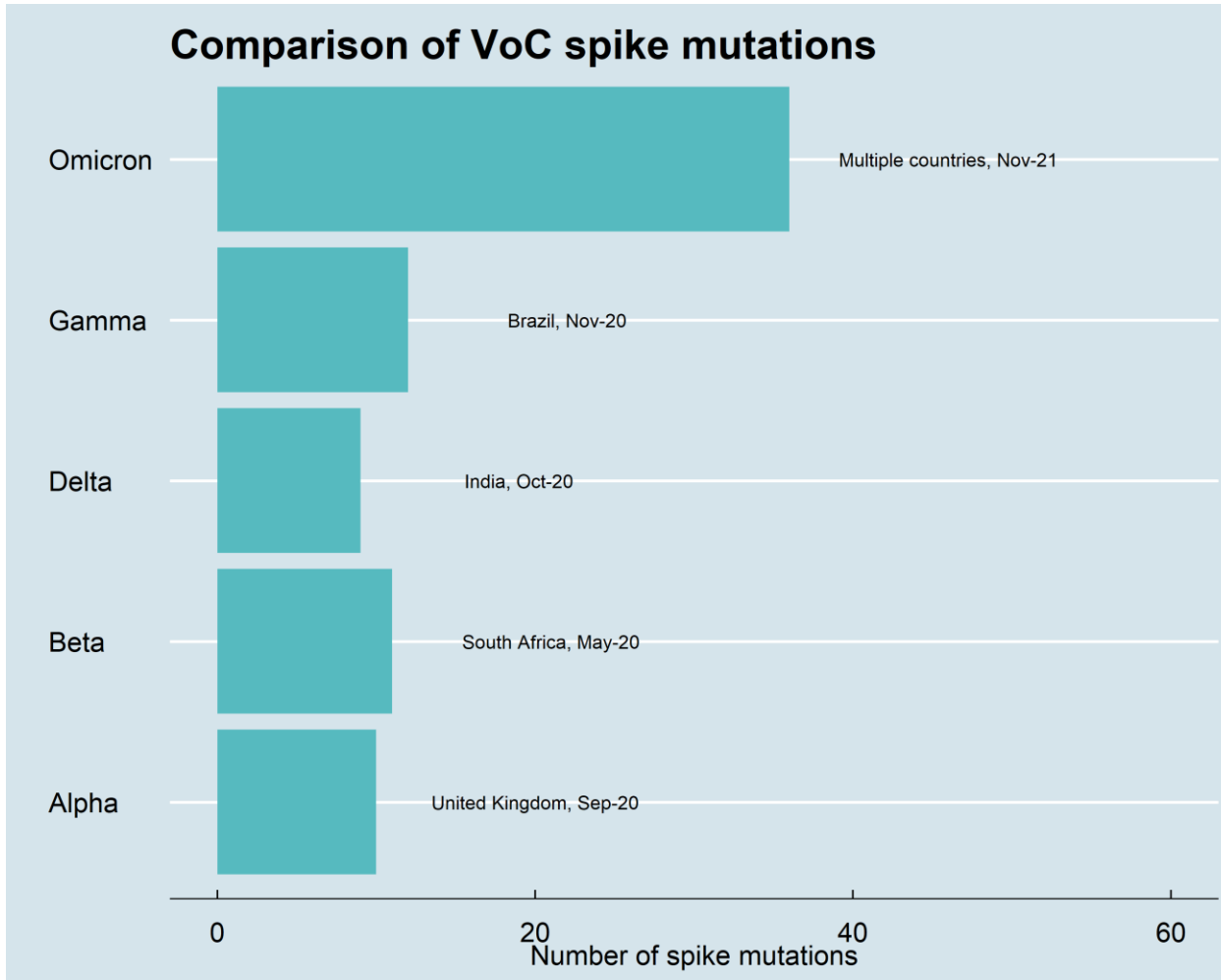
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3. Appendix – literature review, modelling methodology and assumptions

A.1 Literature review – what we know about the Omicron variant



Omicron has more mutations in the spike protein than previous variants. While some of these mutations may be associated with increased infectiousness, others may be associated with reduced severity.

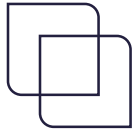


Note: Graph annotations indicate the month, year, and location where each variant was first sequenced (WHO).

