NIPH
Norwegian Institute of Public Health

Situational awareness and forecasting for Norway

FHI COVID-19 modelling team

Week 46 - 10 November 2020

Highlights:

- **New short-term predictions for Bergen:** In this report we have added a section on scenario-based short-term predictions for Bergen municipality, see Section 10 page 18.
- **National epidemiological situation:** Our models evaluates the present situation as increasing. The reproduction number R_7 acting in our changepoint model from October 1 is estimated to be 1.41 (median, 95% CI 1.31-1.54). This is not statistically significantly different from our last report (3 Nov), but we see a slight increase. The estimated probability that R_7 is larger than 1 continues to be 100%. The national SMC model estimates the 7-days averaged reproduction number two weeks ago to be 1.48 (95% CI 0.97-2.20), confirming the results of the changepoint model.Also here there is a small growing trend. The estimated probability that the daily reproduction number two weeks ago was above 1 is 96.3%.
  Since the start of the epidemic, we estimate that in total 82.000 (95% CI 72.000- 92.000) persons in Norway have been infected. The current estimate of the detection probability is 50% with an increasing trend.
- **National forecasting:** In one week, we estimate 2.500 new cases per day (95%CI 1.800-3.400), and a prevalence (total number of infected people in Norway) of 13.000 (95% CI 10.000-17.000). Hospitalisations and patients on ventilator treatment in one week are estimated to be 200 (median 95% CI 150-1260) and 18 (median 95% CI 10-25), respectively; the corresponding three-week projections are (95% CI 250 - 550) and (95% CI 19 - 51). We see a clear increasing trend. Note: Our model has over-estimated hospitalisations in recent weeks. A long-term scenario projection with the current R suggests a peak in February/March 2021. The probability that the surge capacity will exceed 500 and 1000 ventilator beds are estimated at 99.5% and 18.5%, respectively.
- **Regional epidemiological situation and forecasting:** The model shows large regional differences, with highest reproduction numbers for Oslo, estimated at 1.64 (95% CI 1.35-1.89) [Oct], followed by Viken 1.39 (95% CI 1.15-1.62) [Oct], and Vestland 1.28 (95% CI 0.67-1.80) [Oct]. The lowest reproduction number is estimated in Vestfold and Telemark 0.35 (95% CI 0.03 -0.82) [Sept]. See table **??** for information about all counties.
  Oslo: The number of new cases per day is estimated to be 405 (mean, 95% CI 235 - 630) on November 15, and in three weeks 809 (95% CI 377-1426). Hospital prevalence in one week is estimated to be 42, and in three weeks 60 (95% CI 27-104). See Table 8 and Table 9 for information about expected need for patient beds.
- **Telenor mobility data, local mobility and foreign roamers:** Inter-municipality mobility, measured as outgoing mobility of mobile phones from each municipality clearly decreased in the last weeks, to reach a similar level to the summer period, but still higher than during the March interventions. Analysis of foreign roamers (visitors) shows an increase during the Autumn and a stabilisation in the last weeks. For example, Polish roamers show quite high visiting levels during 2020, and highest levels in October, still with a slight increasing trend. See Fig. 26 for visiting levels by Swedish, Danish and German roamers.

What this report contains:

This report presents results based on a mathematical infectious disease model describing the geographical spread of COVID-19 in Norway. The model consists of three layers:

- Population structure in each municipality.
- Mobility data for inter-municipality movements (Telenor mobile phone data).
- Infection transmission model (SEIR-model)

The model produces estimates of the current epidemiological situation at the municipality, county (fylke), and national levels, a forecast of the situation for the next three weeks, and a long term prediction. We run three different models built on the same structure indicated above: (1) a national changepoint model, (2) a regional changepoint model and (3) a national Sequential Monte Carlo model, named SMC model.

How we calibrate the model: The national changepoint model is fitted to Norwegian COVID-19 hospital incidence data from March 10 until yesterday, and data on the laboratory-confirmed cases from May 1 until yesterday. We do not use data before May 1, as the testing capacity and testing criteria were significantly different in the early period.
Note that the results of the national changepoint model are not a simple average or aggregation of the results of the regional changepoint model because they use different data. The estimates and predictions of the regional model are more uncertain than those of the national model. The regional model has more parameters to be estimated and less data in each county; lack of data limits the number of changepoints we can introduce in that model. In the regional changepoint model, each county has its own changepoints and therefore a varying number of reproduction numbers. Counties where the data indicate more variability, have more changepoints.
The national SMC model is currently calibrated only to the hospitalisation incidence data (same data as described above). We are working on extending it to use also the test data.

Telenor mobility data: The mobility data account for the changes in the movement patterns between municipalities that have occurred since the start of the epidemic.

How you should interpret the results: The model is stochastic. To predict the probability of various outcomes, we run the model many times in order to represent the inherent randomness.
We present the results in terms of mean values, 95% confidence intervals, medians, and interquartile ranges. We emphasise that the confidence bands might be broader than what we display, because there are several sources of additional uncertainty which we currently do not fully explore: firstly, there are uncertainties related to the natural history of SARS-CoV-2, including the importance of asymptomatic and presymptomatic infection. Secondly, there are uncertainties related to the timing of hospitalisation relative to symptom onset, the severity of the COVID-19 infections by age, and the duration of hospitalisation and ventilator treatment in ICU. We continue to update the model assumptions and parameters in accordance with new evidence and local data as they become available. A full list of all updates can be fount at the end of this report.
Estimates of all reproduction numbers are uncertain, and we use their distribution to assure appropriate uncertainty of our predictions. Uncertainties related to the model parameters imply that the reported effective reproductive numbers should be interpreted with caution.

When we forecast beyond today, we use the most recent reproduction number for the whole future, if not explicitly stated otherwise.

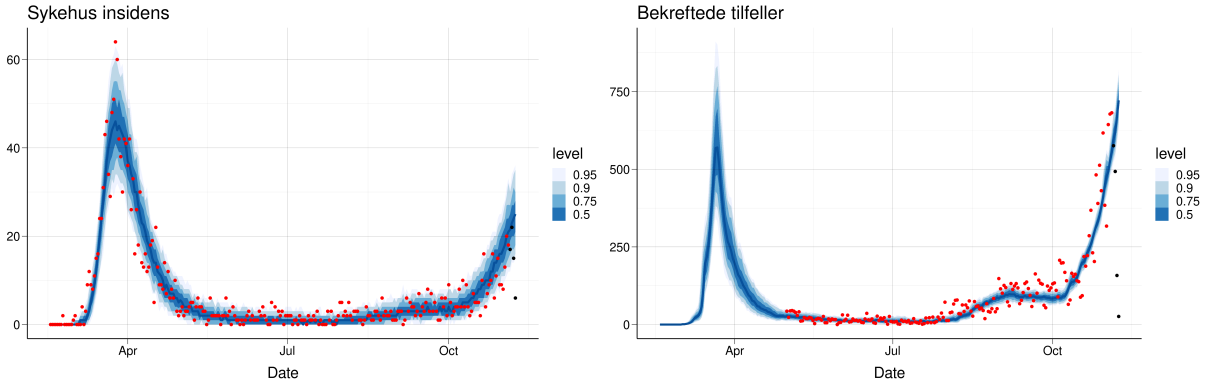
In this report, the term patient in ventilator treatment includes only those patients that require either invasive mechanical ventilation or ECMO (Extracorporeal membrane oxygenation).

1 Estimated national reproduction numbers

Calibration of our national changepoint model to hospitalisation incidence data and test data leads to the following estimates provided in table 1. Figure 1 shows the estimated daily number of COVID-19 patients admitted to hospital (1a) and the estimated daily number of laboratory-confirmed SARS-CoV-2 cases (1b), with blue medians and interquantile bands, which are compared to the actual true data, provided in red. The uncertainty captures the uncertainty in the calibrated parameters in addition to the stochastic elements of our model and the variability of other model parameters.

Table 1: Calibration results

Parameter	Mean	Median	Confidence interval (95 %)
R0	3.56	3.53	(2.74-4.34)
R1	0.46	0.45	(0.36-0.55)
R2	0.78	0.77	(0.47-1.15)
R3	0.84	0.84	(0.54-1.12)
R4	0.83	0.83	(0.26-1.32)
R5	1.13	1.12	(0.92-1.37)
R6	0.92	0.92	(0.81-1.02)
R7	1.42	1.41	(1.31-1.54)

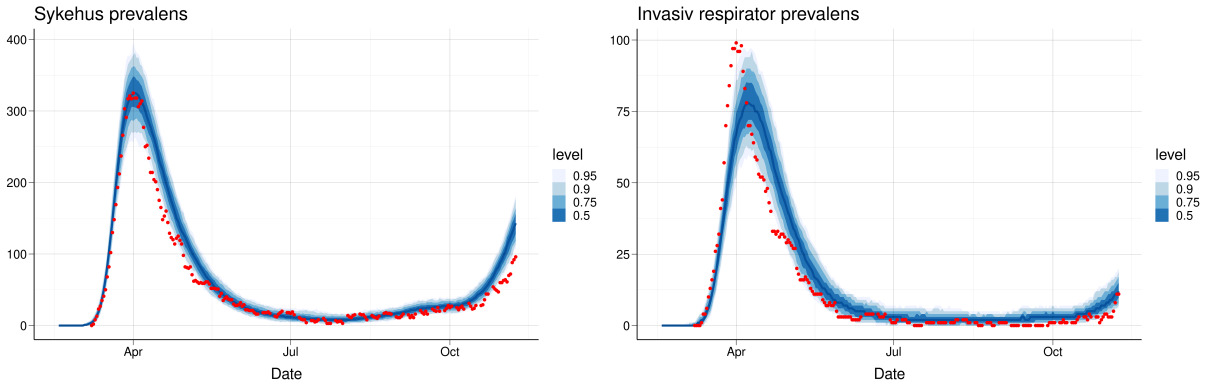


(a) Hospital admissions

(b) Test data

Figure 1: A comparison of true data (red) and predicted values (blue) for hospital admissions and test data. The last four data points (black) are assumed to be affected by reporting delay. B) Comparison of our simulated number of positive cases, with blue median and interquartile bands to the actual true number of positive cases, provided in red. The uncertainty captures the uncertainty in the calibrated parameters, in addition to the stochastic elements of our model and the variability of other model parameters. Note that we do not capture all the uncertainty in the test data–our blue bands are quite narrow. This is likely because we calibrate our model parameters on a 7-days moving average window of test data, instead of daily. This is done to avoid overfitting to random daily variation. Moving averages over 7 days are less variable than the daily data.

In figure 2, we show how our national model fits the national hospital prevalence data (2a) and the daily number of patients receiving ventilator treatment (2b). Those data sources are not used to estimate the parameters, and can therefore be seen as a validation of the model assumptions.



(a) Hospital prevalence

(b) Ventilator prevalence

Figure 2: A comparison of true data (red) and predicted values (blue) for hospital and respirator prevalence.

1.1 National SMC-model: Estimated daily reproduction numbers

In the SMC-model, we allow for estimation of a different reproduction number for each day t. To reduce spurious fluctuation, we report a 7-days moving average, $R(t)$, representing the average reproduction number for the whole week before day t. However, until March 8 we keep the reproduction number constant. By assuming a time varying reproduction number $R(t)$, we can detect changes without introducing explicit changepoints. Thus, we can easier detect unexpected changes. However, the SMC model requires additional parameters to be estimated, one per day. Estimating all these parameters is a difficult task, which we solve by using a method called Sequential Monte Carlo, see the Methods section at the end for details.

A patient hospitalised today was infected on average two weeks ago. Hence, hospitalisation data of today carry mainly information about the transmissibilty 14 days ago. The estimated reproduction number of 14 days ago is thus the last one which is based on sufficient data. More recent reproduction numbers are based on diminishing information, and in particular there are no data to inform $R(t)$ of today. Therefore, the uncertainty of the estimates of $R(t)$ for the last 14 days is very large. This is true for the reported 7-day-average reproduction numbers R_t. In the changepoint model, we keep the reproduction number constant after the last change point. In this way, there are more hospitalisation data points to inform the estimate of the most recent reproduction number. For this reason and because the model is also informed by test data, the confidence intervals were more narrow.

The figure below shows the SMC estimate of the 7-day-average daily reproduction number $R(t)$ from the start of the epidemic in Norway and until today. In the figure we plot the 95% confidence interval and quantiles of the estimated posterior distribution of $R(t)$.

1.1 National SMC-model: Estimated daily reproduction numbers

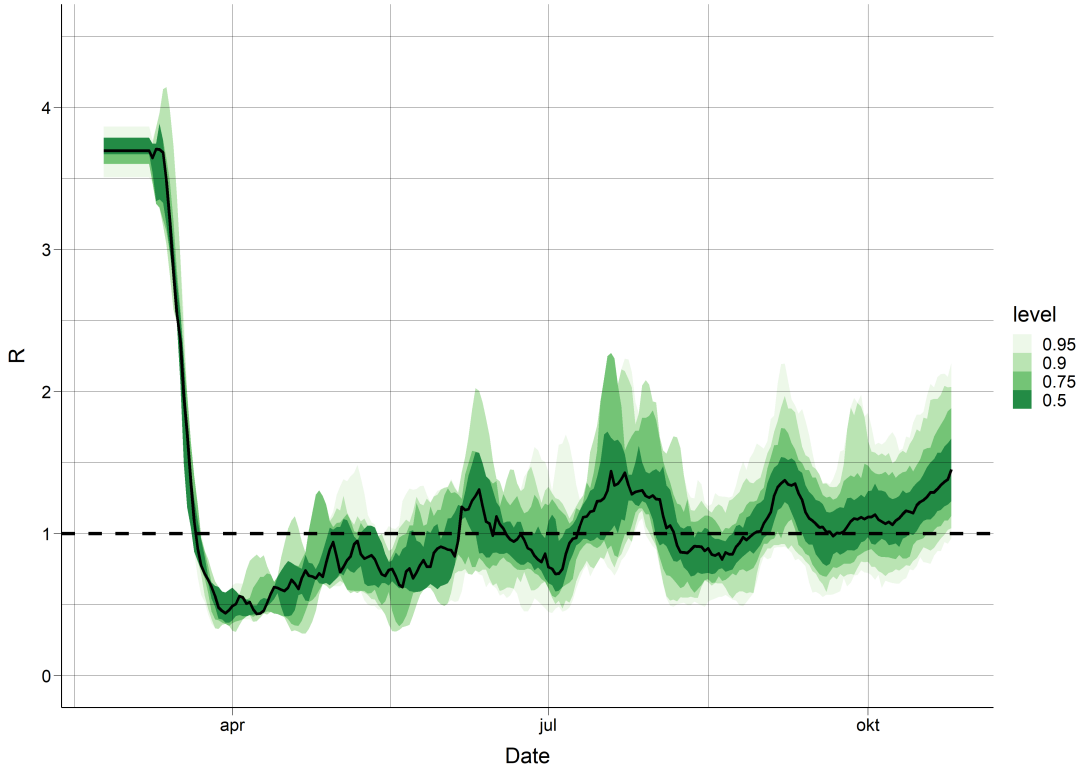


Figure 3: R(t) estimates until 14 days ago using a Sequential Monte Carlo (SMC) approach calibrated to incidence data. The large uncertainty during the last 14 days reflects the lack of available data due to the time lag between infection, symptoms onset and hospitalisation. Therefore we omit the plot of the last 14 days. The green band shows the 95% posterior confidence interval. We observe that $R(t)$ dropped below 1 in the middle of March, corresponding to the lockdown. It remained stable around 0.5 until the end of April, when it increased to 1 in the beginning of May. It then kept oscillating below and above 1, in accordance with increases and decreases of the number of new hospitalisations. $R(t)$ is sensitive to these oscillations in the data. An increase in hospital admissions indicates a daily reproduction number (14 days before on average) above 1. A decrease in hospital admissions suggests that the reproduction number was below 1 (again 14 days prior).

