Norwegian Covid-19 scenarios for Autumn and Winter 2022-2023

FHI COVID-19 MODELLING TEAM, 8 NOV 2022

Sammendrag

I denne rapporten presenterer vi scenarioer for utviklingen av covid-19 høsten og vinteren 2022. Hovedmålet er å illustrere de viktigste usikkerhetene og hvilke parametere som vil påvirke utviklingen av covid-19 framover. Sett i sammenheng kan scenarioene også gi en pekepinn på et mulig spenn av utfall over de neste månedene, men på grunn av den store usikkerheten er det sammenligninger mellom de ulike scenarioene som er mest robust.

Vi undersøker både scenarioer der de nåværende variantene vil fortsette å dominere og scenarioer med nye varianter som vil overta. Uten nye varianter vil det i hovedsak være sesongvariasjon og avtagende immunitet som vil drive en mulig høst-/vinterbølge. Disse to faktorene sammen med usikkerhet rundt nivået av immunitet i befolkningen og usikkerhet om alvorlighet (antall smittede per innleggelse) gir et godt bilde av ulike scenarioer uten nye varianter. I alle disse scenarioene finner vi at ved toppen av en høst/vinter bølge vil det være færre enn 60 nye innleggelser per dag, et tall som er lignende det vi så sommerbølgen med BA.5. Epidemitoppen i disse scenarioene vil være i november eller tidlig desember. En epidemitopp kan også komme senere på grunn av faktorer som ikke er tatt med i modellen, som for eksempel påvirkning (interferens) fra andre sirkulerende virus.

For nye varianter vil en kombinasjon av muligheter for viruset til å omgå vår immunitet sammen med økt alvorlighet være den største faren. Uten økt alvorlighet er det usannsynlig at en epidemitopp vil være mye høyere enn sommerbølgen, men hvis en ny variant har doblet alvorlighet kan vi se en smittetopp som er noe høyere enn den første omikronbølgen i mars 2022.

Fortsatt god overvåkning er viktig for å kunne vurdere hvilket av disse ulike scenarioene som best beskriver virkeligheten, når og hvis man begynner å se tegn til endringer i overvåkningsdataene. Alle scenarioene inkluderer den økende trenden vi nå ser i sykehusinnleggelser. Hvis man kun baserer seg på disse dataene, vil det være vanskelig å skille de ulike scenarioene fra hverandre før man har sett toppen på kurven. Derfor er det viktig med god, bred overvåkning, forskning og internasjonal kunnskap for å kunne skille de ulike scenarioene fra hverandre. I tillegg ville kunnskap om faktisk antall smittede basert på målinger i tilfeldige utvalg av befolkningen gitt et mye bedre kunnskapsgrunnlag for scenarioer.

Scenarioer med nye varianter med økt alvorlighet vil kunne gi smittebølger som kan gi et betydelig press på sykehusene. Samfunnet bør være forberedt på disse scenarioene, selv om de ikke er de mest sannsynlige. I mange av scenarioene vil covid-19 kunne gi en betydelig tilleggsbyrde på sykehus, spesielt hvis en covid-19-bølge overlapper med andre luftveissykdommer.

Modeller er alltid forenklinger av virkeligheten og det er flere faktorer som ikke er med i modellen. Dette inkluderer viral interferens, endringer i befolkningens atferd eller store endringer i import av smitte fra utlandet. I tillegg er det stor usikkerhet rundt hvor mange som tidligere har vært smittet, samt alvorligheten av covid-19 hos smittede nå, som kan gi ganske store utslag i modellene.

Summary

In this report, we present a range of scenarios for the progression of covid-19 for the autumn and winter of 2022/2023. The main goal of these scenarios is to illustrate the key uncertainties and the most important parameters influencing the disease dynamics moving forward. Together the scenarios also give some indication for a likely range of outcomes over the next months. Still, due to large uncertainty in key parameters the scenarios should mainly be used to compare the impact of different parameters.

The report explores both situations where the current variants remain dominant and where a new variant takes over from the present variants. For the current variants, seasonality and waning of immunity would drive a potential wave during the autumn/winter. We find that these two factors in conjunction with uncertainties about population level immunity and severity of the current viruses illustrate well possible scenarios. In all of these scenarios we see a small peak of new hospitalisations, or in a few cases, similar to the peak in June/July 2022 caused by the BA.5 variant. The scenarios indicate that the peak will be in November or early December. The peak could also come later due to factors not included in the model, such as interference from other circulating viruses.

For potential new variants the biggest danger is if they have significant immune escape properties and are more severe. Without a higher severity, new variants are unlikely to cause a significantly higher wave than the BA.5 wave. With a severity twice of the current variants, we could see a peak slightly higher than the peak in March from the BA.2 variant.

Continued good surveillance is important to understand which, if any, of the scenarios best describe reality. All the scenarios include the currently increasing trend in hospitalisations. Based on data on hospitalisations alone it would be difficult to disentangle the different scenarios unless we get a new variant that grows very quickly. Therefore, it is important with broad surveillance, research and learning from other countries to try to pinpoint which of the possible scenarios have been realised when we see an increase. Population-based data on prevalence from randomised surveys would be very valuable.

The scenarios with a more severe and transmissible new variant can give rise to infection waves that would put a heavy burden on hospitals. Therefore, even if such scenarios are not very likely it is necessary to prepare for such an eventuality. In many of the other scenarios, covid-19 will still put a significant burden on the hospitals, especially if covid-19 overlaps with waves of influenza or other pathogens.

The current model is very simplified and does not consider any viral interference, behaviour change or change in importation due to developments outside Norway. The severity levels in the model are uncertain.

Scenarios

There is a lot of uncertainty regarding the spread of SARS-COV-2 over the next months. In this report we explore the effect of some of the key parameters that will determine the spread and future epidemic trajectories.

- **Level of immunity.** We simulate three levels of immunity in the population derived from infection and vaccination (details available below).
  - Low level: Distribution of immunity against infection by age characterised by an overall immunity level of 28 %
  - Middle level: Distribution of immunity against infection by age characterised by an overall immunity level of 44 %
  - High level: Distribution of immunity against infection by age characterised by an overall immunity level of 60 %
- **Waning of immunity.** We explore three different scenarios for how fast immunity wanes, considering an exponential decay with parameters defined in Menegale *et al.*[1]
  - No waning
  - Medium waning: Exponential decrease of VE with a halftime of 150 days
  - Fast waning: Exponential decrease of VE with a halftime of 100 days
- **Seasonality**. We model three different scenarios:
  - No seasonality,
  - 20% seasonality,
  - 30% seasonality.
- **Severity.** We explore three infection hospitalisation risk (IHR) assumptions:
  - Low severity: 30% Reduced severity
  - Medium severity: Estimated severity during the Omicron waves.
  - High severity: 30% Increased severity
- **New variants.** We explore the impact of the emergence of a new variant with the following characteristics:
  - 20% increased transmissibility
  - 20 percentage-point reduction in protection against infection
  - Both 20% increased transmissibility and a 20 percentage-point reduction in protection against infection

  For each new variant scenario, we explore the outcomes if the variant has the same or twice the severity of the current variants and how large a fraction of new cases came from the new variant on the 1st of Oct 2022.

There are additional factors which contribute to the uncertainty that we do not include in the model, including:

- Viral interference
- Behaviour changes outside of seasonality effects, including potential interventions
- Additional vaccination after the start of the simulations. Vaccinations with 3rd and 4th doses prior to the start of the simulations are included in the initial conditions, but no additional vaccination is considered.
- Level of COVID-19 in other countries and consequent pressure in Norway through importation

Section 1: Current variants will continue to dominate

We first explore scenarios where the current BA.5 variant or variants with similar properties will continue to dominate in Norway. For each scenario, exploring different levels of waning, seasonality

- [1] Menegale *et al.*, Waning of SARS-CoV-2 vaccine-induced immunity: A systematic review and secondary data analysis. MedRXiv (2022), https://doi.org/10.1101/2022.07.04.22277225 and severity, we fit the transmissibility parameter (beta) such that the model explains the number of observed hospitalisations during October.

In figure 1 we combine the results from all these scenarios to give an overall picture of the results. In the scenarios, we will have at most 50 admissions per day, which is similar to the peak of the BA.5 wave observed at the end of June. The results show that with low waning/seasonality we will have a flat trend followed by a decline. In contrast, for higher seasonality/faster waning we will see peak in late November or early December (see section "All combinations" below for a more detailed visualisation of the scenarios).