- SARS-Cov-2's spike protein has an important role in infectiousness and severity of Covid-19, as it is how the virus attaches to human cells.*
- Many mutations in this area may change the infectiousness, severity, and ability of the variant to evade immunity.
- Omicron is thought to be more infectious. However, mutations in this area may also contribute to reducing the severity of resulting illness after infection. **

* <https://www.who.int/en/activities/tracking-SARS-CoV-2-variants/>

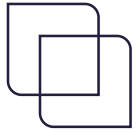
** [biorxiv.org/content/10.1101/2021.12.17.473248v2](https://doi.org/10.1101/2021.12.17.473248v2)



Although evidence is still in early stages, laboratory and real-world studies to date indicate that while Omicron is more infectious and vaccines are less effective at preventing infections, illnesses resulting from infections may be less severe.

	Infectiousness	Vaccine efficacy (i.e. immune escape)	Severity
Omicron characteristics, relative to Delta (previously dominant variant in Italy and Finland)	<ul style="list-style-type: none">• Data and laboratory studies to date indicate that Omicron is 2-3 times more infectious than delta.• As studied populations are now highly vaccinated or have high levels of natural immunity, it is difficult to attribute the increase in observed infectiousness of Omicron relative to Delta to innate infectiousness or to immune escape/decreases in vaccine efficacy. It is likely to be a combination of both.	<ul style="list-style-type: none">• Data and laboratory studies to date indicate that vaccines are 25-66% as effective at preventing Omicron compared to Delta infections (varies by dose).• As studied populations are now highly vaccinated or have high levels of natural immunity, it is difficult to attribute the increase in observed infectiousness of Omicron relative to Delta to innate infectiousness or to immune escape/decreases in vaccine efficacy. It is likely to be a combination of both.	<ul style="list-style-type: none">• While studies and emerging data are still in early stages, several studies are now pointing to Omicron infections being milder than Delta infections. Real-world data suggests that patients' hospital admission risk decreased by 62%.• This effect is demonstrated even when variation in vaccination status is accounted for.

A.2: Modelling methodology



Background on SARS-Cov-2 infection spread dynamics

One measure of how easily a virus is spread from one person to another is the virus' reproductive ratio (called its 'R' value). R_t represents the average number of secondary infections that will result from an initial infection at a given time.

Effective reproduction number is determined by the following:

- **R_0 , basic reproduction number:** the average number of secondary infections resulting from an initial infection in a fully susceptible population.
- **Vaccination-induced immunity:** the proportion of the population prevented from being infected by the virus (either symptomatically or asymptotically) and hence prevented from spreading the virus due to being vaccinated.
- **Natural immunity:** the proportion of the population prevented from being infected by the virus (either symptomatically or asymptotically) and hence prevented from spreading the virus due to previous exposure to the virus
- **Behavioural patterns:** different patterns in interactions may hinder the spread of a virus. For example, reduced social interactions, social distancing and masks will contribute to reducing the spread.

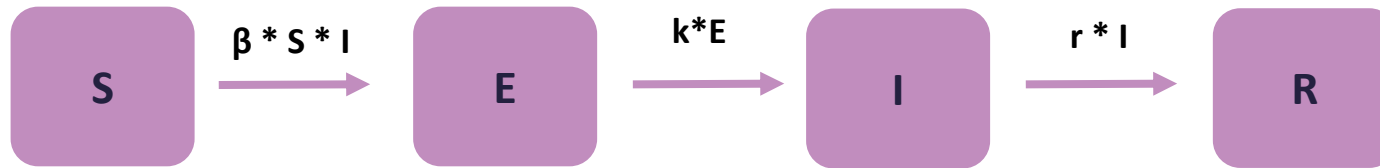
If $R_t > 1$, the virus will spread in a population.