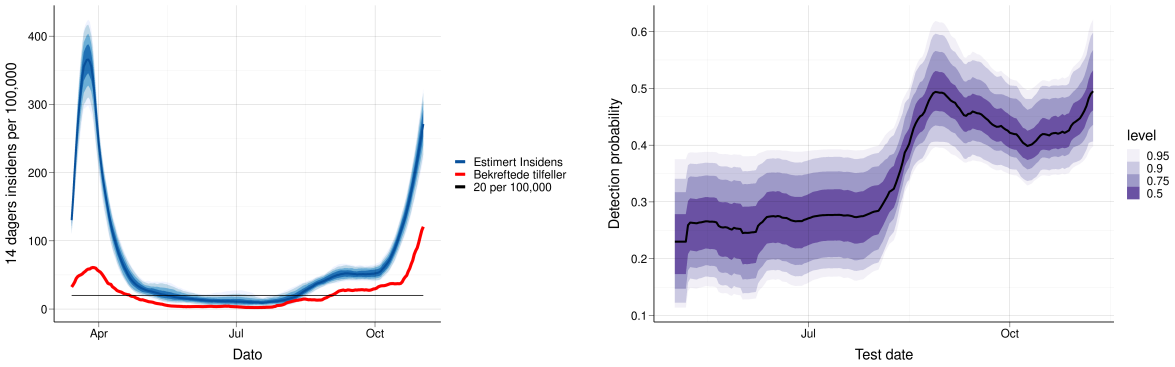
2 National estimate of cumulative (total) number of infections

The national changepoint model estimates the total number of infections and the symptomatic cases that have occurred (Table 2).
Figure 4a shows the modelled expected daily incidence (blue) and the observed daily number of laboratory-confirmed cases (red). When simulating the laboratory-confirmed cases, we also model the detection probability for the infections (both symptomatic, pre-symptomatic and asymptomatic), Figure 4b. There are two differences between this estimate of the detection probability and the previous one provided in figure 4a. In figure 4b, we calibrate our model to the true number of positive cases, instead of using the test data directly. Furthermore, in figure 4a we use a parametric model to estimate the detection probability that depends on the true total number of tests performed.

Table 2: Estimated cumulative number of infections, 2020-11-08

Region	Total	Symptomatic	No. confirmed	Fraction reported	Min. fraction
Norway	81457 (71871; 92020)	51123 (45179; 57354)	24727	30%	27%

Fraction reported=Number confirmed/number predicted; Minimal fraction reported=number confirmed/upper CI



(a) Number of laboratory-confirmed cases vs model-based estimated number of new infected individuals

(b) Estimated detection probability for an infected case per calendar day

Figure 4

3 National 3-week predictions: Prevalence, Incidence, Hospital beds and Ventilator beds

The national changepoint model estimates the prevalence and daily incidence of infected individuals (asymptomatic, pre-symptomatic and symptomatic) for the next three weeks, aggregated to the whole of Norway (table 3). In addition, the table shows projected national prevalence of hospitalised patients (hospital beds) and prevalence of patients receiving ventilator treatment (ventilator beds). The projected epidemic and healthcare burden are illustrated in figure 5.

Table 3: Estimated national prevalence, incidence, hospital beds and ventilator beds. Median/Mean (CI)

	1 week prediction (Nov 15)	2 week prediction (Nov 22)	3 week prediction (Nov 29)
Prevalence	13456/13150 (9953-17836)	18194/17684 (12687-25702)	24505/23605 (16006-36698)
Daily incidence	2487/2437 (1797-3394)	3354/3266 (2243-4920)	4521/4344 (2853-6908)
Hospital beds	200/198 (150-259)	273/266 (198-368)	374/367 (255-554)
Ventilator beds	18/18 (10-26)	25/25 (15-37)	34/34 (19-51)

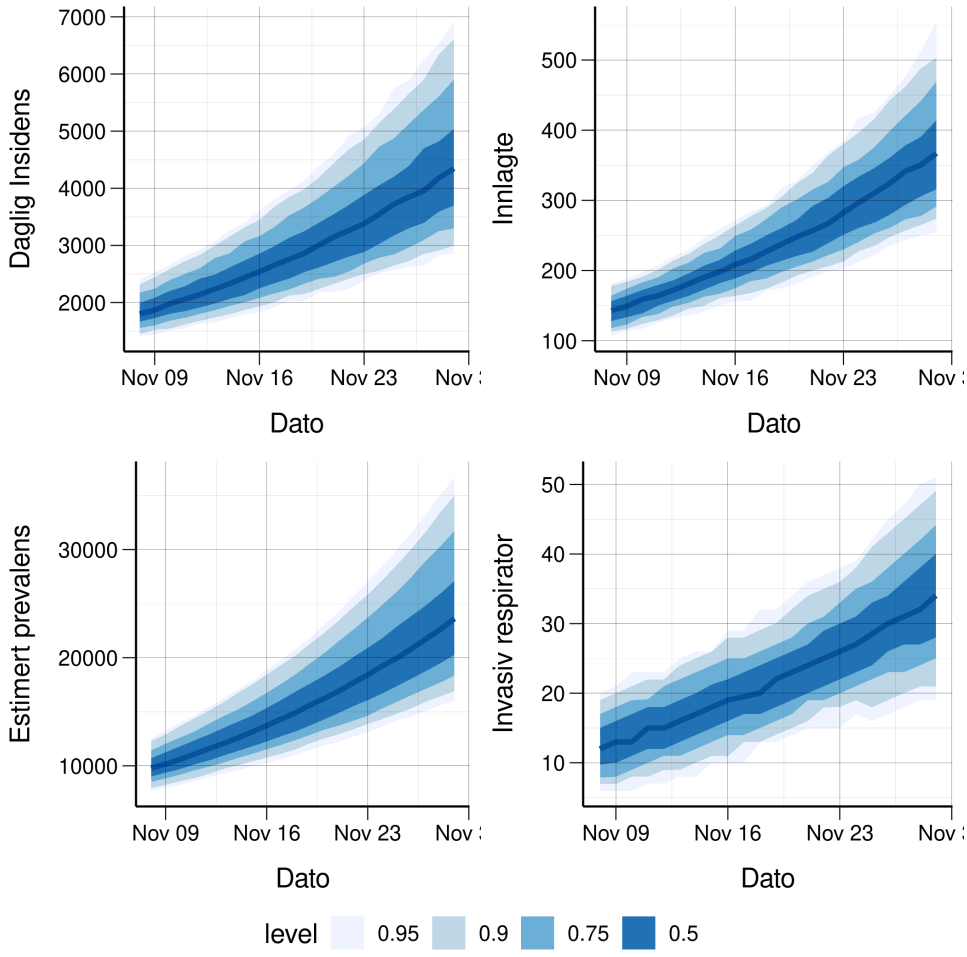


Figure 5: National 3 week predictions for incidence (top left),prevalence (bottom left),hospital beds (top right) and ventilator beds (bottom right)

4 National long-term predictions: Prevalence, Hospital beds and Ventilator beds

Results from 12-month forecasting of the calibrated national changepoint model, showing expected prevalence (Figure 6a), hospital beds (Figure 6b) and ventilator beds (Figure 6c). The figures are made using the 200 candidate models, where the reproductive numbers are varying according to their estimated uncertainty as of today. The confidence intervals shown in the plots are two-tailed around the median, and therefore the upper 95 % level shows the 97.5 % boundary. Note that age-specific attack rate after 21 days of projection is assumed to follow the demography in each county, instead of being informed by the current age-distribution of the laboratory-confirmed cases.

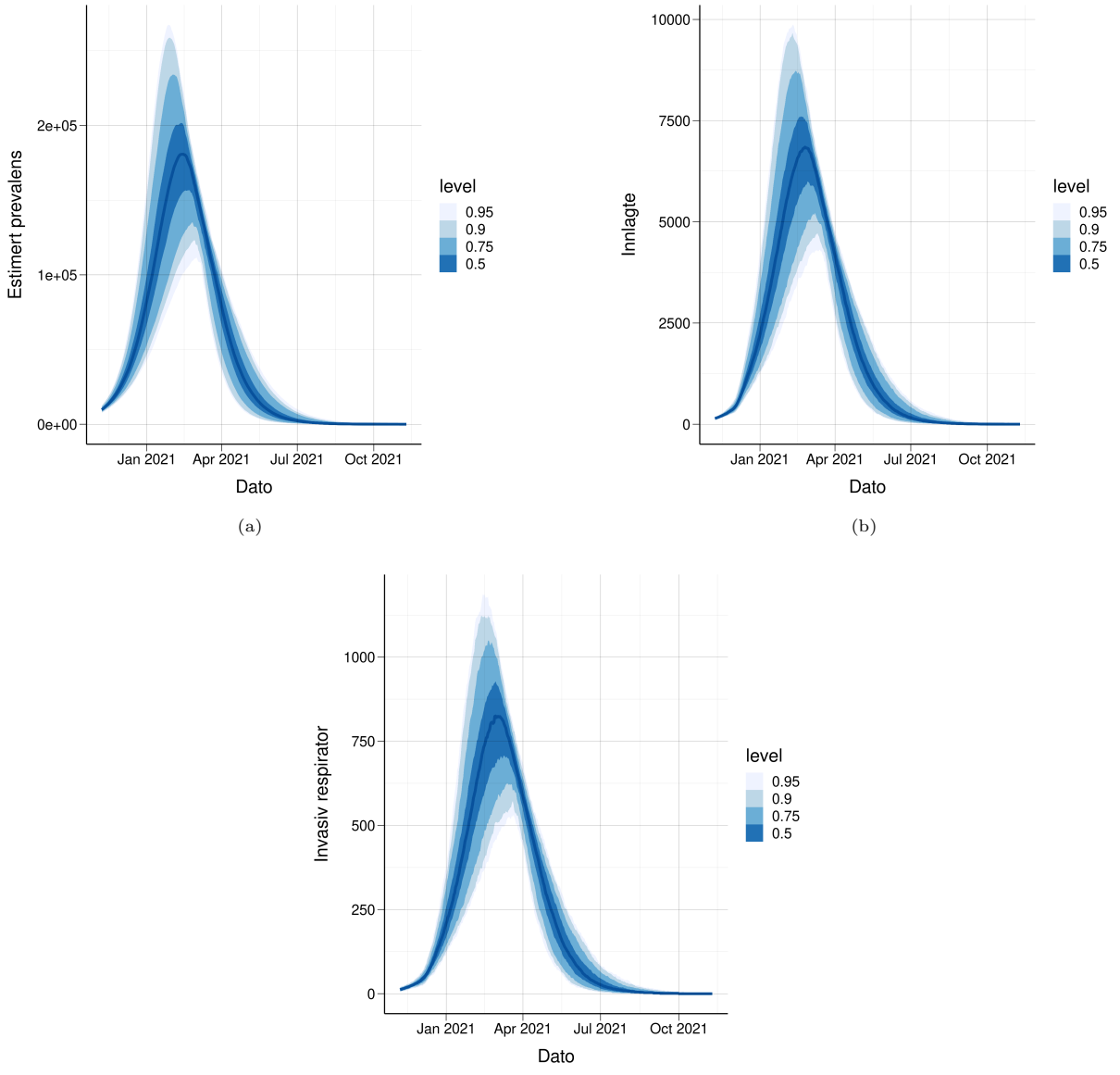


Figure 6: Long-term predictions for prevalence (a),hospital beds (b) and ventilator beds (c)

The probability of a surge capacity need above **500 ICU** beds is **99.5 %**. We estimate the probability of a surge capacity need above **1000 ICU** beds to be equal to **18.5 %**.

5 National scenario-based long-term predictions: Hospital beds and Ventilator beds

Here we show how the epidemic estimated from the national changepoint model will develop under three assumed epidemiological scenarios, by fixing the effective reproduction number to be 1.3, 1.4 or 1.5, from today. We show the daily number of COVID-19 patients in hospital, including patients receiving ventilator treatment, (Figure 7, and the daily number of patients on ventilator treatment, figure 8. Note that age-specific attack rate after 21 days of projection is assumed to follow the demography in each county, instead of being informed by the current age-distribution of the laboratory-confirmed cases. Additional information about the total attack rate (cumulative incidence) and healthcare burden and surge capacity for these scenarios are provided in Table 4.

Table 4: Predicted numbers of total infected, total number of hospitalisations, total number needing ventilator treatment, and the predicted peak number in ward (not in respirator), hospitalised (both with and without ventilator treatment) and ventilated treatments based on three different scenarios with R effective equal to 1.3, 1.4 and 1.5.