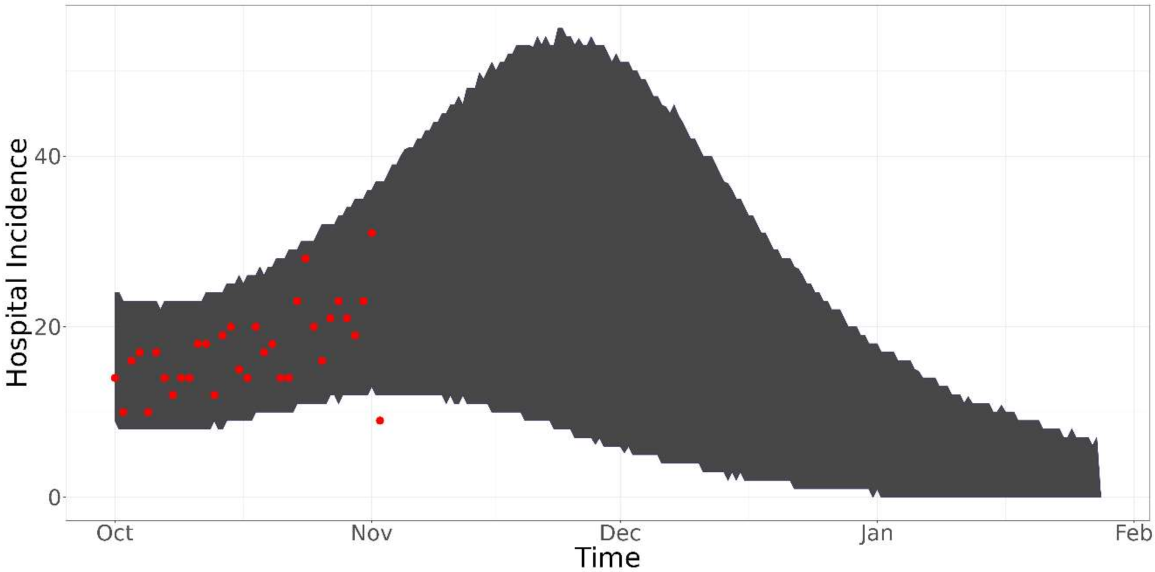

Figure 1: Daily hospitalisation incidence as a function of time for all the scenarios where the current variant remains dominant. The red points indicate hospitalisation incidence data from 1st of October to 2nd of November.

Figure 2-4 show the daily incidence of new infections, hospital prevalence and invasive respirator prevalence for the same scenarios as in Figure 1.

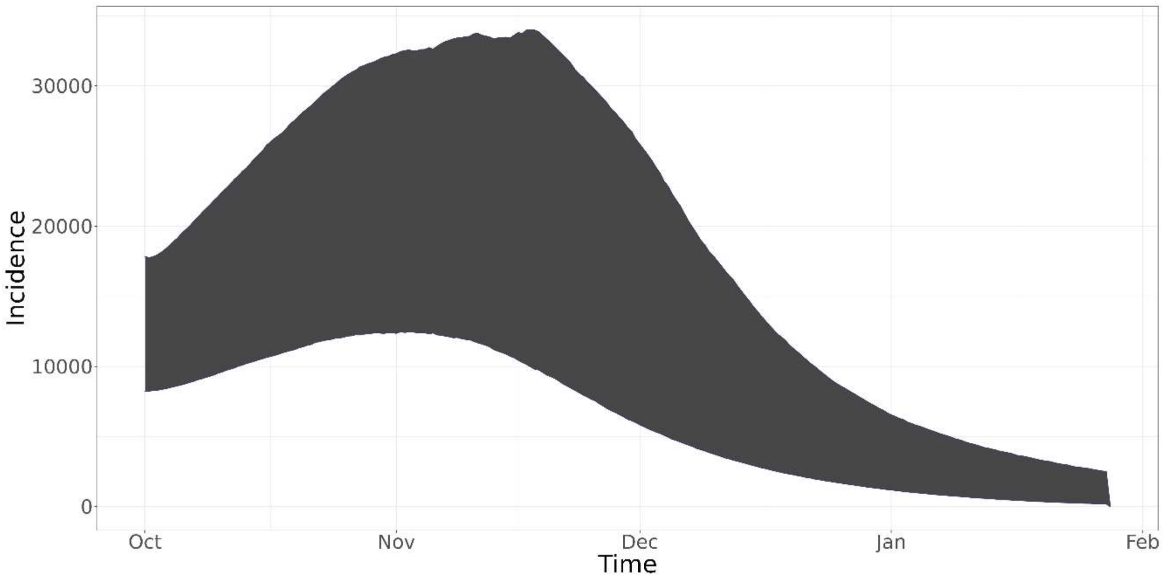

Figure 2: Incidence of infection as a function of time for all the scenarios where the current variant remains dominant.

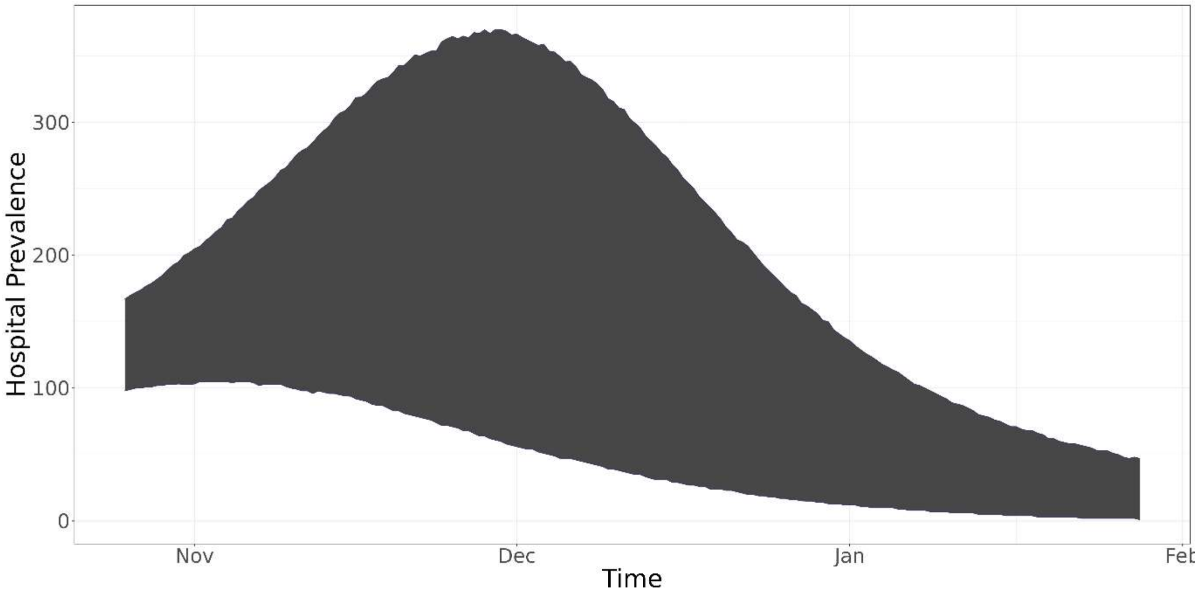

Figure 3: Hospitalisation prevalence a function of time for all the scenarios where the current variant remains dominant.