Basic SEIR modelling review

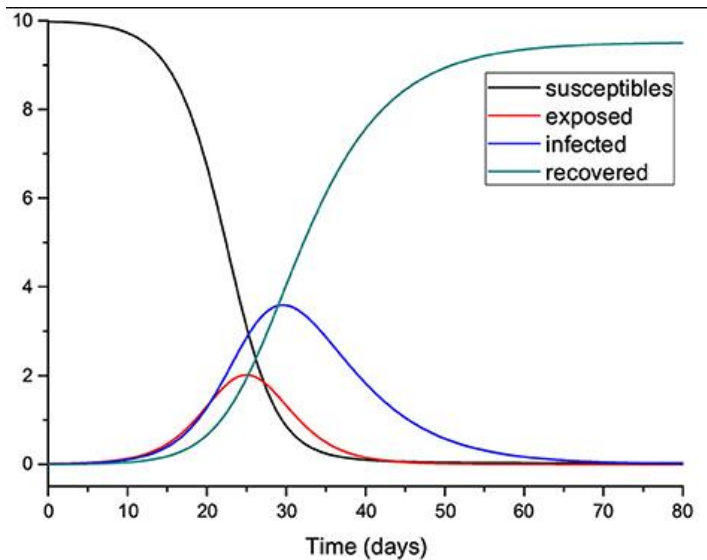
The entire population is split into groups corresponding to the *S*, *E*, *I*, and *R* states

- **S**usceptible
- **E**xposed
- **I**nfected
- **R**emoved



where:

- β is the parameter for infectivity
- r is the constant per capita recovery rate
- k is the constant per capita progression from exposed to infectious rate



Assumptions

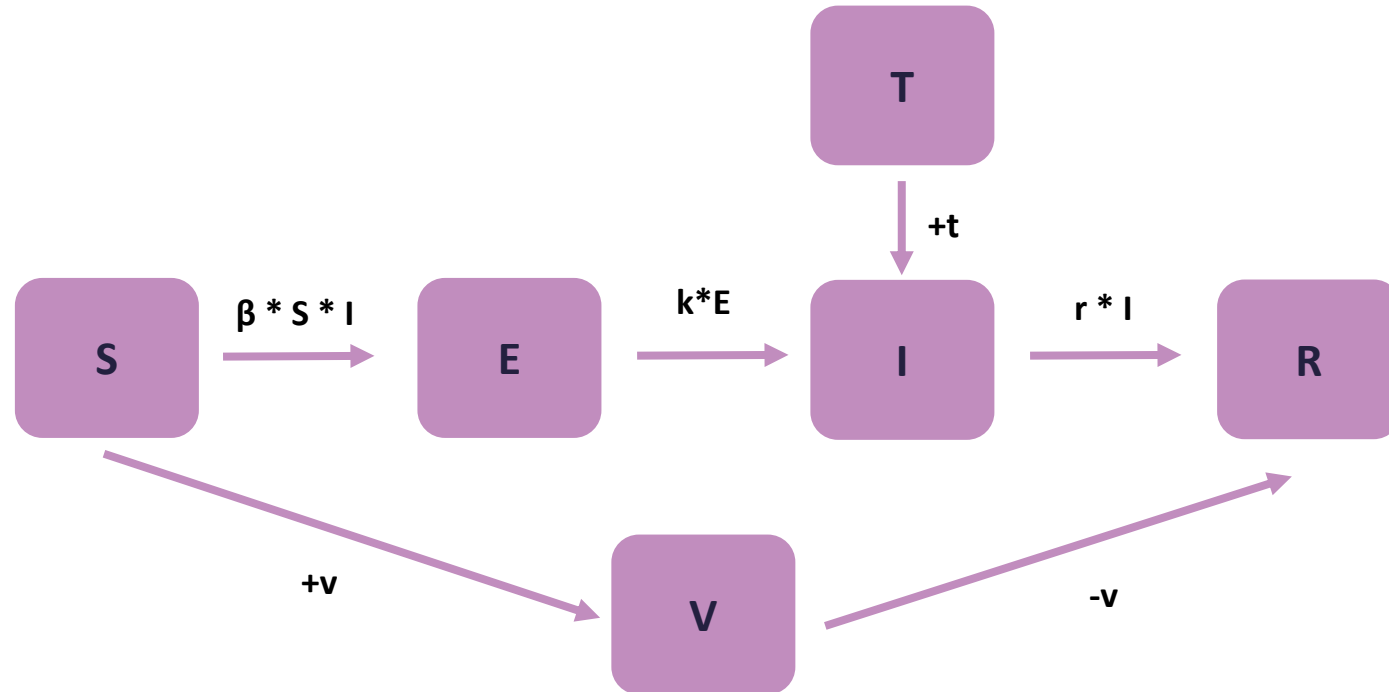
- No one is added to the susceptible group, since we are ignoring births and immigration
- The only way an individual leaves the susceptible group is by becoming infected
- A fixed fraction of the infected group recovers (or dies) every day and is immune to the disease