	Reff=1.3	**Reff=1.4**	**Reff=1.5**
Total:			
Attack rate (infected)	2.260.000(2.240.000 - 2.270.000)	2.710.000(2.700.000 - 2.720.000)	3.090.000(3.080.000 - 3.090.000)
Hospitalisations	70.000(69.400 - 70.600)	84.300(83.600 - 84.800)	96.000(95.300 - 96.600)
Patients on ventilator	4.340(4.210 - 4.450)	5.200(5.070 - 5.310)	5.900(5.760 - 6.020)
At peak			
Hospital beds, excl. vent.	3.800(3.710 - 3.930)	5.780(5.640 - 5.920)	7.870 (7.730 - 8.020)
Hospital beds, incl. vent.	4.320(4.210 - 4.450)	6.540 (6.380 - 6.700)	8.890(8.730 - 9.050)
Ventilator beds	534 (500 - 570)	799 (759 - 846)	1.080 (1.030 - 1.120)

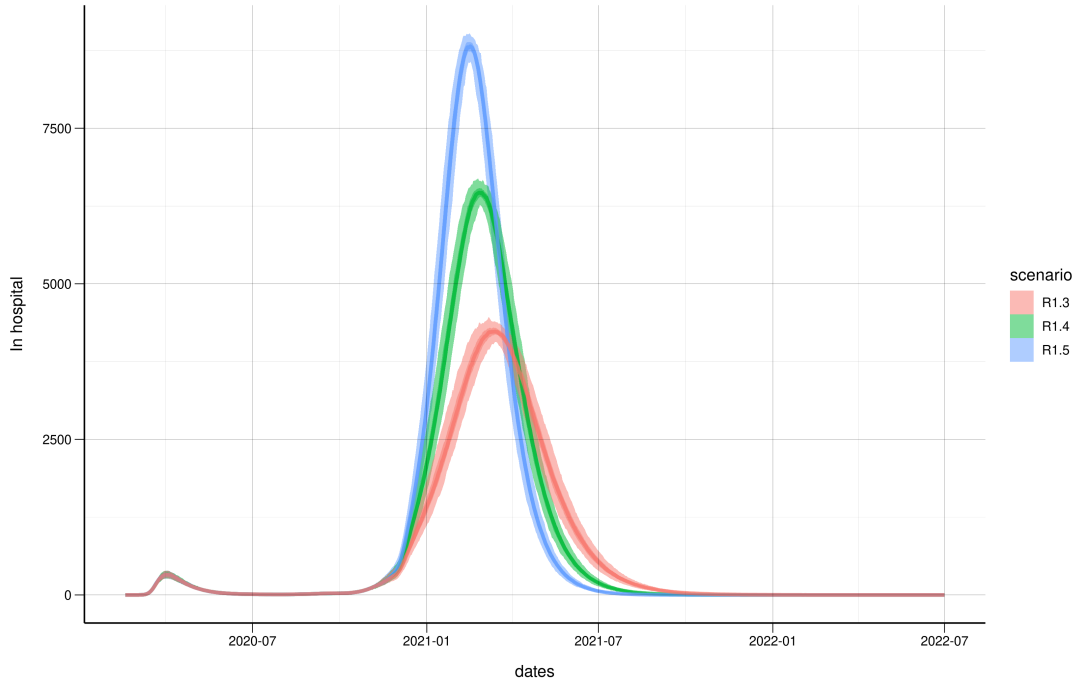


Figure 7: Predicted number of COVID-19 patients in hospital based on three different scenarios with R effective equal to 1.3, 1.4 and 1.5. Shaded areas show interquartile range and 95% confidence interval around the median.

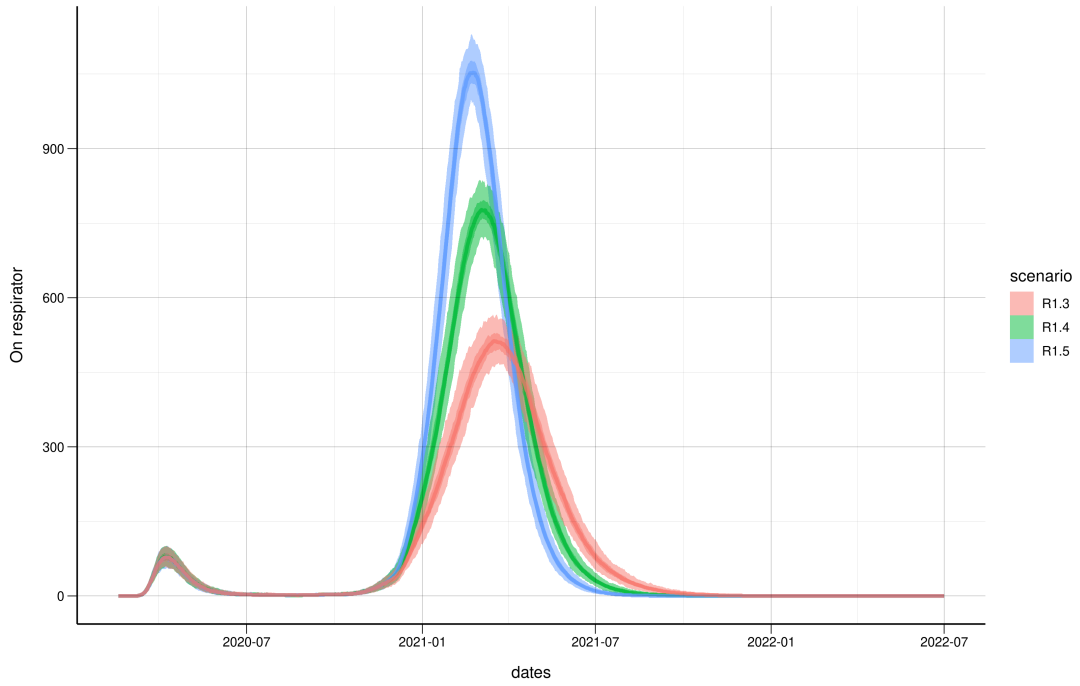


Figure 8: Predicted number of COVID-19 patients needing ventilator treatment based on three different scenarios with R effective equal to 1.3, 1.4 and 1.5. Shaded areas show interquartile range and 95% confidence interval around the median.

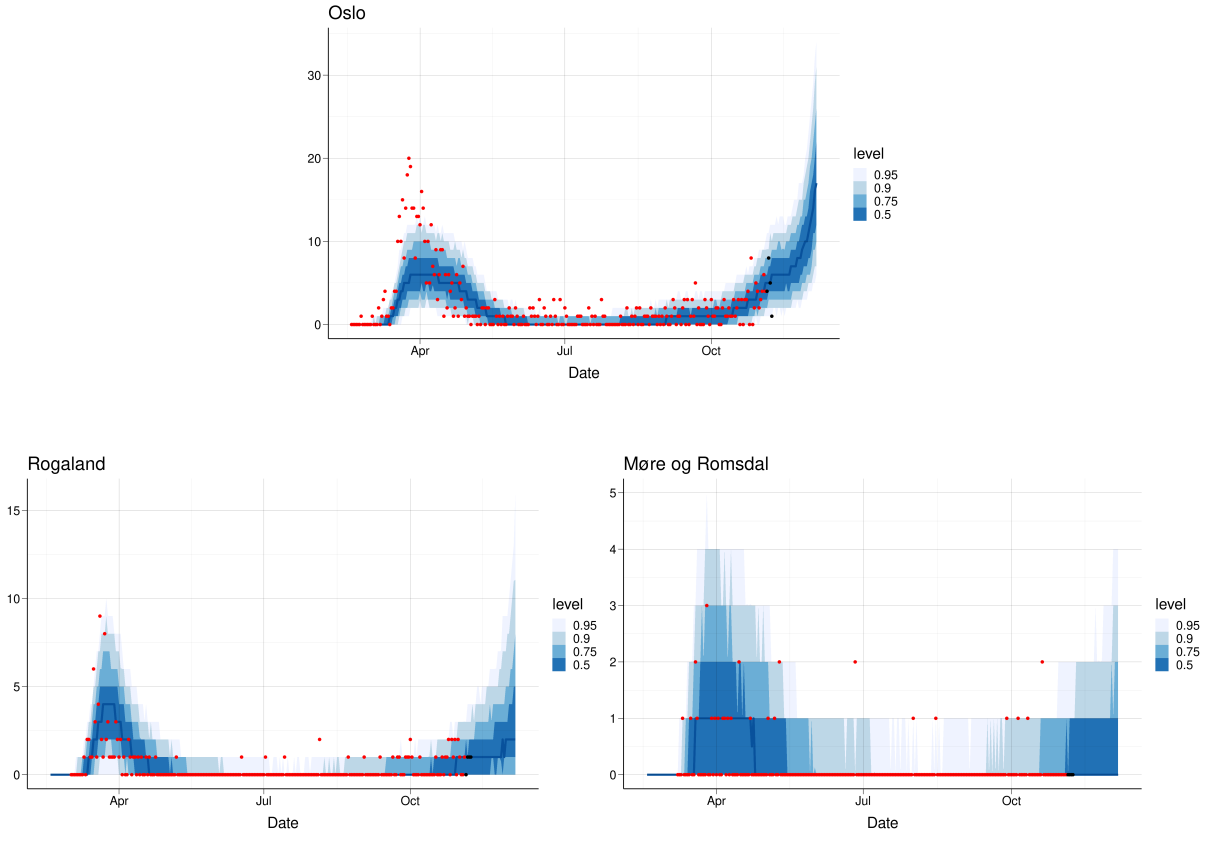
6 Estimated regional reproduction numbers

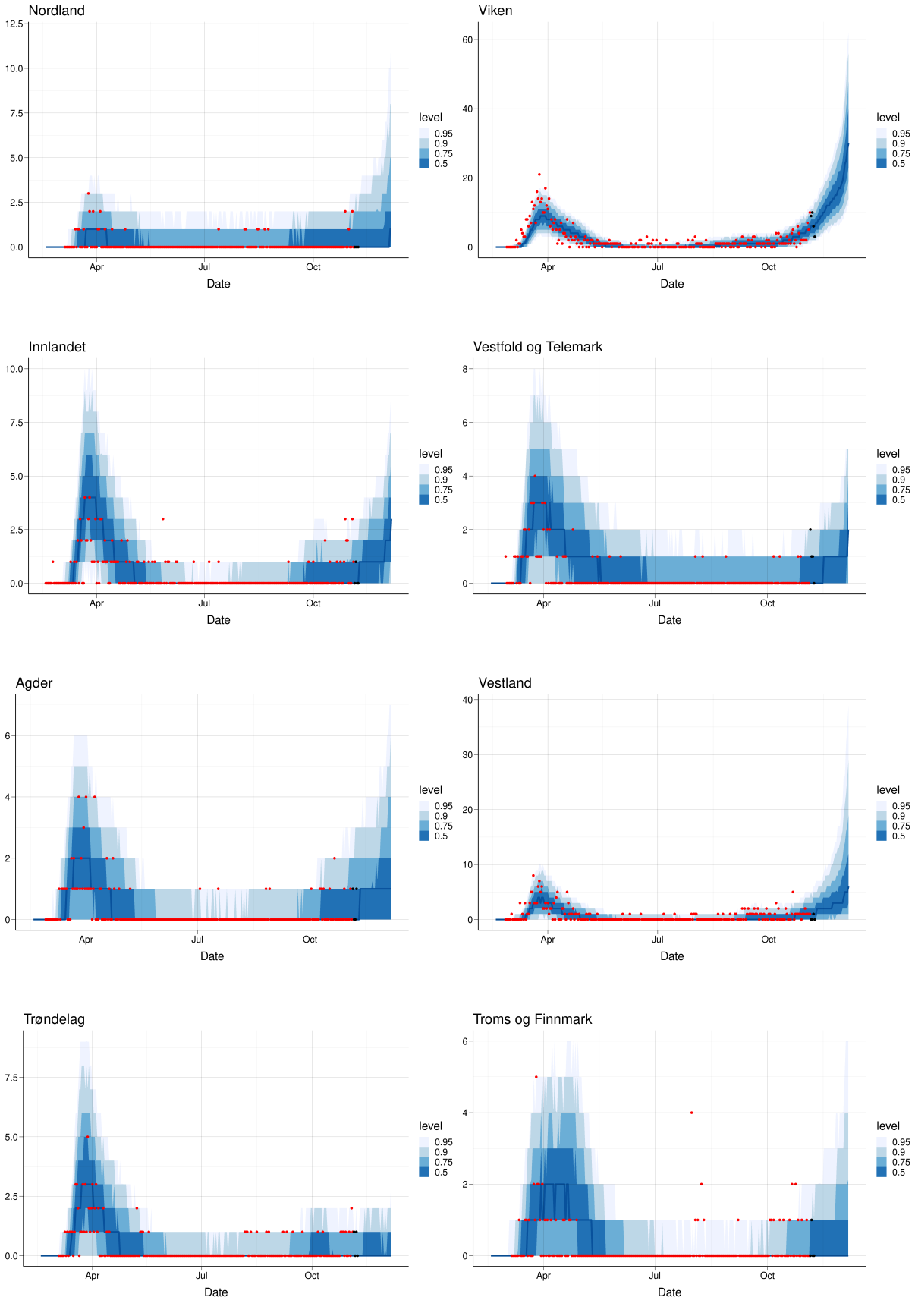
Calibration of our regional changepoint model to hospitalisation incidence data and test data leads to the following estimates for current regional reproduction numbers by county (Table **??**). A full list of all regional reproduction numbers can be found at the end of the report.
Below we show the estimated daily number of COVID-19 patients admitted to hospital and the estimated daily number of laboratory-confirmed SARS-CoV-2 cases for each county. Model estimates are shown with blue medians and interquantile bands, which are compared to the actual true data, provided in red. The blue bands describe the uncertainty in the calibrated parameters, in addition to the stochastic elements of our model. Last four data points are shown in black as they may be affected by reporting delay.