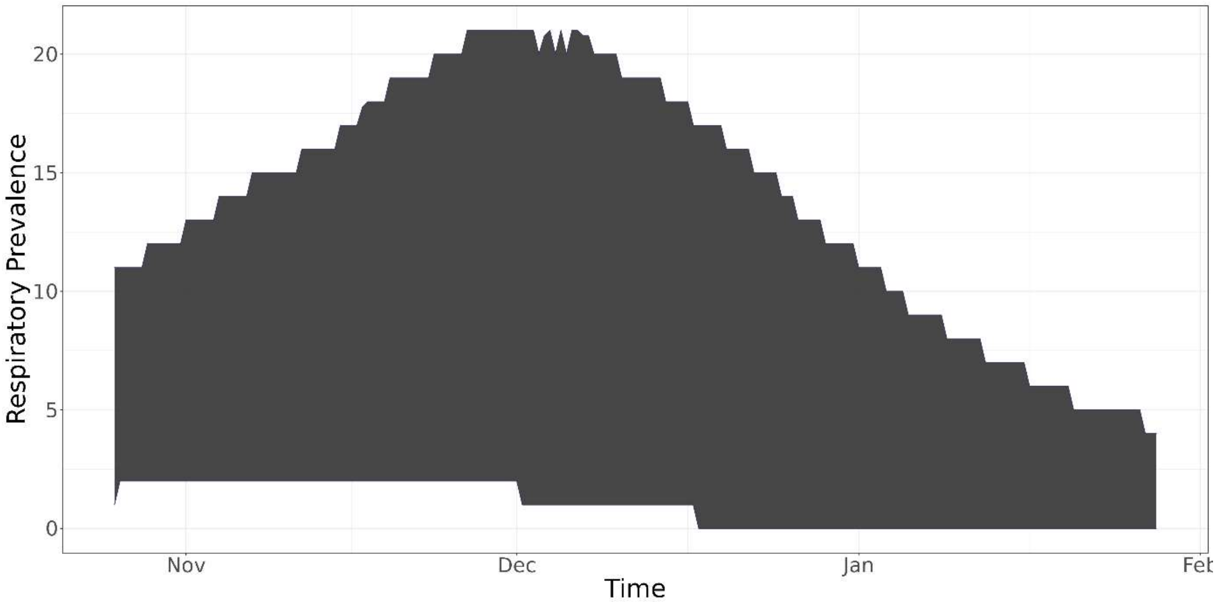

Figure 4: Prevalence of people needing respirator treatment as a function of time for all the scenarios where the current variant remains dominant.

Effect of seasonality

Seasonality is likely one of the key drivers of the recurring winter waves for respiratory infections. This effect is likely due both to biological and behavioural changes with temperature. Covid-19 likely has a seasonal effect in transmission[2], but it is uncertain how large this effect is. We have chosen to investigate scenarios where the seasonal variation, i.e. the difference in transmissibility between the

[2] D'Amico et al 2022 "COVID-19 seasonality in temperate countries" https://www.sciencedirect.com/science/article/pii/S0013935121019150

coldest and warmest day of the year, is either 0, 20% or 30%. In figure 5, we show the effect of changing the seasonality while assuming no waning of immunity. Without any waning or seasonality (left panel), the current increasing trend will quickly turn and we get a fadeout of the epidemic from more or less the present level of hospitalisation incidence. With seasonality we could expect a wave that would keep increasing for some weeks with a maximal peak of between 30 and 40 admissions to hospital per day.

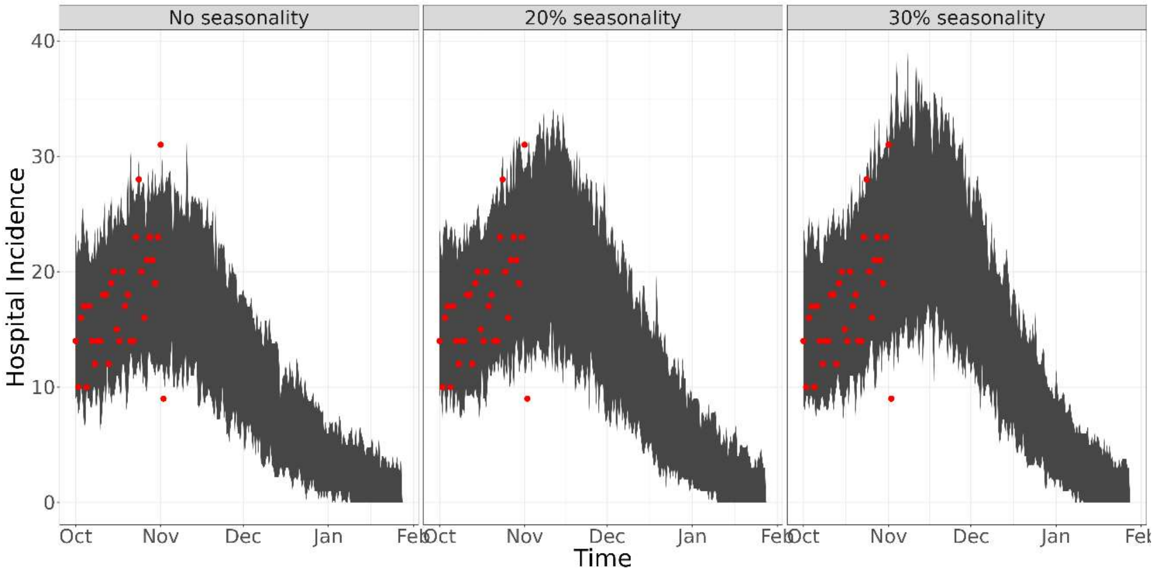

Figure 5: Daily hospital incidence. Effect of changing the seasonality in scenarios with no waning.

Effect of waning

Waning immunity is the other key factor that could drive a new wave of SARS-COV-2 infections. We model immunity in a simplified way by defining how quickly immunity wanes from the initial population immunity at the start of the simulation period (see details below). We run the model with no waning, and with two levels of waning based on Menegale *et al*. Figure 6 shows the epidemic evolution assuming waning immunity, but no seasonality.

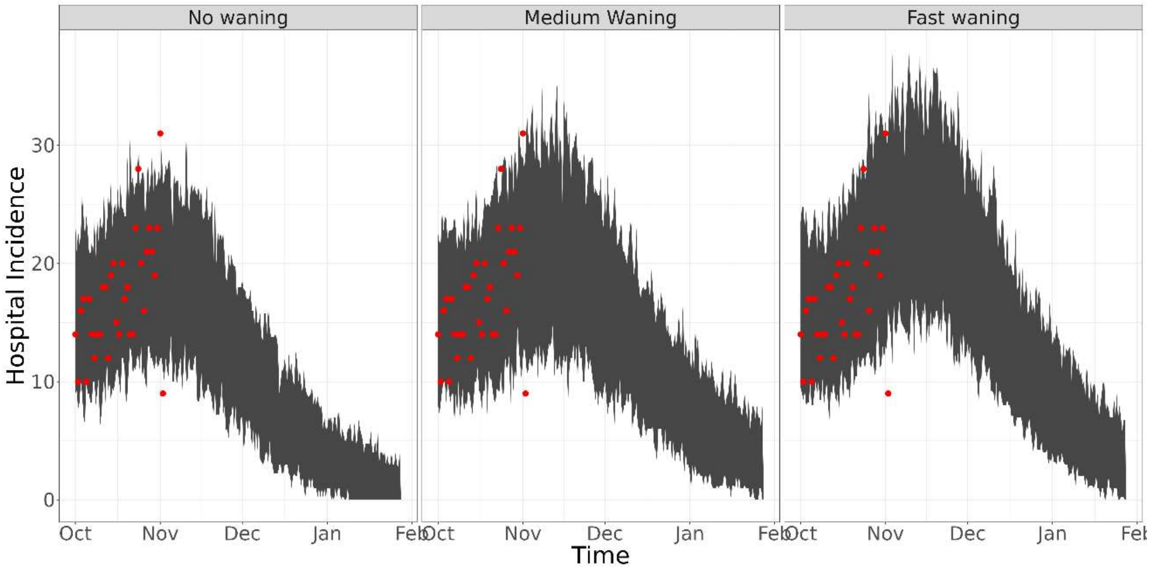

Figure 6: Daily hospital incidence. Effects of changing the speed of the waning of immunity with no seasonality

Effect of initial immunity levels

The overall immunity level and the distribution of immunity in the population are currently the most important factors determining the spread. See below for details about estimation of population immunity. We investigate three different amounts of population immunity in figure 7 with medium waning and 20% seasonality. The effects are somewhat counter-intuitive because we have calibrated every model separately to data. The model clearly shows that higher levels of immunity lead to less spread, but for a model with high immunity to explain the observed data it needs to assume a higher intrinsic transmissibility of the virus. In addition, high levels of immunity mean that the population has more immunity to lose. The result is that the scenario with high initial immunity gives the largest peaks.