Our modelling approach: SEIR modelling including vaccinations and imported cases

The entire population is split into groups corresponding to the *S*, *E*, *I*, and *R* states and others

- **S**usceptible
- **E**xposed
- **I**nfectious
- **R**emoved
- **V**accinated
- **T**ransported cases

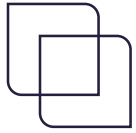


where:

- β is the parameter for infectivity
- r is the constant per capita recovery rate
- k is the constant per capita progression from exposed to infectious rate
- v is the change in vaccine induced immunity in the population
- t is daily travel-imported cases

Assumptions

- No one is added to the susceptible group, since we are ignoring births and immigration
- The only way an individual leaves the susceptible group is by becoming infected or vaccinated
- A fixed fraction of the infected group recovers (or dies) every day and is immune to the disease



Scenarios considered in the modelling

Key question:

What would the impact of different travel policies have been on the outcome of Omicron spread in Italy / Finland?

What would the spread and impact of the Omicron variant in Italy / Finland have been under the following scenarios:

- Pre-departure antigen (24h) or PCR testing (48h) - Italy
- Pre-departure antigen (48h) or PCR testing (48h) - Finland
- Actual policy (a combination of all of the above, at different points in time)
- No testing or quarantine

Key question:

Now that the Omicron variant is highly prevalent in Italy / Finland, what would the relative impact of domestic measures be compared to further travel restrictions?

What will the the spread and impact of the Omicron variant in Italy / Finland be under the following scenarios:
Italy:

- Mandatory masks, symptomatic testing
- Some restrictions on businesses (i.e. green pass/super green pass)
- Intermediate scenario: Limits on gathering sizes to 10 people, in addition to some restrictions of businesses
- Stay at home order: businesses closed, schools and universities closed in conjunction

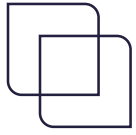
Finland:

- Symptomatic testing
- Mandatory masks and work-from home order
- Intermediate scenario: Some restrictions to businesses and limits of gathering sizes to 10 people
- Stay at home order: businesses closed, schools and universities closed in conjunction

Compared with:

- Continued pre-departure policy or
- No testing or quarantine January onwards

A.3: Literature review and modelling assumptions



Assumptions: travel volumes and air passenger prevalence

Model input	Description	Value	Source														
Median infectious days an air passenger spends at their destination	Without quarantine and testing schemes, when a passenger is infected in another country, they will spend some of their infectious days in their country of departure and some in their country of arrival. Using a simulation model based on a paper from LSHTM, we estimated that the median number of infectious days a passenger will spend in their country of arrival is 3.	3 days	Oxera and Edge Health (2021) 'Effectiveness of dual-testing schemes for air passengers'. For LSHTM's work see: Clifford et al. (2020), 'Strategies to reduce the risk of SARS-CoV-2 re-introduction from international travellers', 25 July.														
Air passenger volumes (Italy)	We use publicly available data on passenger volumes from the Association of Italian airports (AIGA). We assume that most passengers are completing round trips, so total passenger volumes are divided by two to get inbound passengers. We project travel volumes by scaling the latest available values using seasonal scaling factors from 2019 (pre-pandemic). As data from November 2021 and December 2021 was not yet publicly available, at the time of writing we use the same assumptions for these months as well.	<table border="1"> <thead> <tr> <th>2021/2022</th> <th>Inbound passengers</th> </tr> </thead> <tbody> <tr> <td>October</td> <td>5,339,928</td> </tr> <tr> <td>November</td> <td>4,167,357</td> </tr> <tr> <td>December</td> <td>4,232,595</td> </tr> <tr> <td>January</td> <td>3,926,630</td> </tr> <tr> <td>February</td> <td>3,479,699</td> </tr> <tr> <td>March</td> <td>4,407,654</td> </tr> </tbody> </table>	2021/2022	Inbound passengers	October	5,339,928	November	4,167,357	December	4,232,595	January	3,926,630	February	3,479,699	March	4,407,654	https://assaeroporti.com/statistiche_202110/
2021/2022	Inbound passengers																
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Air passenger volumes (Finland)	We use publicly available data on passenger volumes from the Finish National Statistics Office. We use arriving passenger data. We project travel volumes by scaling the latest available values using seasonal scaling factors from 2019 (pre-pandemic). As data from November 2021 and December 2021 was not yet publicly available, at the time of writing we use the same assumptions for these months as well.	<table border="1"> <thead> <tr> <th>2021/2022</th> <th>Inbound passengers</th> </tr> </thead> <tbody> <tr> <td>October</td> <td>382,728</td> </tr> <tr> <td>November</td> <td>432,580</td> </tr> <tr> <td>December</td> <td>443,064</td> </tr> <tr> <td>January</td> <td>393,528</td> </tr> <tr> <td>February</td> <td>375,352</td> </tr> <tr> <td>March</td> <td>432,295</td> </tr> </tbody> </table>	2021/2022	Inbound passengers	October	382,728	November	432,580	December	443,064	January	393,528	February	375,352	March	432,295	https://www.stat.fi/til/ilma/2021/06/ilma_2021_06_2021-07-28_tie_001_en.html
2021/2022	Inbound passengers																
October	382,728																
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December	443,064																
January	393,528																
February	375,352																
March	432,295																
Air passenger Covid-19 prevalence	We estimate the prevalence of incoming air passengers, using UK Government Test-and-Trace data available up to 13 December. Using tourism data and passengers numbers by country for Italy and Finland, we adjust the UK values with relative weights to estimate a country-specific proxy for the prevalence among inbound passengers. We conservatively use prevalence in mid-October, before the UK government moved to Day 2 antigen testing.	Italy prevalence: 0.53% Finland prevalence: 0.70%	https://www.gov.uk/government/publications/weekly-statistics-for-nhs-test-and-trace-england-2-to-8-december-2021 https://www.bancaditalia.it/pubblicazioni/indagine-turismo-internazionale/2021-indagine-turismo-internazionale/statistiche_ITI_18062021.pdf https://www.finavia.fi/en/about-finavia/about-air-traffic/traffic-statistics/traffic-statistics-year														
Percent of positive traveller cases attributed to Omicron	The percentage share of Omicron cases are based on the European average from the "SARS-CoV-2 variants dashboard" disclosed by the European Centre for Disease Prevention and Control.	<table border="1"> <thead> <tr> <th>Date</th> <th>% of positive omicron</th> </tr> </thead> <tbody> <tr> <td>November</td> <td>0.12%</td> </tr> <tr> <td>December</td> <td>30.66%</td> </tr> <tr> <td>January</td> <td>70.94%</td> </tr> </tbody> </table>	Date	% of positive omicron	November	0.12%	December	30.66%	January	70.94%	https://www.ecdc.europa.eu/en/covid-19/situation-updates/variants-dashboard https://www.iss.it/cov19-cosa-fa-iss-varianti						
Date	% of positive omicron																
November	0.12%																
December	30.66%																
January	70.94%																



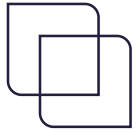
SARS-Cov-2 and Omicron-specific parameters (1)

Model input	Description	Value	Source
Ro	Initial data suggests that the Rt and secondary attack rates of the Omicron variant is 2-3 times higher than that of the Delta variant. While some of this difference is likely due to differing immunity for the variants in the population, we conservatively assume that Omicron is 2.5 times more infectious than delta.	8, assuming that Delta has an Ro of ~3.2 (this assumes pre-pandemic mixing patterns).	https://www.medrxiv.org/content/10.1101/2021.12.19.21268038v1.full.pdf , https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1043466/20211222_OS_Daily_Omicron_Overview.pdf , https://github.com/blab/rt-from-frequency-dynamics/tree/master/estimates/omicron-countries . Ro of Delta: https://academic.oup.com/jtm/article/28/7/taab124/6346388
Days infectious	We use the median time an individual is infectious calculated from previous variants.	7.35 days	Oxera and Edge Health (2021) 'Effectiveness of dual-testing schemes for air passengers'. For LSHTM's work see: Clifford et al. (2020), 'Strategies to reduce the risk of SARS-CoV-2 re-introduction from international travellers', 25 July.
Incubation period	Preliminary evidence suggests that the time from exposure to symptoms is shorter for the Omicron variant compared to other variants.	3 days	https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2021.26.50.2101147
Estimates of Omicron cases compared to Delta cases	The ECDC publishes estimates of the % of sequenced samples which were determined to be Omicron by EU country. We use this to estimate the curves shown on pages 9 and 18.	---	https://www.ecdc.europa.eu/en/covid-19/situation-updates/variants-dashboard
Delay between vaccination and vaccine efficacy	While immunity builds up over time after individuals are vaccinated, there is still substantial protection from vaccinations (~60%) on the first day after vaccination. Using a step function we are able to approximate this effect.	Step function, 1 week	http://www.bccdc.ca/Health-Info-Site/Documents/COVID-19_vaccine/Public_health_statement_deferred_second_dose.pdf