Table 5: Estimated current regional reproduction numbers

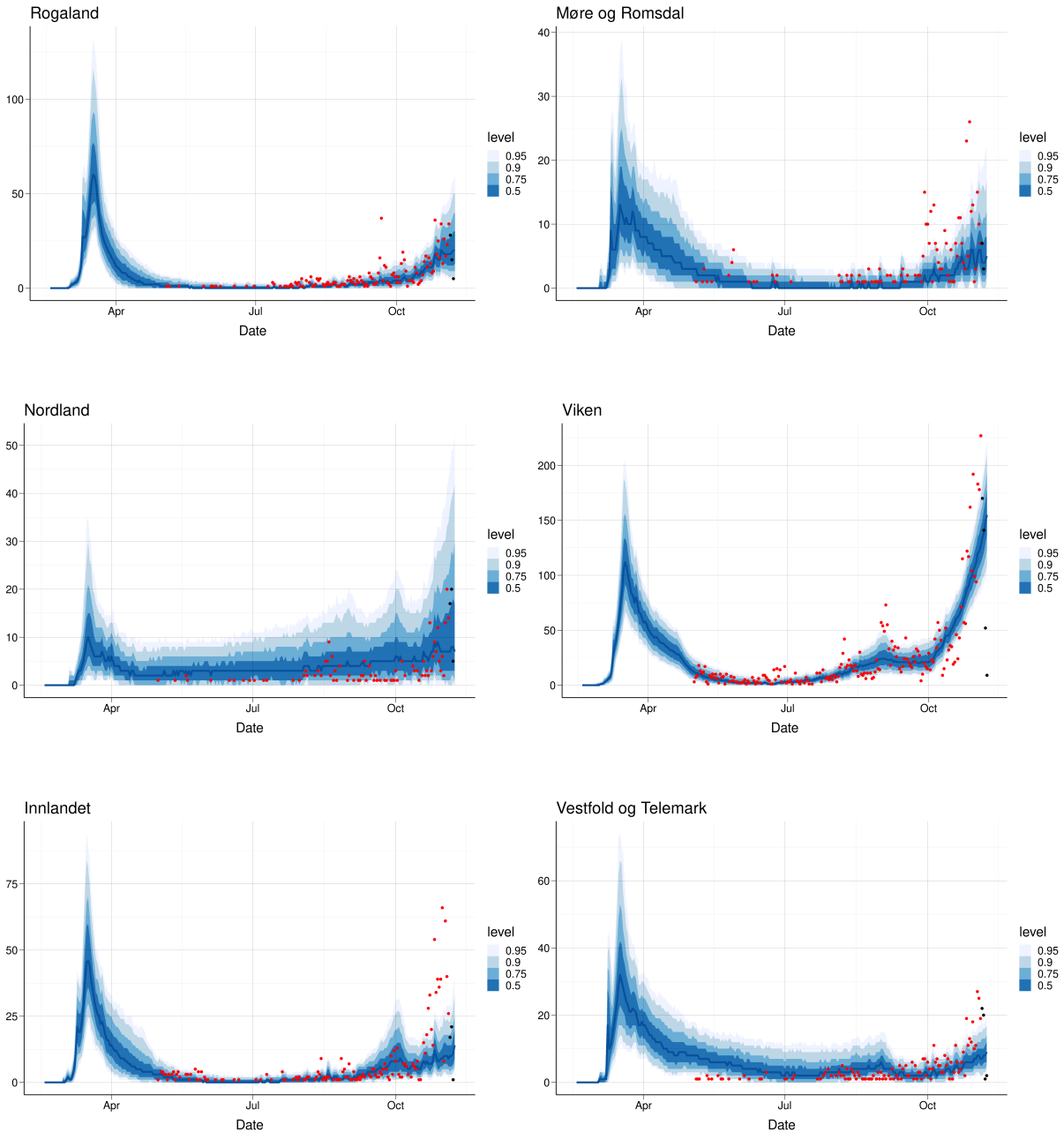
Mean (95% CI)	Parameter	County	From
1.64 (1.35-1.89)	R5	Oslo	2020-10-01
1.13 (0.63-1.61)	R4	Rogaland	2020-10-01
0.83 (0.23-1.4)	R4	Møre og Romsdal	2020-10-01
0.96 (0.25-1.67)	R4	Nordland	2020-10-01
1.39 (1.15-1.62)	R5	Viken	2020-10-01
0.64 (0.11-1.21)	R4	Innlandet	2020-10-01
0.35 (0.03-0.82)	R3	Vestfold og Telemark	2020-09-01
1.1 (0.75-1.46)	R3	Agder	2020-09-01
1.28 (0.67-1.8)	R5	Vestland	2020-10-01
0.5 (0.05-1)	R4	Trøndelag	2020-10-01
0.94 (0.29-1.57)	R4	Troms og Finnmark	2020-10-01

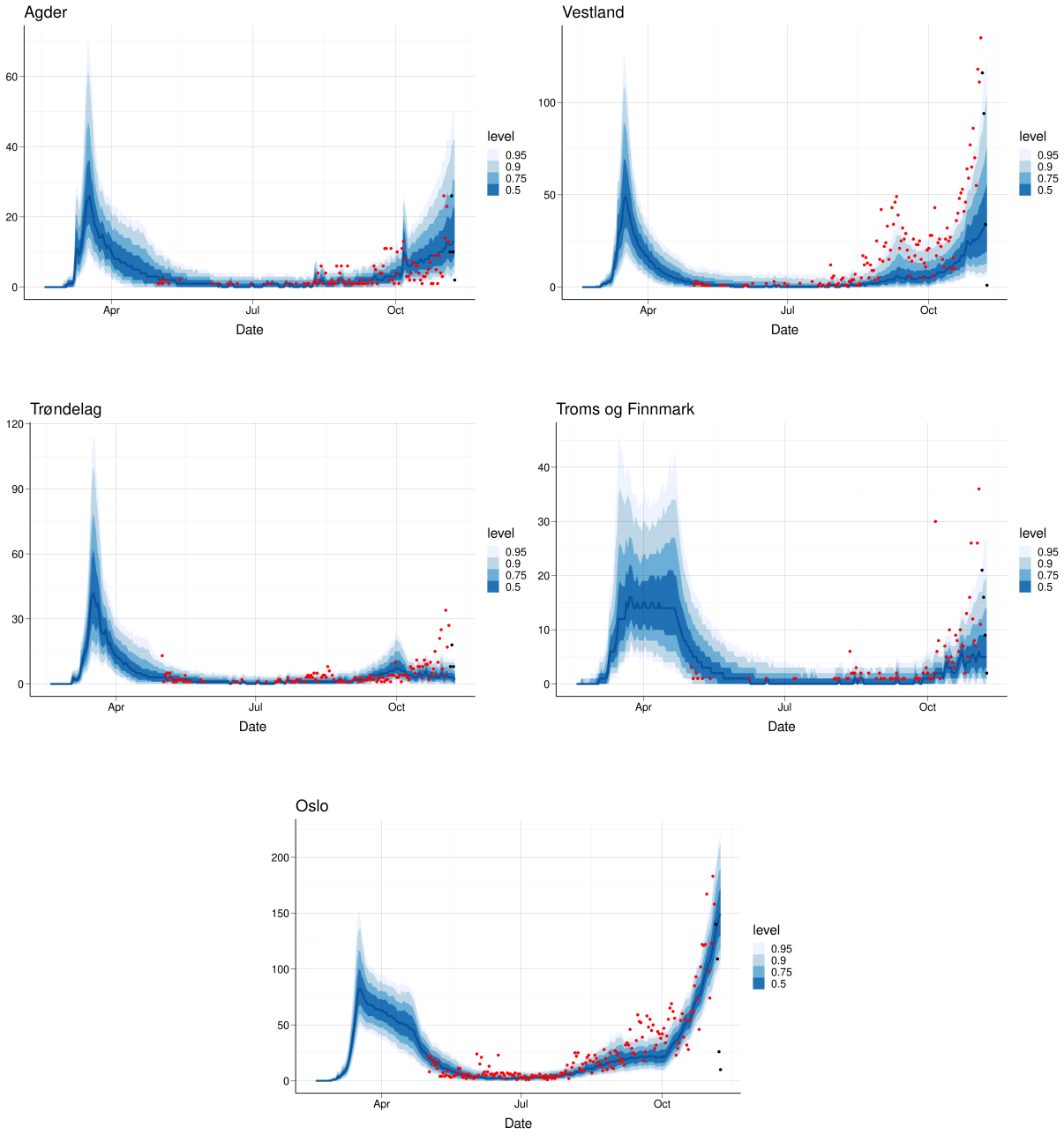
Estimated vs observed hospital incidence data by county:




Nordland
Viken
Innlandet
Vestfold og Telemark
Agder
Vestland
Trøndelag
Troms og Finnmark
level
0.95
0.9
0.75
0.5
Apr
Jul
Oct
Date

Estimated vs observed lab-confirmed test data by county:




Agder
Vestland
Trøndelag
Troms og Finnmark
Oslo
level
0.95
0.9
0.75
0.5
Apr
Jul
Oct
Date

7 Regional 3-week predictions: Cumulative (total) incidence and Prevalence

Below is shown the estimated short-term forecasting of total incidence of infected individuals (table 6) and daily incidence (table 7) for each county.

Table 6: Estimated cumulative number of infections, 2020-11-08

Region	Total	Symptomatic	No. confirmed	Fraction reported	Min. fraction
Agder	3774 (2219; 5979)	2383 (1460; 3648)	760	20%	13%
Innlandet	4828 (3275; 6961)	3055 (2135; 4376)	1341	28%	19%
Møre og Romsdal	2278 (1282; 3866)	1494 (873; 2466)	507	22%	13%
Nordland	3723 (1566; 6913)	2280 (980; 4137)	404	11%	6%
Oslo	22588 (16936; 29142)	13341 (9995; 17118)	7411	33%	25%
Rogaland	5275 (3421; 8034)	3399 (2264; 5039)	1213	23%	15%
Troms og Finnmark	3406 (1779; 5990)	2142 (1173; 3721)	691	20%	12%
Trøndelag	4193 (2437; 6792)	2681 (1589; 4257)	1036	25%	15%
Vestfold og Telemark	5541 (3582; 8811)	3502 (2299; 5468)	772	14%	9%
Vestland	6612 (3053; 12054)	4104 (2031; 7197)	3655	55%	30%
Viken	22551 (16816; 28958)	13953 (10600; 17754)	6731	30%	23%

Fraction reported=Number confirmed/number predicted; Minimal fraction reported=number confirmed/upper CI

Table 7: Predicted incidence per day: Median/Mean (CI)

Region	1 week prediction (15 Nov)	2 weeks prediction (22 Nov)	3 weeks prediction (29 Nov)
Agder	40/51 (13-147)	45/60 (12-199)	52/70 (13-232)
Innlandet	59/63 (25-133)	68/76 (26-176)	86/100 (34-240)
Møre og Romsdal	18/24 (3-72)	16/25 (2-95)	16/28 (1-126)
Nordland	26/43 (4-165)	25/54 (2-230)	23/69 (1-341)
Oslo	391/405 (235-630)	561/580 (300-969)	770/809 (377-1426)
Rogaland	80/98 (23-263)	87/122 (21-387)	100/155 (19-585)
Troms og Finnmark	18/27 (3-99)	19/33 (2-149)	19/42 (1-212)
Trøndelag	16/20 (4-55)	12/16 (1-59)	11/16 (2-63)
Vestfold og Telemark	35/38 (18-77)	41/44 (19-86)	58/62 (26-119)
Vestland	141/179 (33-574)	183/249 (29-914)	232/352 (33-1438)
Viken	731/760 (434-1213)	922/973 (501-1682)	1162/1247 (592-2286)

8 Regional 3-week predictions: Hospital beds and ventilator beds

Below is shown the estimated short-term forecasting of expected hospital prevalence (table 8) and patients on ventilator treatment for each county (table 9).

Table 8: Number of hospitalisation beds occupied by Covid-19 patients: Median/Mean (CI)

Region	1 week prediction (15 Nov)	2 weeks prediction (22 Nov)	3 weeks prediction (29 Nov)
Agder	4/6 (0-18)	4/6 (0-20)	5/7 (1-24)
Innlandet	5/6 (1-16)	8/8 (2-20)	9/10 (2-25)
Møre og Romsdal	2/3 (0-10)	2/3 (0-11)	2/3 (0-13)
Nordland	3/5 (0-18)	3/6 (0-23)	4/7 (0-29)
Oslo	41/42 (22-68)	46/48 (24-77)	59/60 (27-104)
Rogaland	8/8 (1-22)	9/11 (1-30)	11/13 (2-44)
Troms og Finnmark	2/3 (0-10)	2/3 (0-12)	2/4 (0-18)
Trøndelag	2/2 (0-8)	2/2 (0-9)	2/3 (0-9)
Vestfold og Telemark	3/4 (0-11)	4/5 (1-12)	5/6 (1-15)
Vestland	12/14 (2-37)	16/19 (3-57)	20/27 (2-94)
Viken	55/56 (29-91)	78/81 (43-132)	104/108 (55-184)

Table 9: Number of ICU beds occupied by Covid-19 patients: Median/Mean (CI)

Region	1 week prediction (15 Nov)	2 weeks prediction (22 Nov)	3 weeks prediction (29 Nov)
Agder	0/1 (0-3)	0/1 (0-3)	0/1 (0-3)
Innlandet	0/1 (0-2)	1/1 (0-3)	1/1 (0-4)
Møre og Romsdal	0/0 (0-2)	0/0 (0-2)	0/0 (0-2)
Nordland	0/1 (0-2)	0/1 (0-3)	0/1 (0-4)
Oslo	4/4 (1-9)	5/5 (1-10)	6/6 (1-12)
Rogaland	1/1 (0-3)	1/1 (0-4)	1/1 (0-5)
Troms og Finnmark	0/0 (0-2)	0/0 (0-2)	0/0 (0-2)
Trøndelag	0/0 (0-2)	0/0 (0-2)	0/0 (0-2)
Vestfold og Telemark	0/0 (0-2)	0/1 (0-2)	0/1 (0-3)
Vestland	1/1 (0-4)	1/2 (0-6)	2/2 (0-9)
Viken	5/5 (1-10)	7/7 (2-14)	10/10 (3-19)

9 Scenario-based short-term predictions for Oslo:

Oslo has experienced increasing infection levels in the last months. Rising case numbers can lead to less efficient contact tracing due to a lack of resources. This, in turn, can cause the reproductive number to increase.To explore the short-term consequences of a less effective contact tracing in Oslo, we compare projections of the regional changepoint model, where the current reproduction number in Oslo (R5=1.64) is increased to 1.70; 1.75 and 1.80 from today, respectively. In these scenarios we assume no change to the reproductive numbers in the other counties. Table 10 and Figure compares these projected scenarios with a projection of the current epidemiological situation in Oslo.