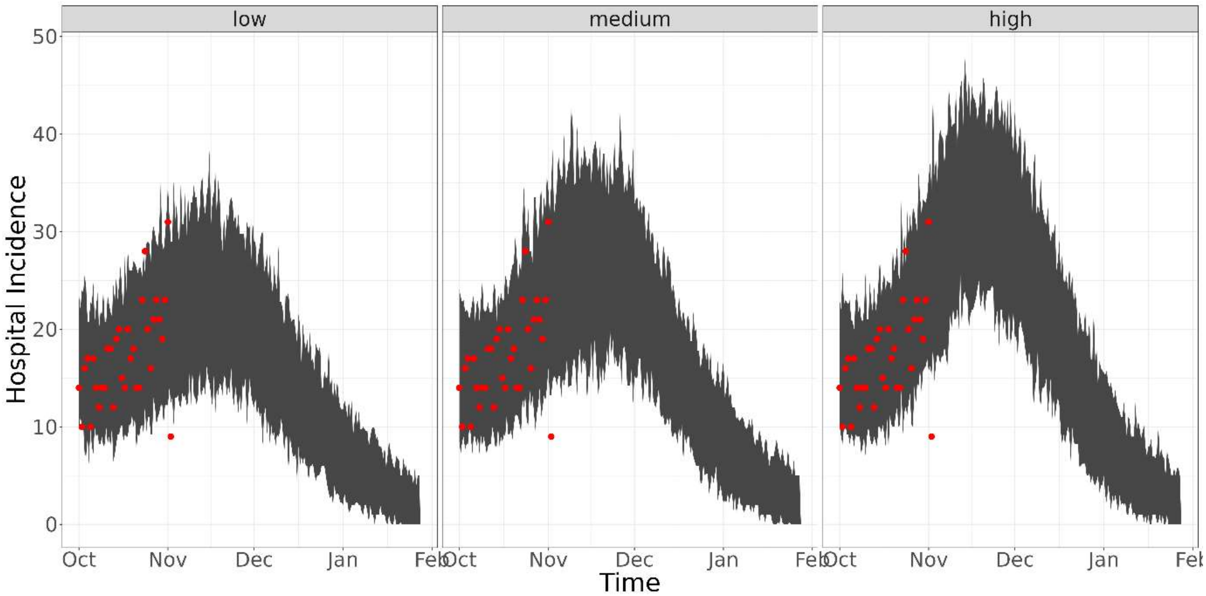

Figure 7: Daily hospital incidence. Effects of changing the initial immunity levels in the population with medium waning and 20% seasonality.

Effects of uncertainty about severity

One of the critical parameters in the model is the infection hospitalisation risk (IHR). This parameter determines how many infections there are per hospitalisation. Unfortunately, we do not know exactly what the IHR is for Norway since we do not have good measurements of how many people have been infected. The IHR used in the scenarios with "medium severity" is based on an estimate that gave a reasonably good fit to the Omicron wave, assuming that in early January about twice as many people were infected as tested positive.

Due to uncertainty about the IHR, we show in figure 8 the effect of changing severity up or down by 30% for scenarios with medium waning and 20% seasonality.

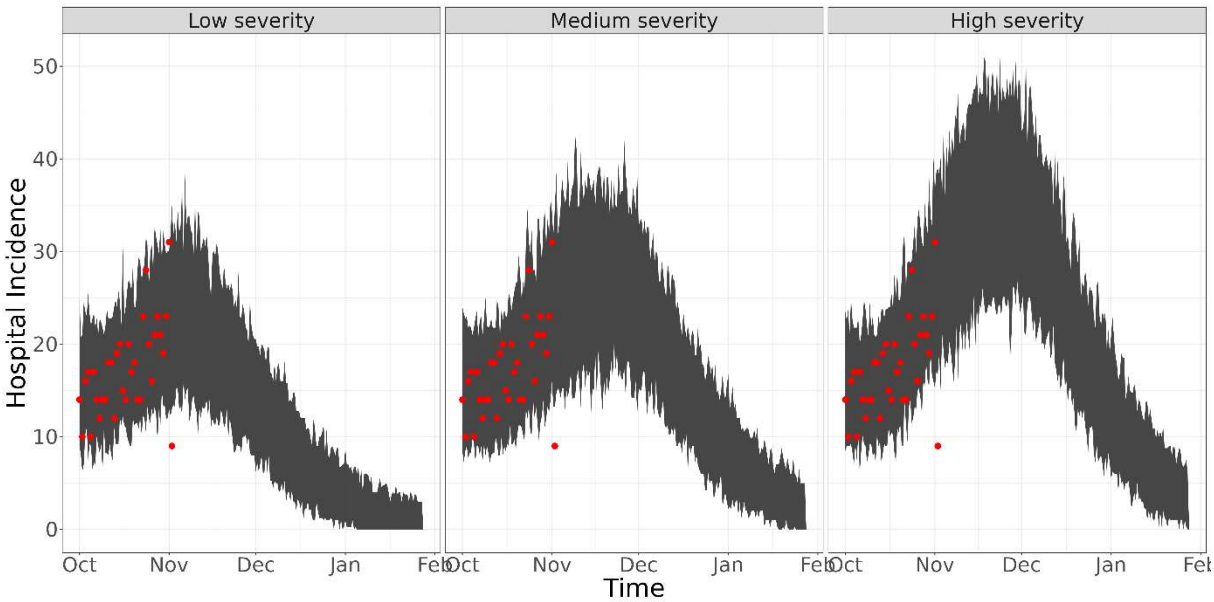

Figure 8: Daily hospital incidence. Effect of changing severity up or down by 30% for scenarios with medium waning and 20% seasonality.

All combinations

Figure 9 shows all the combinations of the scenarios above, assuming medium initial immunity. We see that in none of the scenarios do we get more than 60 daily hospitalisations.

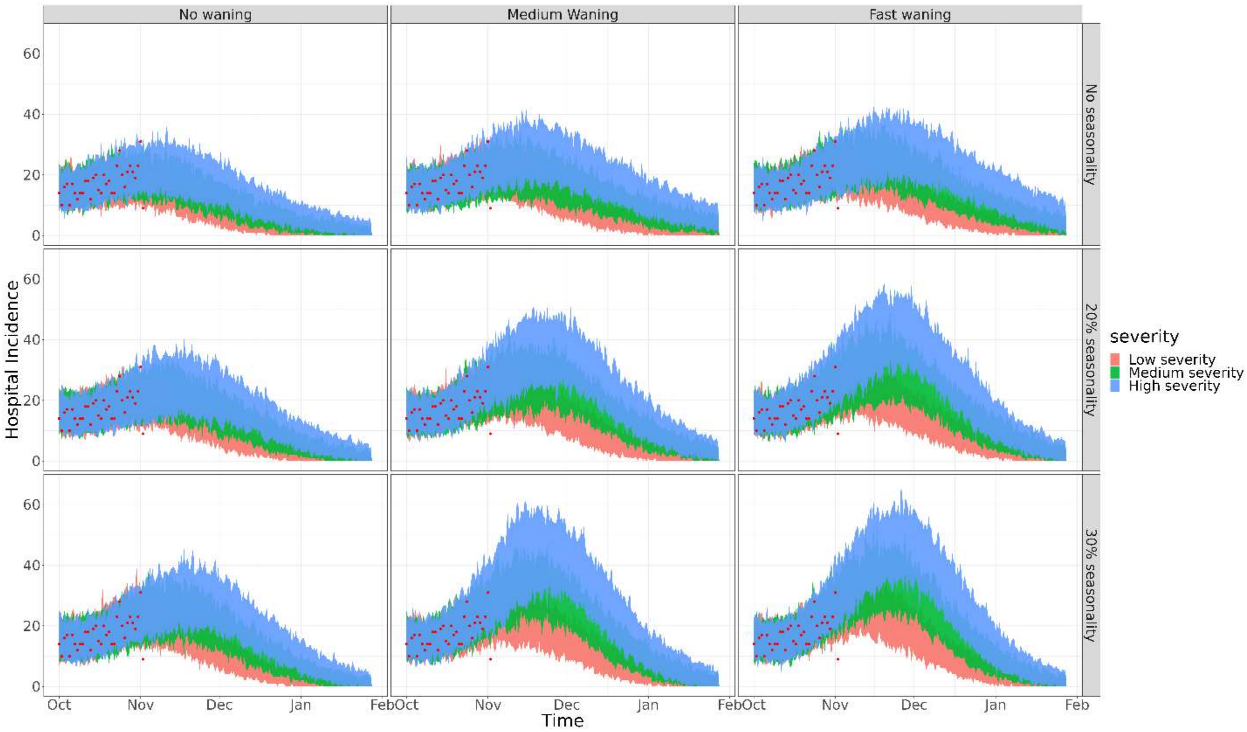

Figure 9: Daily hospital incidence for different scenarios with varying waning, seasonality and severity with medium immunity initial conditions.