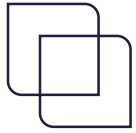
SARS-Cov-2 and omicron-specific parameters (2)

Model input	Description	Value	Source
Impact of natural immunity (for the Alpha variant)	<p>Studies conducted in England suggest that a previous history of infection reduces the risk of re-infection by 84%. Infections with previous variants were protective against infection with the Alpha variant. Immunity was observed for a minimum of 7 months after initial infection.</p> <p>We assume that the immunity for the Delta variant is similar, and apply scaling based on estimates of the relative efficacy of vaccines to the Omicron and Delta variants.</p>	84% decrease in risk of infection, immune escape of 16%	https://www.sciencedirect.com/science/article/pii/S0140673621006759?casa_token=d-Aupl8roEYAAAAA:E_YnW1p75HIEH7DgPN_N_7aCANo7QcSrK93TlvcAS2khOBLt6rCwhCpwh8eYPh-bMGlscQ6k
Natural immunity for Omicron compared to Delta variant	<p>We estimate this using the relative efficacy (for vaccinated individuals with 2 or 3 doses) against the Omicron variant compared to the Delta variant, using a weighted average of the Pfizer +Pfizer and AZ + Pfizer combination.</p>	54%	https://www.imperial.ac.uk/media/imperial-college/medicine/mrc-gida/2021-12-16-COVID19-Report-48.pdf
Unvaccinated population who has previously been infected	<p>We conservatively assume that a portion of the unvaccinated population have natural immunity, based on confirmed covid cases in Italy and Finland in the 7 months prior to November 2021.</p> <p>Using modelling comparing reported cases with the actual burden of disease, we estimate that that only roughly a third of cases are reported.</p>	Finland: 14% Italy: 21%	https://covid19.who.int/info?openIndex=2 https://demo.istat.it/popres/index.php?anno=2021&lingua=ita https://www.stat.fi/til/vaerak/tau_en.html
Estimated relative efficacy of vaccinations against Omicron variant compared to the Delta variant	<p>Modelling from Imperial has estimated the relative efficacy of vaccinations against the Omicron variant, extrapolating laboratory studies to real-world efficacy. We supplement this with data on real-world efficacy, which is now starting to become available.</p> <p>These estimates are conservative compared to the range of scenarios estimated by other modelling groups (LSHTM).</p>	See table 1, page 14	https://www.imperial.ac.uk/media/imperial-college/medicine/mrc-gida/2021-12-16-COVID19-Report-48.pdf and https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1043807/technical-briefing-33.pdf for real-world supplementary data. https://cmmid.github.io/topics/covid19/reports/omicron_england/report_11_dec_2021.pdf



Assumptions: travel testing efficacy

Model input	Description	Value	Source
Pre-departure antigen or pre-departure PCR, 48 hours before departure	We use the efficacy of pre-departure testing at screening incoming air passenger infectious days as a model input. We used the estimated efficacy of antigen and PCR tests taken 48 h pre-departure, taking the weighted average assuming that 2/3s of passengers will opt for the cheaper antigen test option.	48%	Oxera and Edge Health (2021), 'Assessment of the effectiveness of rapid testing for SARS-CoV-2'.
Pre-departure antigen 24 hours before departure of PCR 48 hours pre-departure	We use the efficacy of pre-departure testing at screening incoming air passenger infectious days as a model input. The estimated efficacy of these two different types of tests taken at different time periods is the same. From some countries pre-departure PCR testing is 72 h pre-departure, however we conservatively assume that PCR testing is 48 h from all countries.	54%	Oxera and Edge Health (2021), 'Assessment of the effectiveness of rapid testing for SARS-CoV-2'.