Table 10: 4 week predictions in Oslo: Prevalence and Incidence (mean/median (CI))

Scenario	Prevalence	Incidence
Current	5596/5528 (3326-8108)	1091/1066 (663-1635)
R=1.70	6124/6008 (3564-9316)	1211/1186 (682-1855)
R=1.75	6562/6468 (3931-9655)	1311/1291 (762-1884)
R=1.80	7097/7013 (4111-10831)	1430/1433 (834-2164)

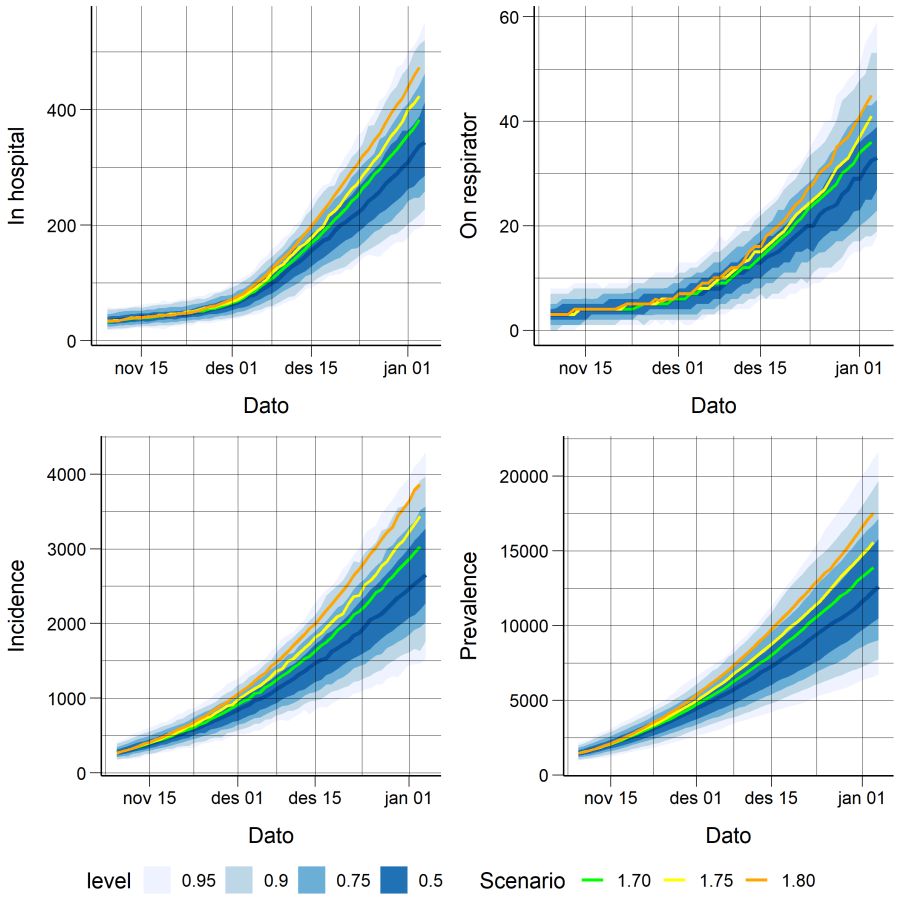


Figure 19: Future predictions for Oslo assuming the reproductive number will remain constant vs median of alternative scenarios. Confidence intervals correspond to "current scenario". Parameters showed are: Hospitalisations (top left), On respirator (top right),Incidence (bottom left) and Prevalence (bottom right).

10 Scenario-based short-term predictions for Bergen:

Similarly to the previous section, we explore the potential effect in Bergen municipality of an hypothetical increase in the reproduction number in Vestland. We compare projections of the regional changepoint model using the median reproduction number in Vestland (R5=1.28), with several scenarios (1.35,1.40,1.45) where the reproduction number is increased from today. As before, in these scenarios we assume no change to the reproductive numbers in the other counties. Table 11 and Figure compares these projected scenarios with a projection of the current epidemiological situation in Bergen.

Table 11: 4 week predictions in Bergen: Prevalence and Incidence (mean/median(CI))

Scenario	Prevalence	Incidence
Current	821/734 (321-2076)	145/131 (55-360)
R=1.35	958/852 (391-2321)	173/153 (69-410)
R=1.40	1073/938 (387-2630)	196/170 (77-484)
R=1.45	1202/1075 (474-2929)	221/199 (90-533)

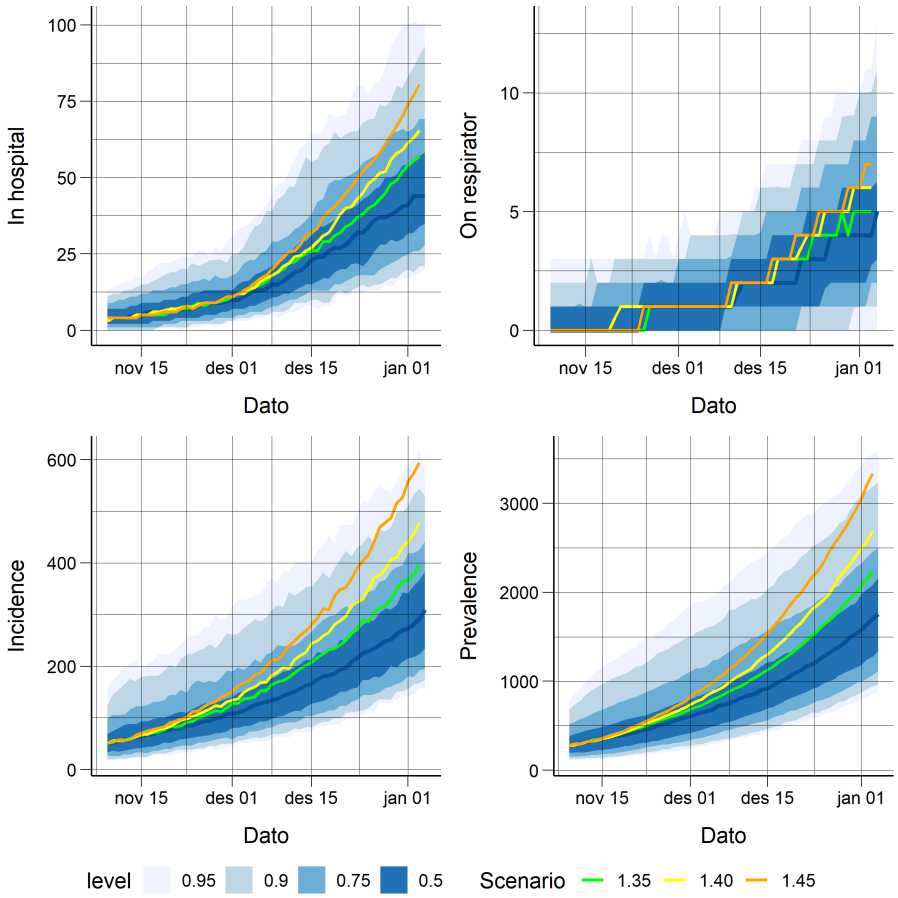
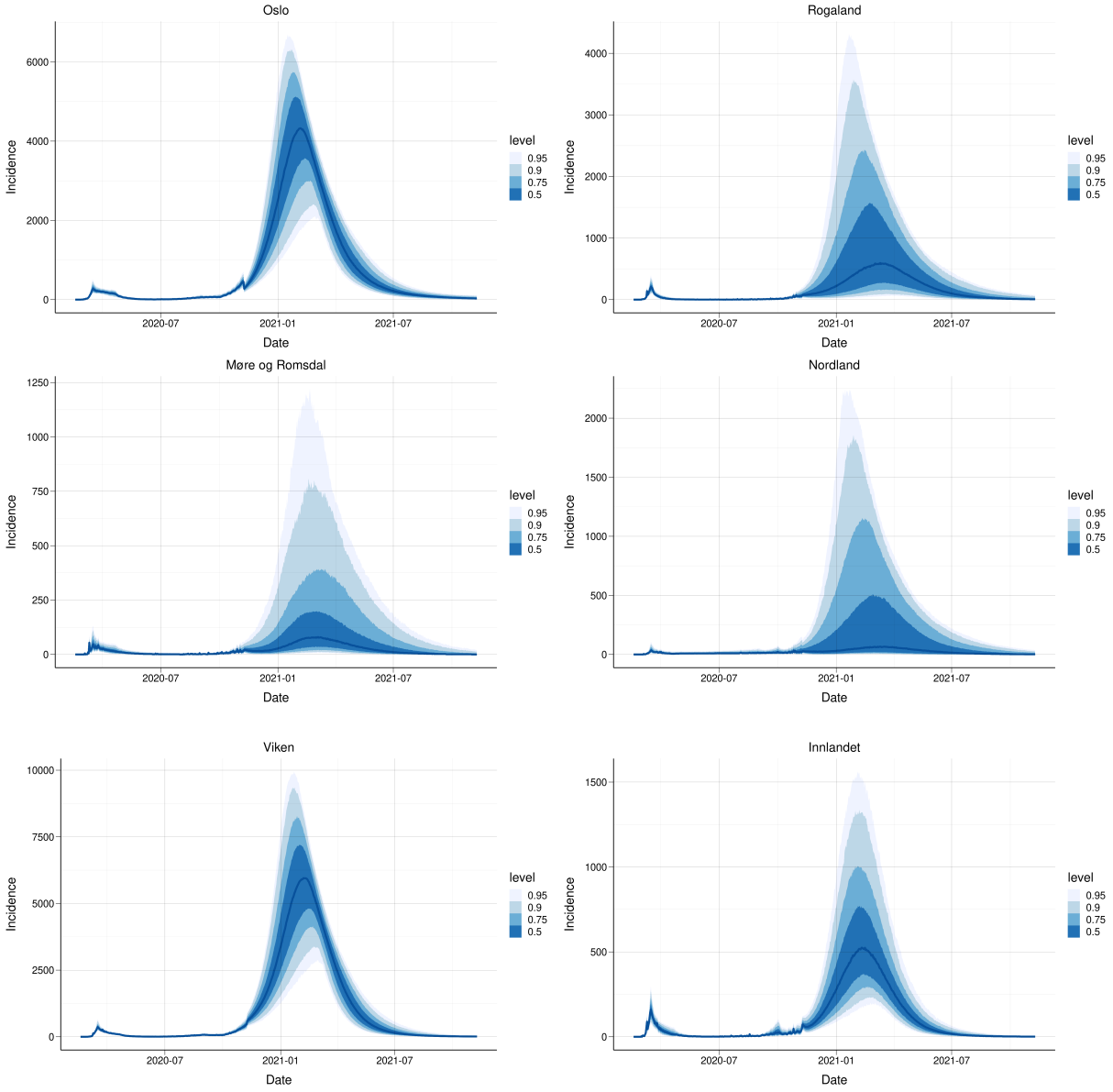


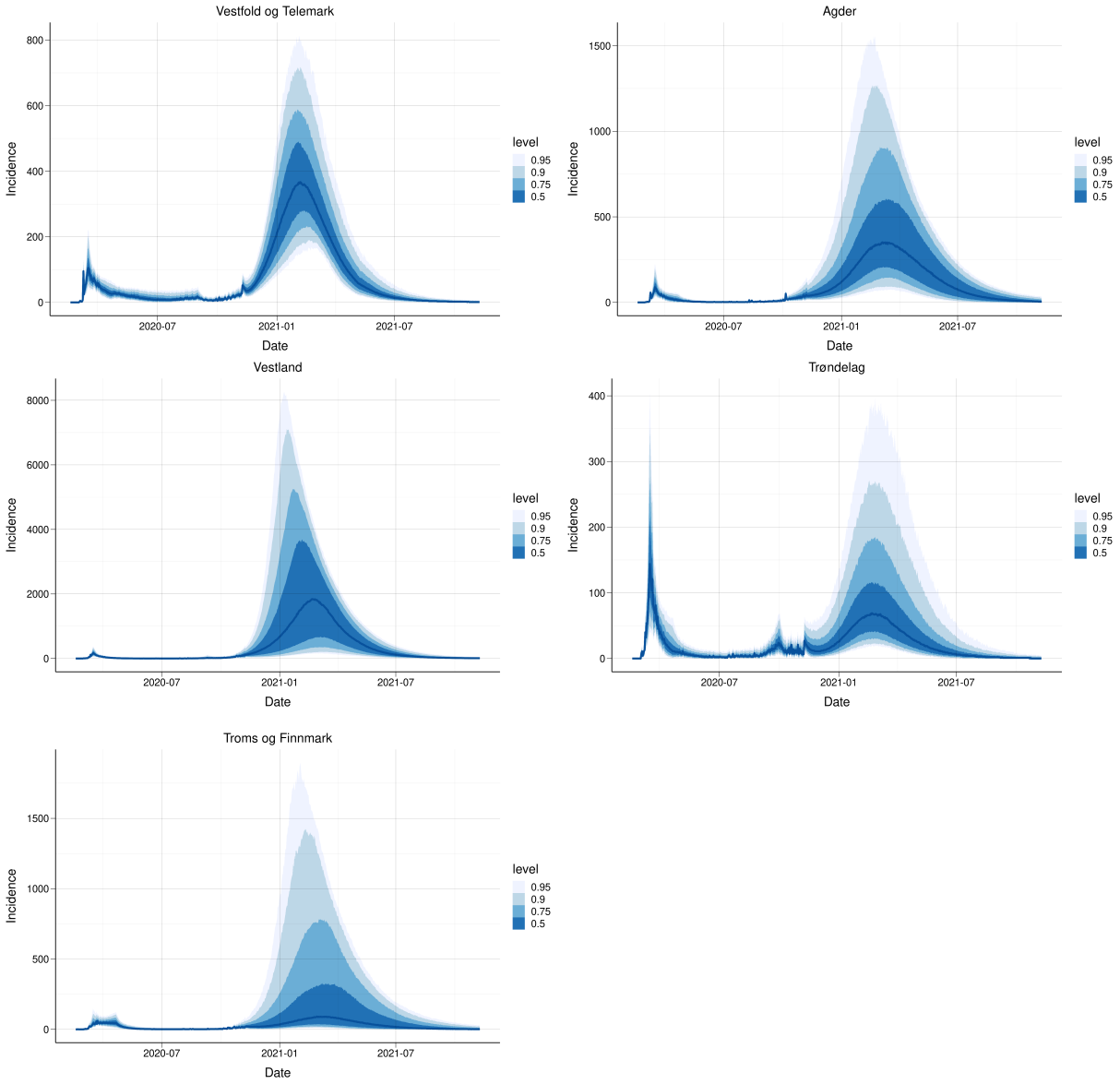
Figure 20: Future predictions for Bergen assuming the reproductive number will remain constant vs median of alternative scenarios. Confidence intervals correspond to "current scenario". Parameters showed are: Hospitalisations (top left), On respirator (top right),Incidence (bottom left) and Prevalence (bottom right).

11 Regional long-term predictions

11.1 Incidence

Predicted incidence (asymptomatic,pre-symptomatic and symptomatic) of the calibrated regional change-point model for each county per day, with confidence intervals.