Section 2: New variants take over

A large part of the infection dynamics of SARS-COV-2 has been driven by new variants. Introducing a new variant at this stage of the pandemic could give rise to a large range of possible outcomes based on the effective reproduction number and the effective severity of the new variant. These effective quantities are a combination of the virus variants' intrinsic properties and the immunity in the population.

In "Oppdrag 610[3]", we previously investigated the consequences of such an extensive range of possible virus variants. In figure 10 we have modelled the peak number of people admitted to hospital for different values of effective reproduction number and severity. An effective severity of one corresponds approximately to the initial Omicron wave in Norway. We can see that for a new dominating variant to threaten hospital capacity, it likely needs to be more severe than the Omicron variants we have experienced so far. Figure 11 shows the peak prevalence of people needing respirator treatment for the same scenarios.

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[3] Endelig svar på covid-19-oppdrag fra HOD 610 – Om strategi og beredskapsplan for håndteringen av covid-19-pandemien https://www.helsedirektoratet.no/tema/beredskap-og-krisehandtering/koronavirus/faglig-grunnlag-til-helse-og-omsorgsdepartementet-covid-19/Oppdrag%20610%20-%20Om%20strategi%20og%20beredskapsplan%20for%20h%C3%A5ndteringen%20av%20covid-19-pandemien.pdf/_/attachment/inline/ef320c55-9901-4a21-9284-d3cde2dccb9e:1edd9dfe1e297f418f8c069ea0414f72c702eaa1/Oppdrag%20610%20-%20Om%20strategi%20og%20beredskapsplan%20for%20h%C3%A5ndteringen%20av%20covid-19-pandemien.pdf

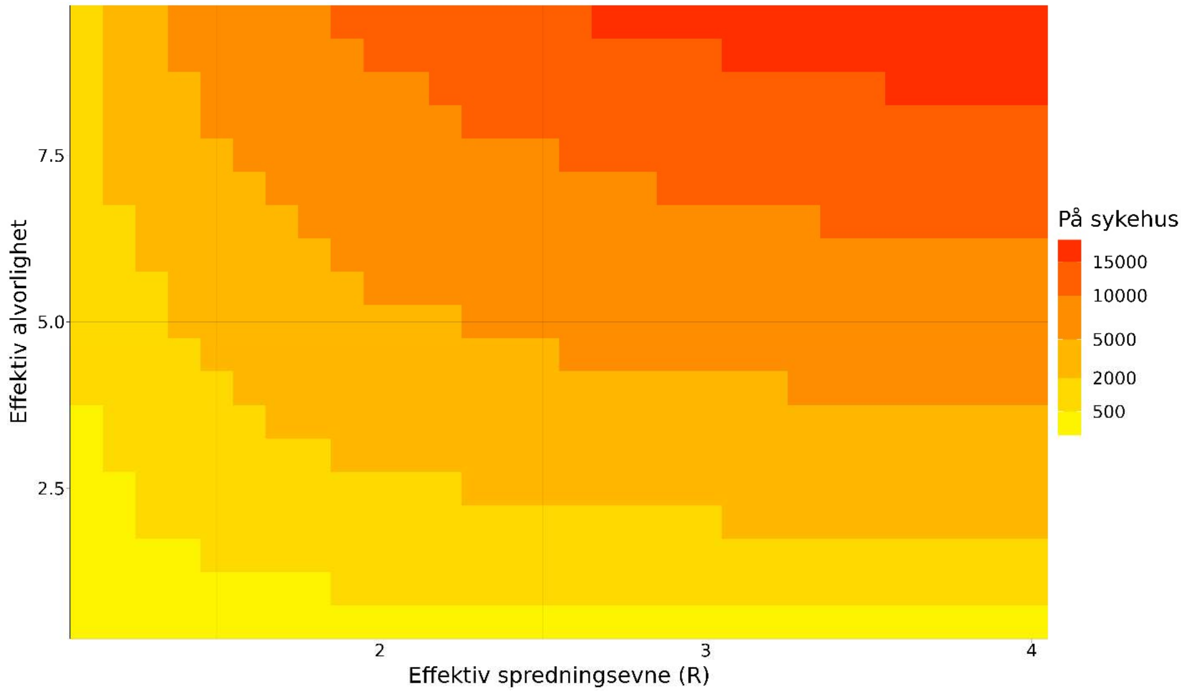

Figure 10: Peak number of people admitted to hospital at the same time for different values of effective reproduction number and severity.

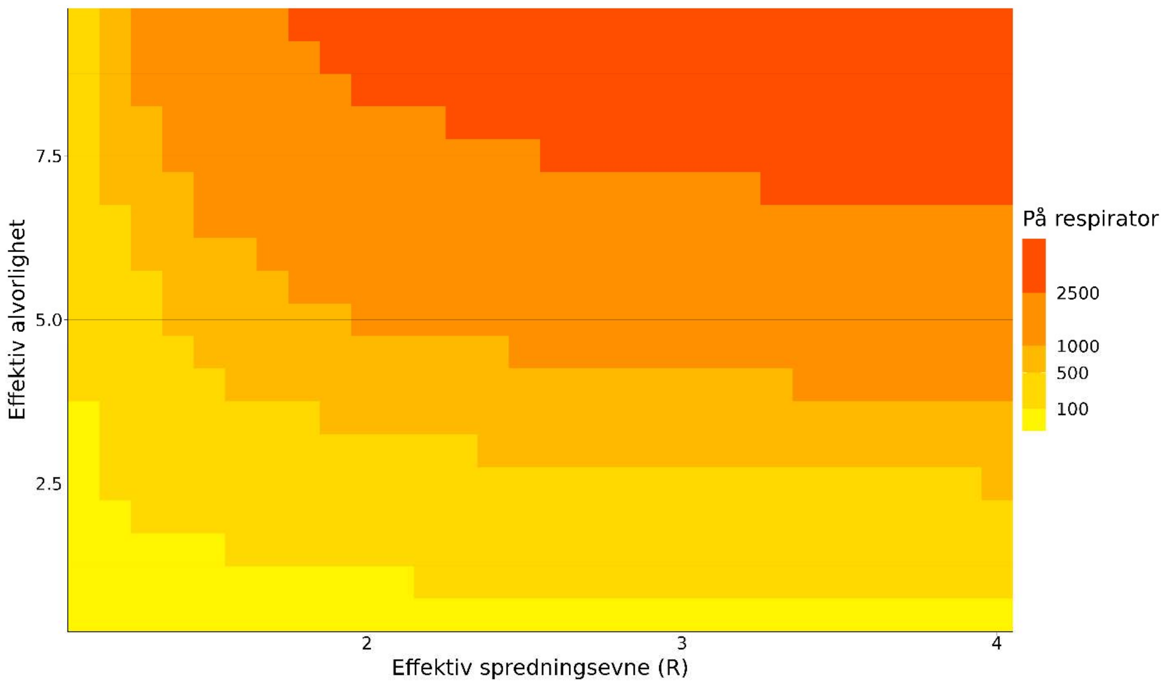

Figure 11: Peak number of people needing respirator treatment at the same time for different values of effective reproduction number and severity.

Scenarios with new variants

We simulate some examples of new variants to illustrate how a new strain can take over and which parameters will determine how severe a wave from a new variant will be.

Figure 12 shows new hospitalisations from the current and the new variant in a scenario with 20% seasonality and medium waning. We can see that the new variant needs to have twice the severity of the current variants to qualitatively change the picture.