Assumptions: vaccine roll-out

Model input	Description	Value	Source
Historic vaccination rates	We use age-stratified daily vaccination data for Italy and Finland to estimate age-stratified vaccination uptake. We divide vaccine counts by population pyramid estimates to obtain vaccination rates.	See source.	https://sampo.thl.fi/pivot/prod/en/vaccreg/cov19cov/summary_cov19covareatime https://github.com/italia/covid19-opendata-vaccini https://demo.istat.it/popres/index.php?anno=2021&lingua=ita https://www.stat.fi/til/vaerak/tau_en.html
Projected vaccination rates	We calculate the average daily vaccinations delivered by age band in the last week of currently available data to estimate the speed of the vaccination roll-out. We assume that the number of individuals receiving a second dose cannot exceed the number of individuals who had received a first dose 3 months prior. This is based on medical recommendations to get second doses within 3 months of the previous dose. Equally, we assume that the number of individuals receiving a third dose (booster) cannot exceed the number of individuals who had received a second dose. As the speed of vaccination roll-out is dose-specific, to prevent a violation of the assumption above in later stages of the projection, the speed of roll-out of for a dose is set to the speed of the dose of the lower tier where required. We do not assume that anyone under the age of 12 for Finland or 5 for Italy will be vaccinated as they are ineligible for vaccination at the time of writing.	--	https://sampo.thl.fi/pivot/prod/en/vaccreg/cov19cov/summary_cov19covareatime https://github.com/italia/covid19-opendata-vaccini https://demo.istat.it/popres/index.php?anno=2021&lingua=ita https://www.stat.fi/til/vaerak/tau_en.html



Assumptions: impact of domestic social distancing measures on infection spread (Italy)

Model input	Description	Value	Source
Impact of mandatory masks, symptomatic testing	The reduction in R_t resulting from non-pharmaceutical interventions.	-17.9%	https://www.medrxiv.org/content/10.1101/2020.05.28.20116129v4.full.pdf , http://epidemicforecasting.org/containment-calculator https://bmcmmedicine.biomedcentral.com/articles/10.1186/s12916-020-01872-8/figures/5
Impact of some businesses being suspended/restricted (approximation of green pass and super green pass)	The reduction in R_t resulting from non-pharmaceutical interventions. This is additive with impact of mandatory masks, symptomatic testing, limits of gathering sizes to 1000.	-46.3%	https://www.medrxiv.org/content/10.1101/2020.05.28.20116129v4.full.pdf , http://epidemicforecasting.org/containment-calculator
Intermediate restrictions: Impact of limits on gathering sizes to 10 people	The reduction in R_t resulting from non-pharmaceutical interventions. All interventions are additive (i.e. in addition to interventions mentioned in previous scenarios).	-61.0%	https://www.medrxiv.org/content/10.1101/2020.05.28.20116129v4.full.pdf , http://epidemicforecasting.org/containment-calculator
Impact of stay at home order, businesses closed, schools and universities closed in conjunction	The reduction in R_t resulting from non-pharmaceutical interventions. All interventions are additive (i.e. in addition to interventions mentioned in previous scenarios).	-82.2%	https://www.medrxiv.org/content/10.1101/2020.05.28.20116129v4.full.pdf , http://epidemicforecasting.org/containment-calculator



Assumptions: impact of domestic social distancing measures on infection spread (Finland)

Model input	Description	Value	Source
Impact of symptomatic testing	The reduction in R_t resulting from non-pharmaceutical interventions.	-9.6%	https://www.medrxiv.org/content/10.1101/2020.05.28.20116129v4.full.pdf , http://epidemicforecasting.org/containment-calculator https://bmcmmedicine.biomedcentral.com/articles/10.1186/s12916-020-01872-8/figures/5
Impact of work-from-home orders and mask orders	The reduction in R_t resulting from non-pharmaceutical interventions. All interventions are additive (i.e. in addition to interventions mentioned in previous scenarios).	-32.0%	https://bmcmmedicine.biomedcentral.com/articles/10.1186/s12916-020-01872-8#Abs1
Intermediate restrictions: Some restrictions to businesses and limits of gathering sizes to 10 people	The reduction in R_t resulting from non-pharmaceutical interventions. All interventions are additive (i.e. addition to interventions mentioned in previous scenarios).	-61.0%	https://www.medrxiv.org/content/10.1101/2020.05.28.20116129v4.full.pdf , http://epidemicforecasting.org/containment-calculator
Impact of stay at home order, businesses closed, schools and universities closed in conjunction	The reduction in R_t resulting from non-pharmaceutical interventions. All interventions are additive (i.e. addition to interventions mentioned in previous scenarios).	-82.2%	https://www.medrxiv.org/content/10.1101/2020.05.28.20116129v4.full.pdf , http://epidemicforecasting.org/containment-calculator