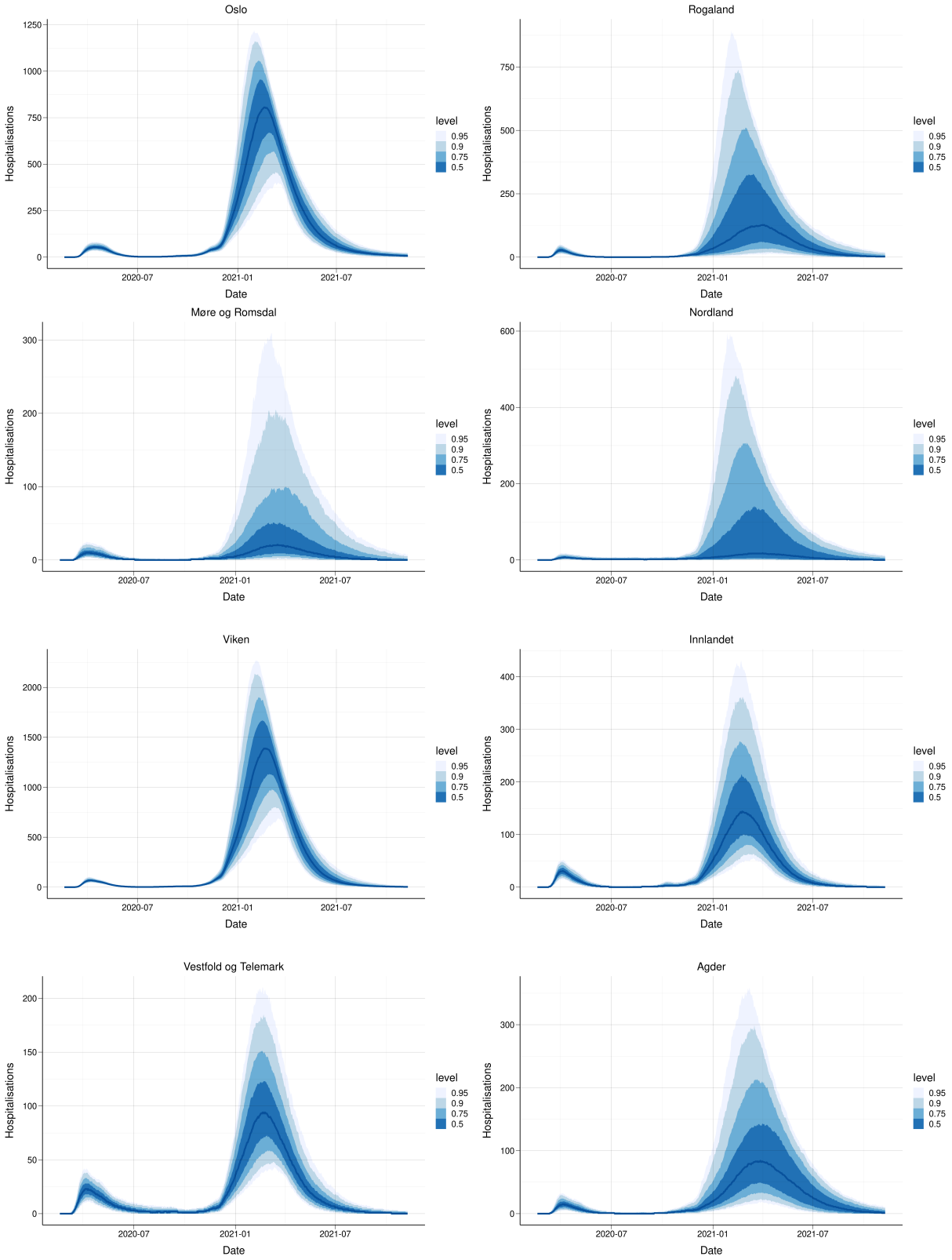




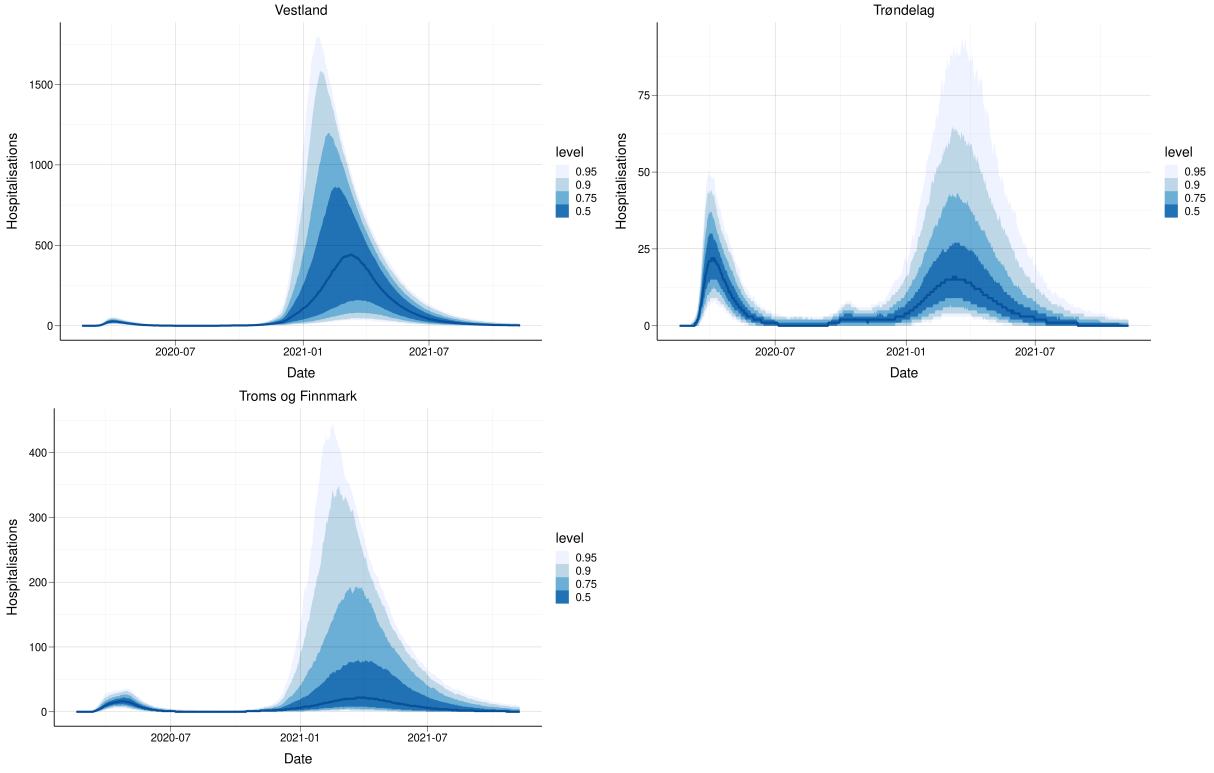
11.2 Hospitalisations

Estimated prevalence of COVID-19 patients in hospital, including patients receiving ventilator treatment.

11.2 Hospitalisations



11.2 Hospitalisations



12 Mobility between municipalities

Number of trips out from each municipality during each day is based on Telenor mobility data. We observed a large reduction in inter-municipality mobility in March (with minimum reached on Tuesday 17 March), and thereafter we see an increasing trend in the mobility lasting until vacation time in July. The drop in mobility in July coincides with the three-week "fellesferie" in Norway, and during August the mobility resumes approximately the same levels as pre-vacation time.

See Figure 21 for an overview of the mobility since March for the 20 largest municipalities, and Figure 22 for Norway's counties (fylker). Figure 23 and 24 are zooming in on the mobility since June 29, for municipalities and counties, respectively.

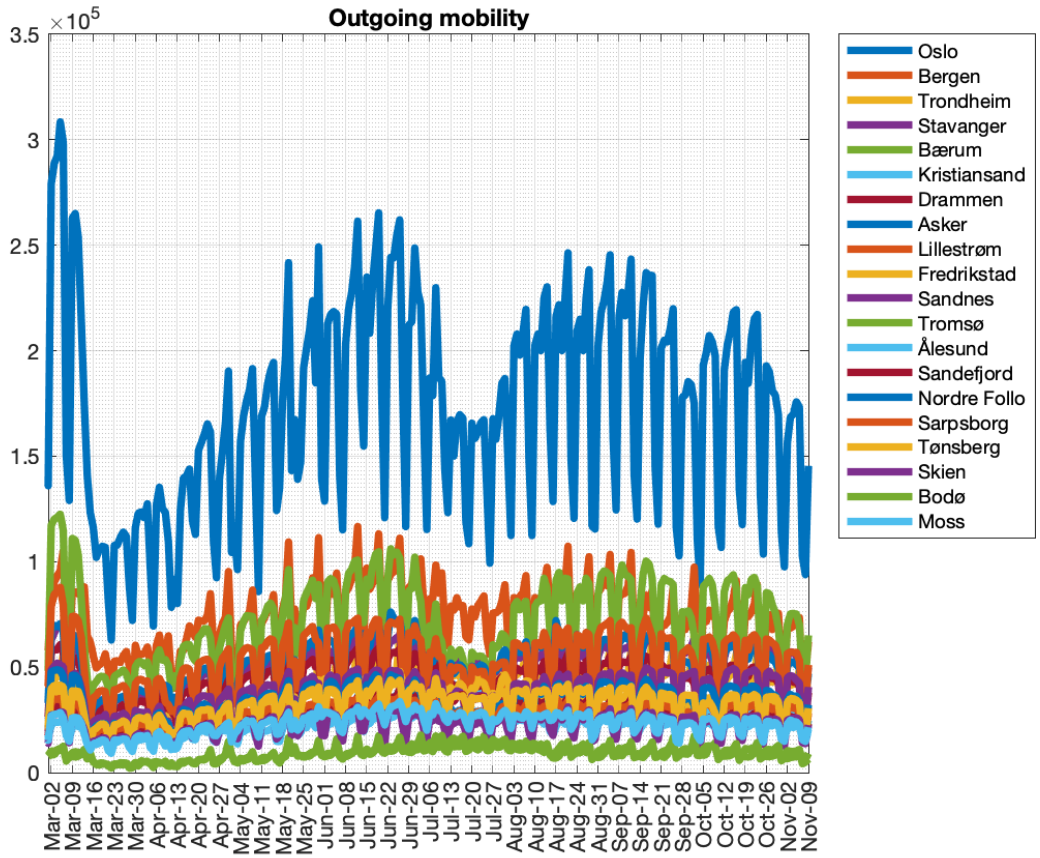


Figure 21: Inter-municipality mobility from week 10 until today.

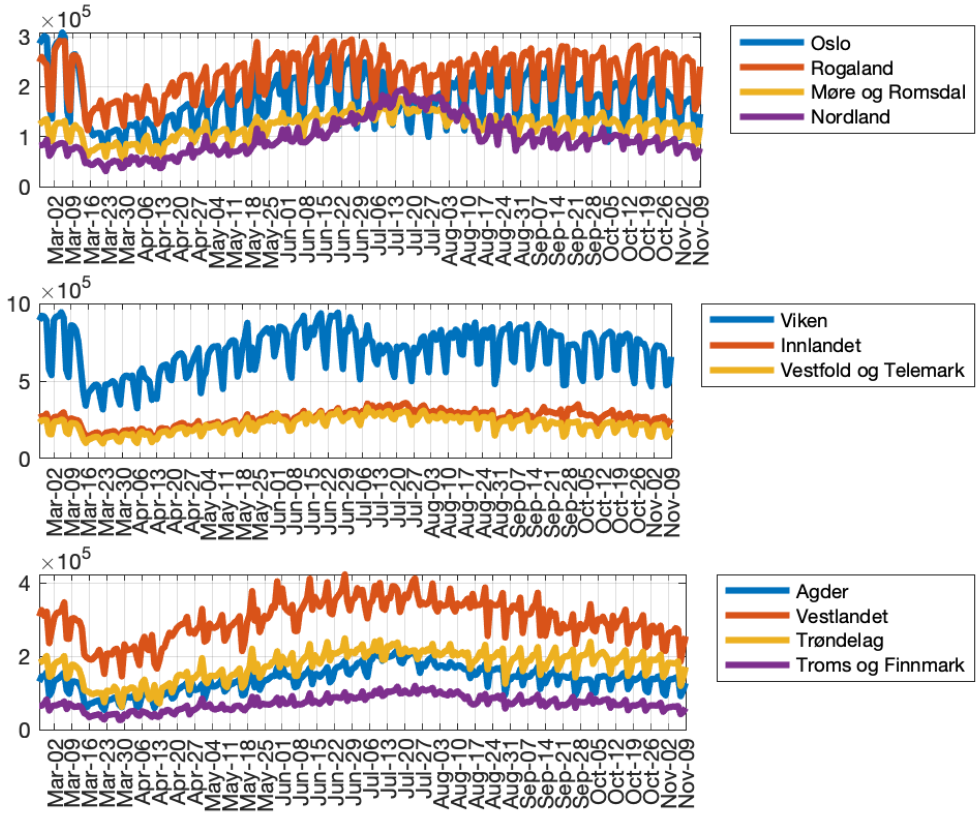


Figure 22: Inter-county mobility from week 10 until today.