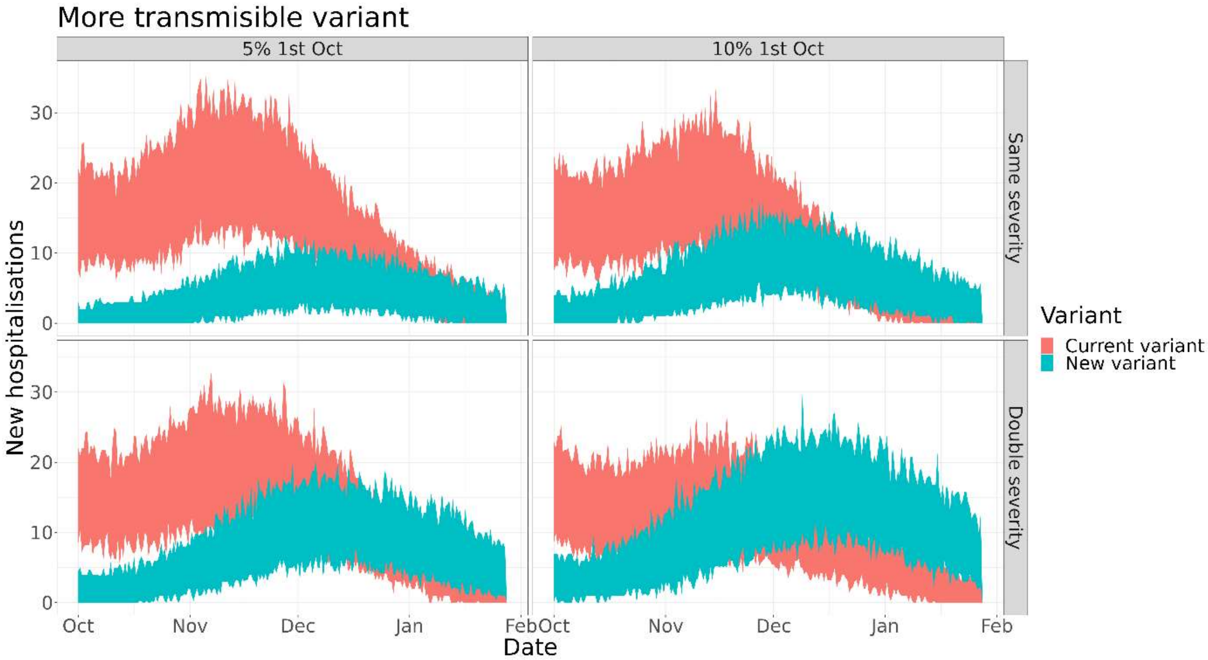

Figure 12: Incidence of hospitalisations from current and new variants with 20% seasonality and medium waning. The new variant is 20% more transmissible.

Figure 13 shows new hospitalisation per day for a variant with a 20 percentage-points reduction in protection against infection. Such a variant would make an important contribution to the dynamics during the winter. It would likely lead to a higher and later peak. These scenarios peak in December instead of November as the scenarios without a new variant. The timing of a peak in scenarios with a new variant depends critically on when the new variant will be introduced and takes over.

Figure 14 shows new hospitalisations for a new variant with both increased transmissibility and higher immune escape. A variant with these properties has a much higher effective spread and will lead to increased hospitalisations. For a new variant with the same severity, we find a peak similar to the BA.5 peak in the summer of 2022. We interpret the scenarios for a new variant with this high transmissibility and two times the severity as a reasonable worst-case based on the new variants we currently can see in national and international surveillance. As described in the section above, if a completely unknown variant takes over, akin to the situation when Omicron took over from Delta, the range of possible outcomes is much larger.

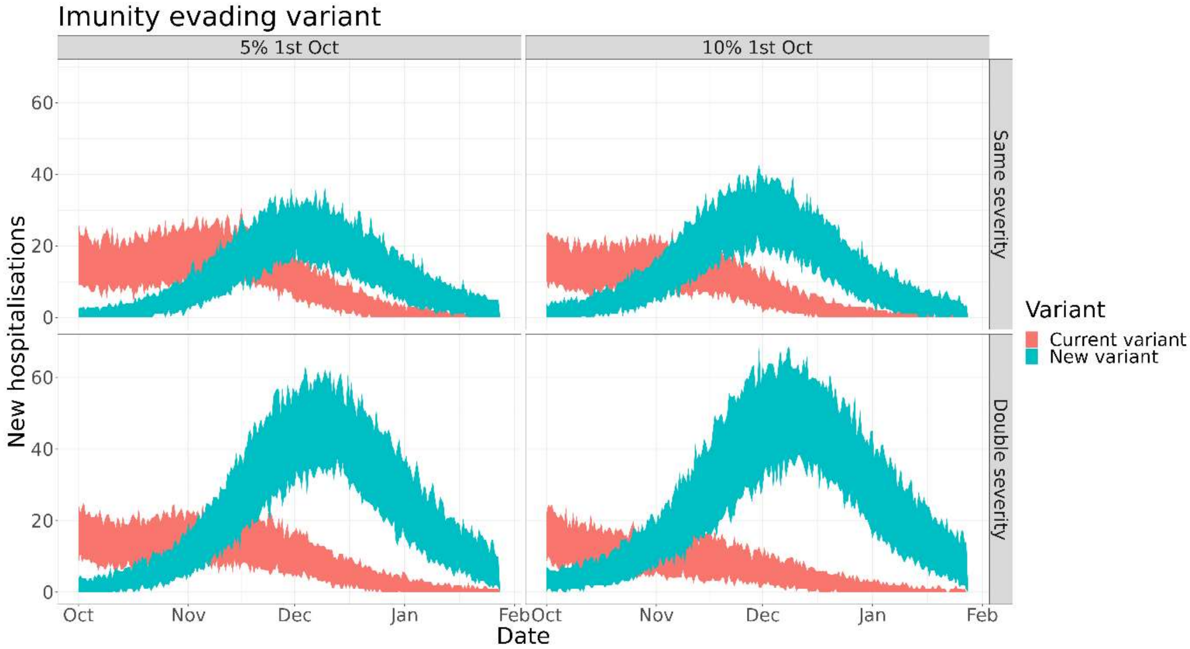

Figure 13: Incidence of hospitalisations from current and new variants with 20% seasonality and medium waning. The new variant has reduced protection from infection by 20 percentage-points.

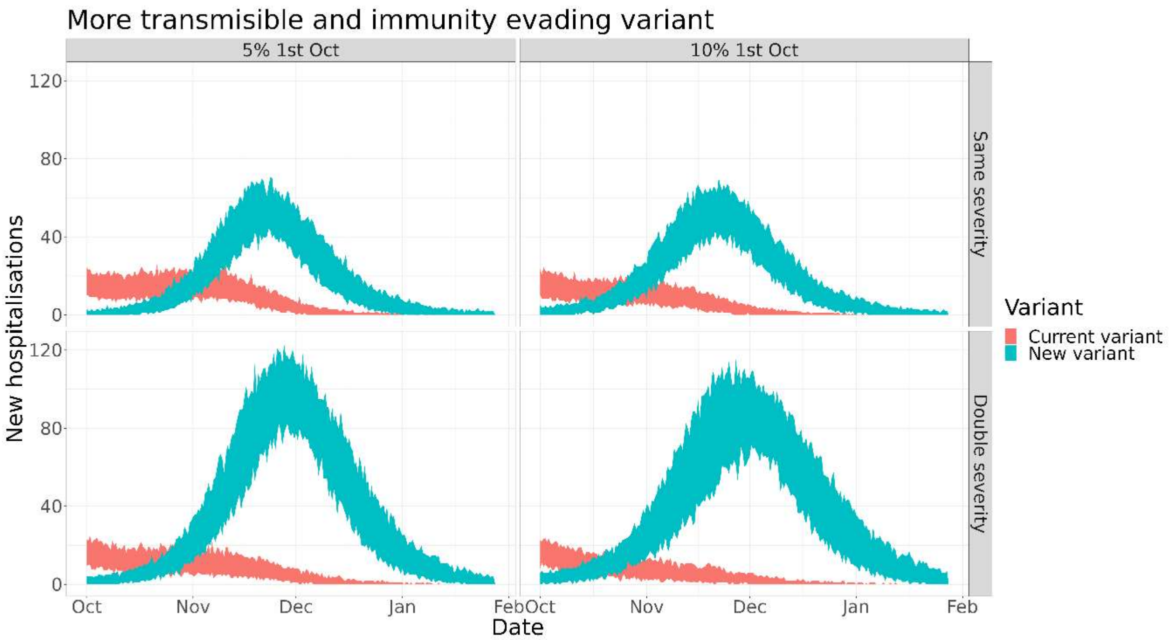

Figure 14: Incidence of hospitalisations from current and new variants with 20% seasonality and medium waning. The new variant has reduced protection from infection by 20 percentage-points and a 20% increased transmissibility.