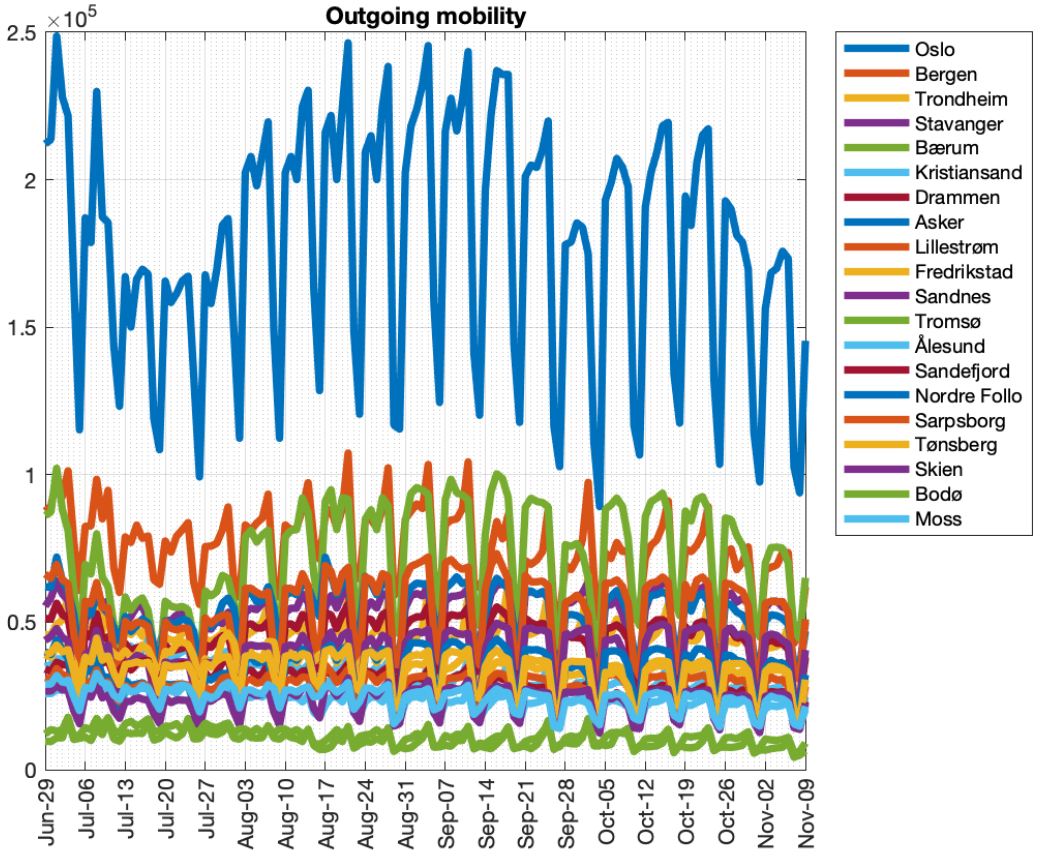


Figure 23: Zoom: Inter-municipality mobility from June 29 until today.

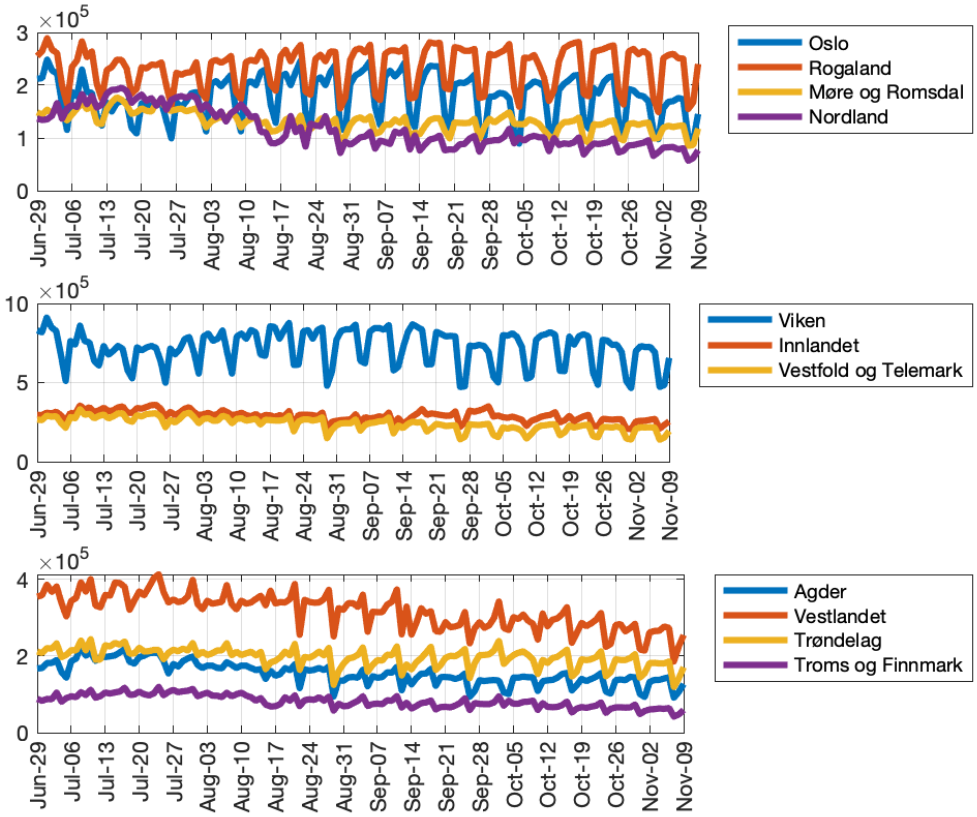


Figure 24: Zoom: Inter-municipality mobility from June 29 until today.

The reduction in movements the last ten days is compared to movements in week 10: Mondays are compared to Monday March 2nd (last Monday before restrictions); Tuesdays are compared to Tuesday March 3rd, etc. until Sundays are compared to Sunday March 8th. For municipalities see Table 12, and for counties see Table 13.

Table 12: Percentage reduction in total mobility out from each municipality.

	31 Oct 2020 Lørdag	01 Nov 2020 Søndag	02 Nov 2020 Mandag	03 Nov 2020 Tirsdag	04 Nov 2020 Onsdag	05 Nov 2020 Torsdag	06 Nov 2020 Fredag	07 Nov 2020 Lørdag	08 Nov 2020 Søndag	09 Nov 2020 Mandag
Hele Norge	9.7%	10.0%	15.0%	14.8%	15.7%	17.6%	18.7%	18.2%	7.4%	18.9%
Oslo	24.1%	24.4%	44.0%	41.6%	41.9%	43.0%	42.0%	31.8%	27.2%	47.9%
Bergen	18.3%	23.0%	21.1%	23.9%	25.6%	23.0%	30.1%	33.6%	22.5%	27.7%
Trondheim	4.0%	0.8%	3.4%	6.9%	7.3%	9.7%	12.8%	18.1%	12.1%	12.4%
Stavanger	2.1%	4.3%	12.7%	13.6%	17.1%	19.8%	21.5%	15.6%	-1.7%	20.5%
Bærum	11.0%	5.1%	40.2%	37.3%	37.7%	38.7%	39.0%	20.6%	6.3%	44.5%
Kristiansand	4.7%	-5.9%	5.0%	4.7%	7.8%	6.8%	12.9%	12.6%	-1.8%	11.4%
Drammen	18.5%	14.2%	24.5%	24.6%	26.3%	29.5%	29.1%	31.7%	19.5%	33.0%
Asker	8.7%	-2.0%	25.6%	24.8%	24.5%	27.4%	26.3%	16.2%	-2.3%	30.7%
Lillestrøm	21.6%	20.5%	28.4%	32.4%	33.8%	35.1%	33.1%	27.7%	18.8%	35.2%
Fredrikstad	6.5%	6.3%	13.2%	9.4%	10.7%	11.9%	11.7%	14.5%	-1.9%	17.1%
Sandnes	0.7%	0.4%	7.4%	8.7%	12.3%	14.3%	15.5%	14.3%	-11.0%	16.5%
Tromsø	-2.9%	15.0%	21.4%	16.1%	26.9%	30.2%	22.8%	22.9%	37.4%	23.4%
Ålesund	7.2%	-1.1%	6.7%	9.1%	10.4%	9.2%	10.6%	19.3%	13.0%	7.6%
Sandefjord	26.4%	19.4%	17.8%	14.9%	15.9%	19.3%	18.7%	31.6%	16.3%	23.8%
Nordre Follo	5.8%	2.5%	28.2%	23.4%	25.9%	25.1%	26.4%	12.9%	-0.7%	32.6%
Sarpsborg	15.4%	12.5%	10.4%	9.9%	12.3%	12.9%	14.3%	19.8%	4.2%	14.4%
Tønsberg	16.5%	13.0%	16.0%	15.1%	15.4%	17.0%	18.7%	23.7%	20.2%	23.1%
Skien	11.7%	11.0%	9.1%	7.5%	7.3%	9.8%	11.8%	21.3%	3.0%	17.6%
Bodø	-13.5%	-7.2%	-1.4%	1.0%	7.6%	10.5%	5.6%	0.3%	11.2%	11.4%
Moss	9.4%	0.1%	14.4%	9.5%	12.9%	15.5%	12.9%	11.7%	0.6%	20.2%

Table 13: Percentage reduction in total mobility out from each county.

	31 Oct 2020 Lørdag	01 Nov 2020 Søndag	02 Nov 2020 Mandag	03 Nov 2020 Tirsdag	04 Nov 2020 Onsdag	05 Nov 2020 Torsdag	06 Nov 2020 Fredag	07 Nov 2020 Lørdag	08 Nov 2020 Søndag	09 Nov 2020 Mandag
Hele Norge	9.7%	10.0%	15.0%	14.8%	15.7%	17.6%	18.7%	18.2%	7.4%	18.9%
Oslo	24.1%	24.4%	44.0%	41.6%	41.9%	43.0%	42.0%	31.8%	27.2%	47.9%
Rogaland	0.6%	2.3%	8.1%	9.3%	11.1%	13.3%	14.1%	12.4%	-9.7%	12.1%
Møre og Romsdal	-0.8%	-11.4%	0.3%	3.5%	5.3%	3.3%	5.9%	13.4%	3.2%	1.5%
Nordland	-7.4%	3.5%	-0.8%	1.4%	3.7%	10.2%	5.8%	7.4%	17.9%	5.2%
Viken	11.6%	11.4%	21.8%	20.4%	21.1%	23.1%	23.8%	18.0%	7.8%	26.6%
Innlandet	13.3%	17.8%	4.7%	4.2%	3.3%	7.4%	9.4%	13.4%	7.2%	4.5%
Vestfold og Telemark	14.8%	11.5%	11.9%	9.4%	10.0%	13.3%	13.3%	19.0%	3.1%	17.5%
Agder	5.4%	4.4%	1.1%	-0.4%	2.6%	4.9%	7.4%	14.5%	-9.2%	5.3%
Vestlandet	12.4%	13.5%	14.5%	16.7%	16.8%	15.2%	21.3%	25.1%	9.1%	16.7%
Trøndelag	-3.0%	-5.2%	-2.3%	1.0%	3.3%	5.1%	7.4%	14.6%	4.4%	3.8%
Troms og Finnmark	13.0%	20.9%	7.8%	7.2%	9.7%	12.6%	15.8%	24.8%	33.3%	10.2%

12.1 Foreign roamers in Norway

An analysis of foreign roamers in Norway for 2020 has been carried out, to better understand the potential virus importation risk that these roamers represent. In Figure 25 the total number of roamers are broken down on different fylker, and from the figure one can see an approximate 40% drop in the number of visiting roamers after the lock-down in March. The number of visiting roamers recover during the Summer, and there is a spike of visitors in August followed by a drop again. During October the levels of visiting, foreign roamers to Norway have reached quite high levels, just 10% short of the all-year high, and Oslo and Viken have seen big increases in visitors.

Figure 26 showcases the levels of roamers from four different countries: Poland, Sweden, Denmark, and Germany, and the figure illustrates where in Norway the roamers of the given nationality are staying. For example, the Polish roamers are typically going to the cities; Oslo, Bergen, Trondheim, and Stavanger, and they show quite high visiting levels during all of 2020, and where the visiting-levels in October are all-time highs for 2020. In comparison, the Danish roamers show a high visiting population early in 2020, and levels drop after the lock-down, with a visiting spike during July followed by a drop after Summer. German roamers show the same behaviour, but at lower, absolute levels. Swedish visitors travel to Oslo mainly, and have now recovered to pre-March visiting levels.

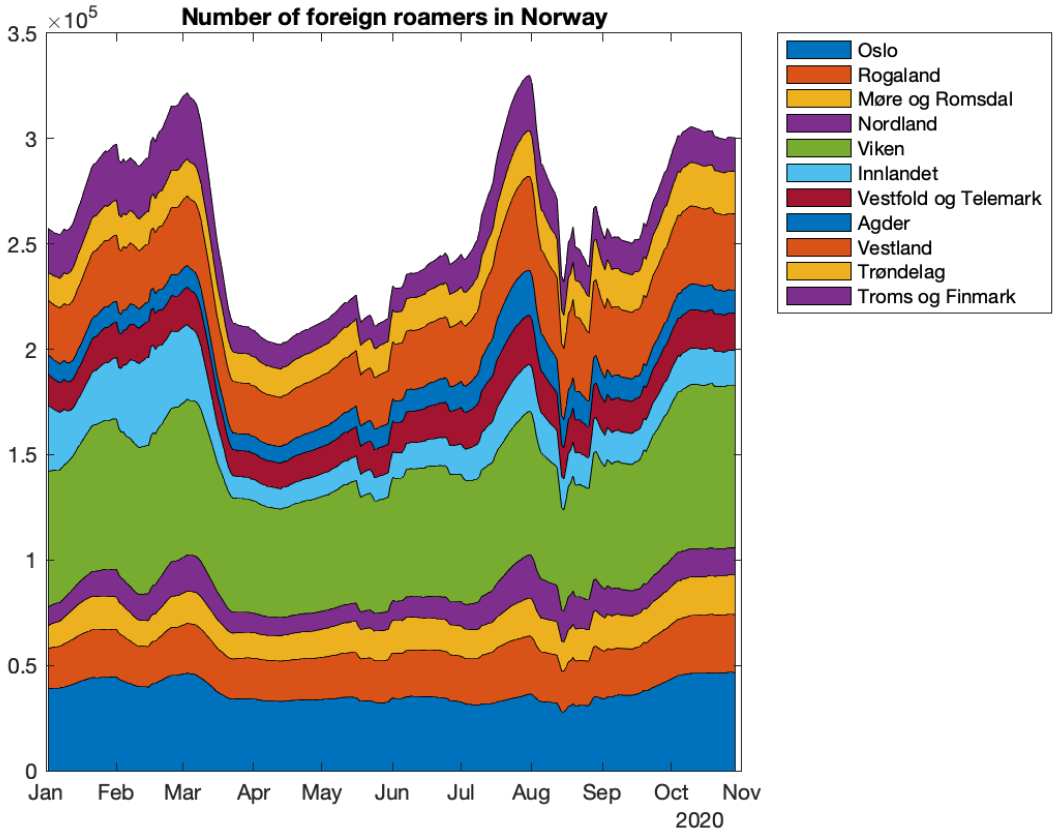


Figure 25: The total number of foreign roamers in Norway broken down on different fylker.