Model details

The model is a metapopulation model with 9 age groups and with 10 population groups for different levels of immunity. We describe below how immunity is initialised and how it wanes. The model builds on a contact matrix based on pre-pandemic survey data from Norway. The epidemiological model is an SEIR-type model with both asymptomatic and symptomatic branches. The epidemiological parameters are detailed in table A1. Asymptomatic fraction and susceptibility varies with age and are shown in table A2. In table A3 we show the most important severity parameters

The source code for running the model is available at:
https://github.com/Gulfa/scenarios_winter2022

Key epidemiological parameters of the model are shown in table A1 and table A2. The main hospitalization parameters of the model are reported in table A3.

Parameter	Value
Latent time	2 days
Pre-symptomatic time	2 days
Infectious time	3 days
Relative infectiousness pre-symptomatic	1.3
Relative infectiousness asymptomatic	0.1

Table A1: Key epidemiological parameters

Age	Susceptibility	Asymptomatic fraction
0-9	0.23	0.47
10-19	0.45	0.47
20-29	0.68	0.32
30-39	0.68	0.32
40-49	0.68	0.32
50-59	0.68	0.32
60-69	0.83	0.2
70-79	1	0.2
80 +	1	0.2

Table A2: Key age-varying epidemiological parameters

Age	Infection hospitalisation risk	Mean length of stay in hospital	Probability of needing respirator treatment given hospitalisation	Length of stay - respirator
0-9	0.0002	1	0.02	4.3
10-19	0.0001	1	0	4.3
20-29	0.0003	2	0.08	4.3
30-39	0.0008	2	0.04	4.3
40-49	0.0009	3	0.01	4.3
50-59	0.002	3	0.05	4.3
60-69	0.003	3	0.01	4.3
70-79	0.004	3	0.07	4.3
80 +	0.008	3	0.03	4.3

Table A3: Key severity parameters used in the model. The infection hospitalisation risk refers to the medium severity scenario. Lengths of stay and probability of needing respirator treatment are estimated from data in Beredt C19.

Calibration to hospital data

We calibrate the initial transmissibility (beta) of the model by maximizing a Poisson likelihood for incidence of new hospitalisations by choosing the best 10 parameter sets from a random sample of 400 beta value from a normal distribution that on the reproduction number scale has a mean of 1 and a standard deviation of 0.5.

For each scenario we show results from 5 repetitions for each of these 10 scenarios for a total of 50 simulations.

Immunity and waning

One of the major uncertainties related to the risk posed by Covid-19 in the present situation, is the overall level of immunity in the population. While we know exactly how many people have been vaccinated with each dose and at what time, we do not know how many have undergone infection. There is clear evidence that infection provides immunity against reinfection and severe disease, although the protection against reinfection wanes with time. In particular, the combination of vaccine and infection, so-called hybrid immunity, seems to give very strong protection, especially against severe disease. Therefore, modelling scenarios for the future depends intimately on the assumptions made about population immunity.

In this report, we have taken a practical and simplified approach to the problem and made three different scenarios for the distribution of immunity against infection in the population at present. We refer to the scenarios as low, medium and high. (Immunity against hospitalisation is treated separately in the model, as an overall protection applied to the entire population, which does not wane.) In each of the immunity scenarios, we make assumptions about

1. The number of vaccines distributed, using the SYSVAK registry. These data are the same for all scenarios. We assume that only doses 3 and 4 give any significant protection against omicron infection.
2. The share of the population infected by Omicron over the past year, and when they were infected. We use data from the survey Symptometer[4] to inform the overall number of infections in different age groups, and when they were infected. We vary our assumptions around these data to make different scenarios. Figures A3 and A4 show the Symptometer data on the distribution of previous infections by age, and the cumulative share of the population that has had an immunologically boosting event (vaccine or infection) as function of time, respectively.
3. How fast the protection against infection, from either vaccination or previous infection, wanes with time. We assume that protection wanes according to an exponential decay function.

Based on this, we make a simulation where random individuals are assigned vaccine and/or previous infection, and the resulting population-level protection in each age group is calculated over time. We do not take into account any complications such as the fact that unvaccinated people are more likely to have been infected. Figure A1 below shows the resulting average immunity over time in each age group, in the medium scenario, and Figure A2 shows the distribution of immunity within each age group, on October 1st, again according to the medium scenario.

[4] https://www.fhi.no/hn/statistikk/symptometer/

In the model, the population in each age group is subdivided into ten compartments with varying immunity, from 0 protection to 1, corresponding to Figure A2. The values shown in Figure A2 are used as initial conditions. The immunity continues to wane in the model, by moving people to compartments with gradually lower immunity as time passes.

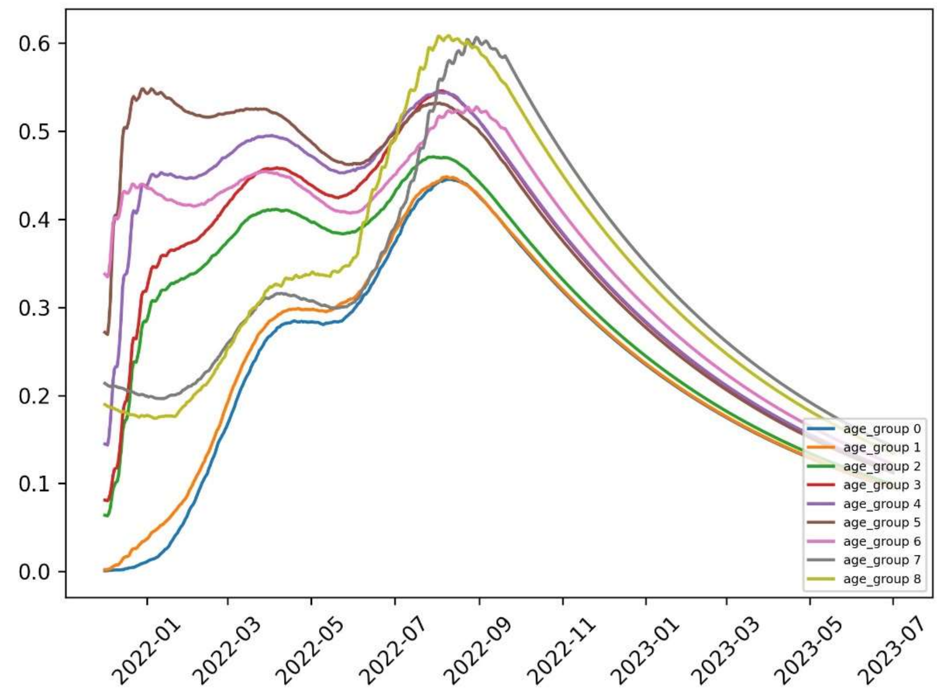

Figure A1: Average protection against infection for each age group, as function of time, in the medium immunity scenario. Note that this is just used to determine initial conditions for the model, and does not take into account the immunity boosting that would result from circulation of the virus in the population during the coming months.

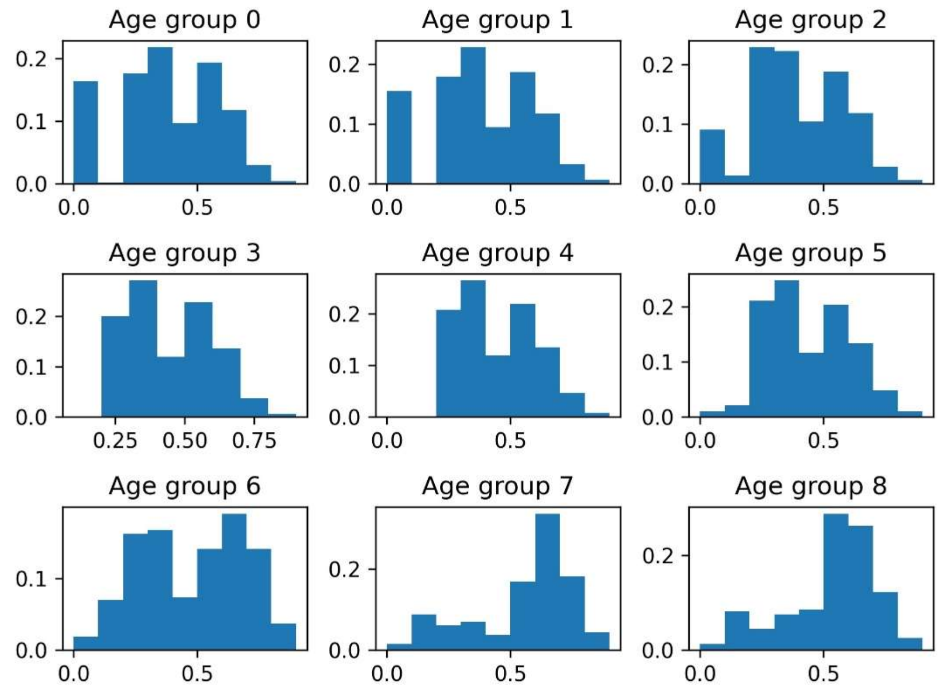

Figure A2: The immunity distribution in each age group on October 1st, in the medium scenario. The age groups are 0: 0-9 years, 1: 10-19 years, etc., with age group 8 containing all people 80 and older. The x axis in each figure is the level of protection against infection, measured from 0 to 1, and the y axis is the share of the population in the age group having that protection level.

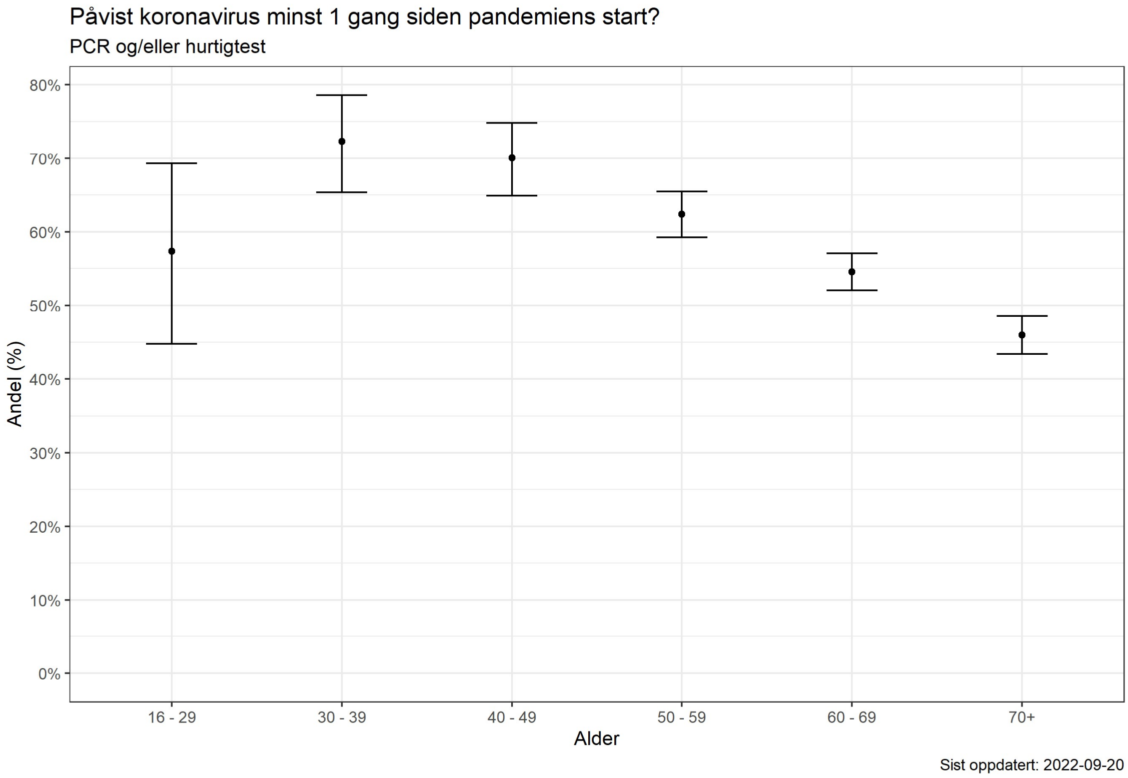

Figure A3: The share of the population reporting having previously had a covid infection, by age group, from the Symptometer survey. In the model, this is used to determine the age distribution of infections, while the overall number of infections is rescaled based on Figure A4.

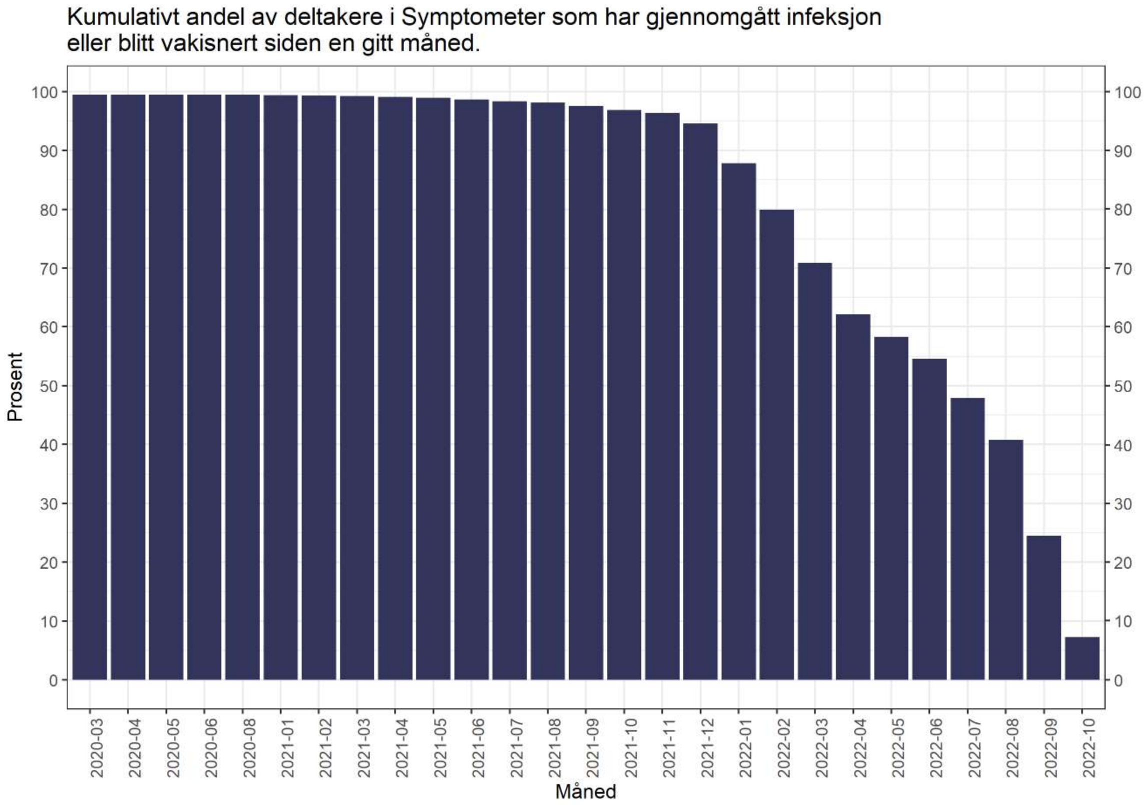

Figure A4: The cumulative share of the population reporting having had an immunological event (vaccination and/or infection) since a given date, from the Symptometer survey.

Waning immunity in the infectious disease model

The model described above determines the initial conditions for the immunity on the 1st of October. We continue to describe waning of immunity when we simulate the spread of disease. The model has 10 compartments with a relative risk of infection from 0.95 - 0.05 corresponding to the 10 groups above. As time passes, each individual will move from higher protection (lower RR) to lower protection based on the average times in table A4.

	Average transition time (days)	
RR Transitions	Medium waning	Fast waning
0.05 -> 0.15	22	14
0.15 -> 0.25	25	16
0.25 -> 0.35	29	19
0.35 -> 0.45	33	22
0.45 - > 0.55	40	27
0.55 -> 0.65	50	34
0.65 -> 0.75	67	45
0.75 - >0.85	102	69
0.85 -> 0.95	220	146

Table A4: Waning times between the different compartments of relative risk for infection for medium and fast waning.