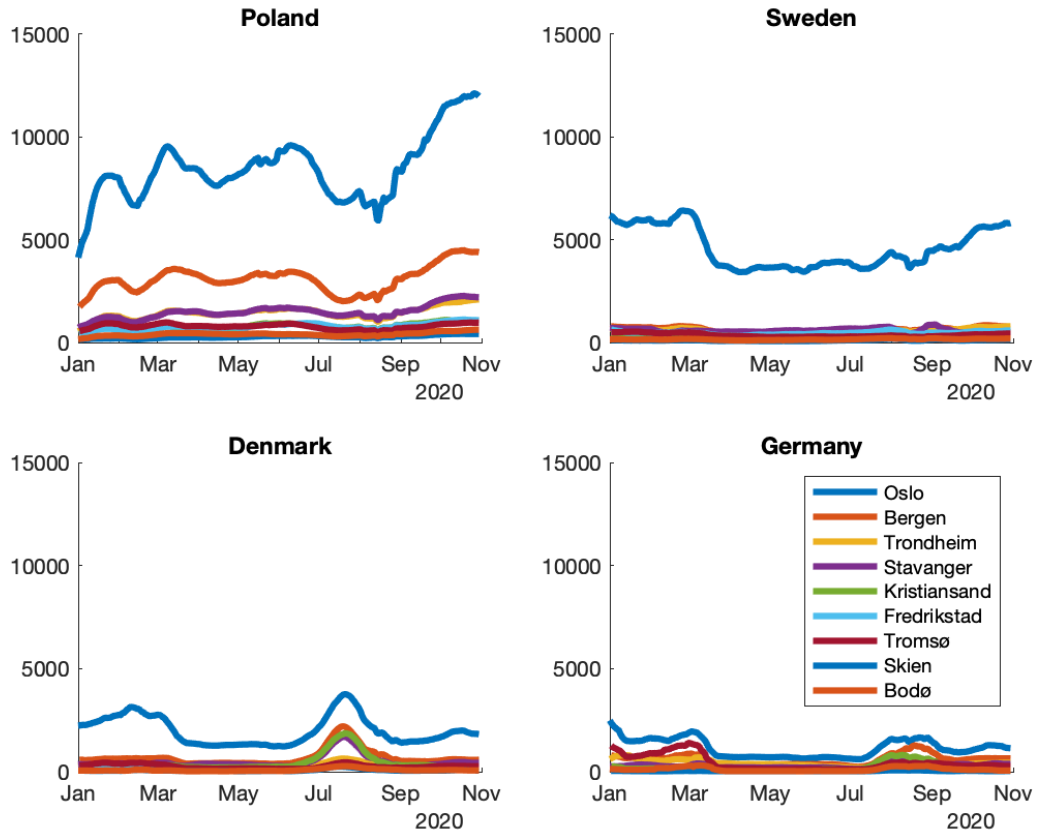


Figure 26: The total number of roamers broken down on the different fylker.

13 Methods

Details on this model can be found here https://www.fhi.no/sv/smittsomme-sykdommer/corona/koronavirus-modellering/. We use assumptions related to hospitalisation stay based on Norwegian data–NPR data linked with MSIS data. The parameters are specified in the report 2020.05.19 Corona report.pdf.
Estimation of the reproduction numbers (and of the amplification factor in seeding of the epidemic at the start) is done using Approximate Bayesian Computation (ABC), as described in Engebretsen et al. (2020): https://royalsocietypublishing.org/doi/10.1098/rsif.2019.0809.
Briefly: We run a sequential Monte Carlo ABC in order to obtain 1000 parameter sets of the different reproduction number for each county, which best fit the hospitalisation data of each county. We also obtain the best estimate for the amplification factor F used to seed the epidemic. Next we run the model with these 1000 parameter sets again, from the beginning until today, plus three weeks into the future, or plus 12 months. Using these 1000 trajectories of the future, we make future predictions and confidence intervals. They account for the changes in the movement patterns between municipalities that have occurred since the start of the epidemic.

New in this report is the use of different number of reproduction numbers in each of the counties (5 in Oslo and Viken, and 4 in the rest). For some of the counties, it is difficult to estimate regionally varying parameters when the hospital incidence data is so low.

Model

We use a metapopulation model to simulate the spread of COVID-19 in Norway in space and time. The model consists of three layers: the population structure in each municipality, information about how people move between different municipalities, and local transmission within each municipality. In this way, the model can simulate the spread of COVID-19 within each municipality, and how the virus is transported around in Norway.

Transmission model

We use an SEIR (Susceptible-Exposed-Infected-Recovered) model without age structure to simulate the local transmission within each area. Mixing between individuals is assumed to be random. Demographic changes due to births, immigration, emigration and deaths are not considered. The model distinguishes between asymptomatic and symptomatic infection, and we consider presymptomatic infectiousness among those who develop symptomatic infection. In total, the model consists of 6 disease states: Susceptible (S), Exposed, infected, but not infectious (E), Presymptomatic infected (E2), Symptomatic infected (I), Asymptomatic infected (Ia), and Recovered, either immune or dead (R). A schematic overview of the model is shown in figure 27.

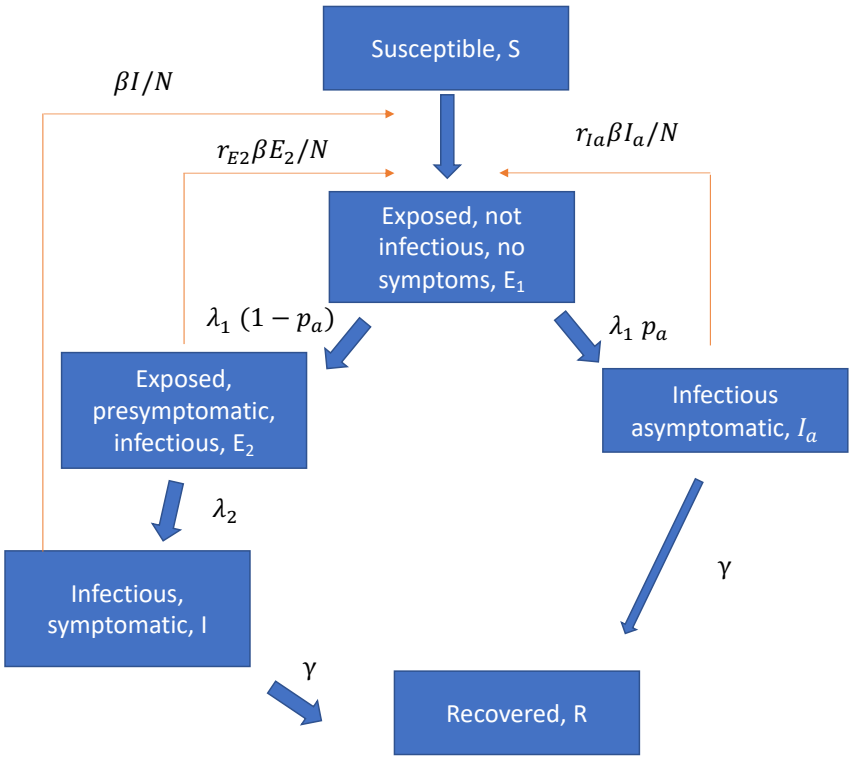


Figure 27: Schematic overview of the model.

Movements between municipalities:

We use 6-hourly mobility matrices from Telenor to capture the movements between municipalities. The matrices are scaled according to the overall Telenor market share in Norway, estimated to be 48%. Since week 8, we use the actual daily mobility matrices to simulate the past. In this way, alterations in the mobility pattern will be incorporated in our model predictions. To predict future movements, we use the latest weekday measured by Telenor. We follow closely the development in the mobility matrices, and weekend patterns will be introduced if necessary.

Healthcare utilisation

Based on the estimated daily incidence data from the model and the population age structure in each municipality, we calculated the hospitalisation using a weighted average. We correct these probabilities by a factor which represents the over or under representation of each age group among the lab confirmed positive cases. The hospitalisation is assumed to be delayed relative to the symptom onset. We calculate the number of patients admitted to ventilator treatment from the patients in hospital using age-adjusted probabilities and an assumed delay.

Seeding

At the start of each simulation, we locate 5.367.580 people in the municipalities of Norway according to data from SSB per January 1. 2020. All confirmed Norwegian imported cases with information about residence municipality and test dates are used to seed the model, using the data available until yesterday. For each case, we add an additional random number of infectious individuals, in the same area and on the same day, to account for asymptomatic imported cases who were not tested or otherwise missed. We denote this by the amplification factor.

Reproduction number, national changepoint model

We assume a first reproduction number R_0 until March 14, a second reproduction number R_1 until April 19, a third reproduction number R_2 until May 10, a fourth reproduction number R_3 until June 30, R_4 until July 31, R_5 until August 31, R_6 from September 1 until September 30, and a seventh reproduction number until today. This last reproduction number is used for the future. The changepoints follow the change in restrictions introduced. We estimate the reproduction numbers so that the predicted number of hospitalised individuals is closest to the true number of hospitalised individuals, from March 10 until the last available data point, and the simulated positive tests are closest to the data on laboratory-confirmed COVID-19 cases from May 1 until the latest available data point. We use a method called sequential ABC which tests millions of combinations of R_0, R_1, R_2, R_3, R_4, R_5, R_6, R_7 and the amplification factor, to determine the 200 ones that lead to the best fits to the hospitalisation incidence. The algorithm is described in Engebretsen et al. (2020) https://royalsocietypublishing.org/doi/10.1098/rsif.2019.0809.

Calibration to test data, national changepoint model

We include the laboratory-confirmed cases in the calibration procedure, as these contain additional information about the transmissibility, and the delay between transmission and testing is shorter than the delay between transmission and hospitalisation. Therefore, we simulate also the number of detected positive cases in our model. We assume that the number of detected positive cases can be modelled as a binomial process of the simulated daily total incidence of symptomatic and asymptomatic cases, with a success probability π_t, which changes every day. We also assume a delay d between the day of test and the day of transmission. In the ABC procedure we thus use two summary statistics, one is the distance between the simulated hospitalisation incidence and the observed incidence, and the other is the distance between the observed number of laboratory-confirmed cases and the simulated ones. As the two summary statistics are not of the same scale, we use two separate tolerances in the ABC-procedure, ensuring that we get a good fit to both data sources.

The data on the number of positive cases are more difficult to use, as the test criteria and capacity have changed multiple times. We take into account these changes by using the total number of tests performed on each day, as a good proxy of capacity and testing criteria. Moreover, we choose not to calibrate to the test data before May 1, because the test criteria and capacity were so different in the early period. The detection probability is modelled as

$$\pi_t = \exp\left(\pi_0 + \pi_1 \cdot k_t\right)/(1 + \exp(\pi_0 + \pi_1 \cdot k_t)),$$

where k_t is the number of tests actually performed on day t, and π_0 and π_1 are two parameters that we estimate, assuming positivity of π_1. We also estimate the delay d. We choose to use a 7-days backwards moving average for the covariate k_t, and to calculate the distance between the observed number of positive tests and the simulated ones using a 7-days backwards moving average. We do this to take into account potential day-of-the-week-effects. For example, it could well be that the testing criteria are different on weekends and weekdays. However, using instead the number of tests and calibrating on a daily basis would lead to a larger day-to-day variance. This is likely why we find that the uncertainty in the simulated positive cases seems somewhat too low, and that we do not capture all the variance in the daily test data. Moreover, the binomial assumption could be too simple, and a beta-binomial distribution would allow more variance. A limitation of our current model for the detection probability, is that we only capture the changes in the test criteria that are captured in the total number of tests performed.

Methods for the regional changepoint model

The method is exactly like the one of the national model, except that every county has its own reproduction numbers (and changepoints for these). We run the sequential Monte Carlo ABC in order to obtain 1000 parameter sets of the different reproduction number for each county, which best fit the hospitalisation data and the test data (7 days moving average) of each county. We also obtain the best estimate for one amplification factor F used to seed the epidemic. Next we run the model with these

1000 parameter sets again, from the beginning until today, plus three weeks into the future (or for an additional year). Using these 1000 trajectories of the future, we make future predictions and confidence intervals. The mobility data are updated until October 31^{th}.
We use of different number of reproduction numbers in each of the counties (5 in Oslo and Viken, and 4 in the rest). For some of the counties, it is difficult to estimate regionally varying parameters when the hospital incidence data is so low.

Parameters used today

Figures 28 and 29 indicate which assumptions we make in our model, related to hospitalisation. We obtained data from the Norwegian emergency registry BEREDT-C19. These estimates will be regularly updated, on the basis of new data.

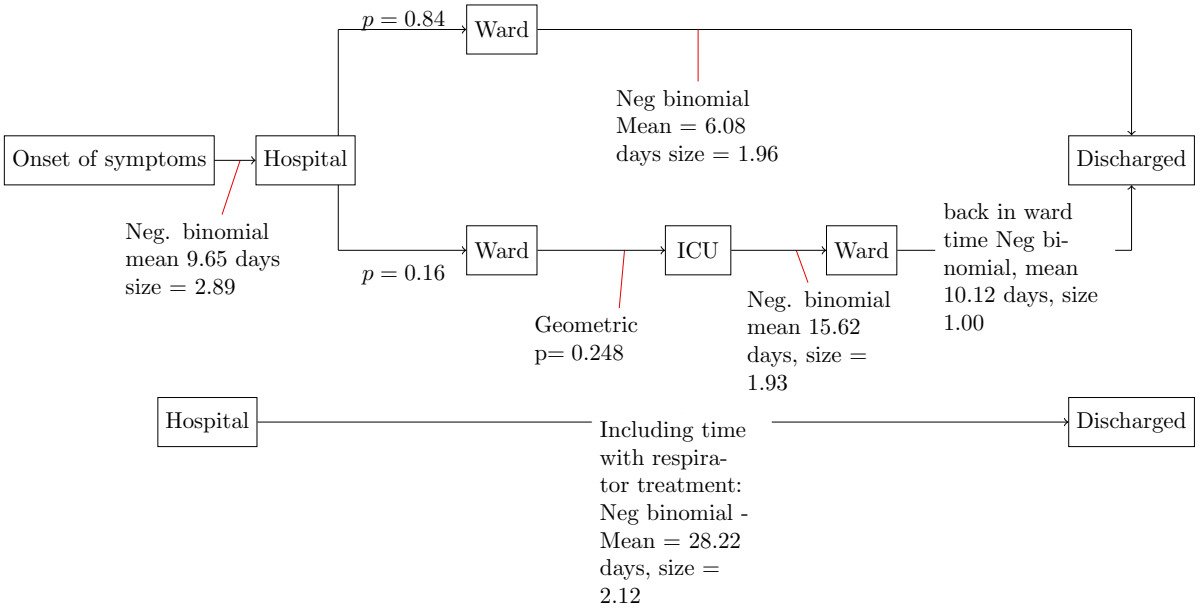


Figure 28: Hospital assumptions and parameters used before 1 August

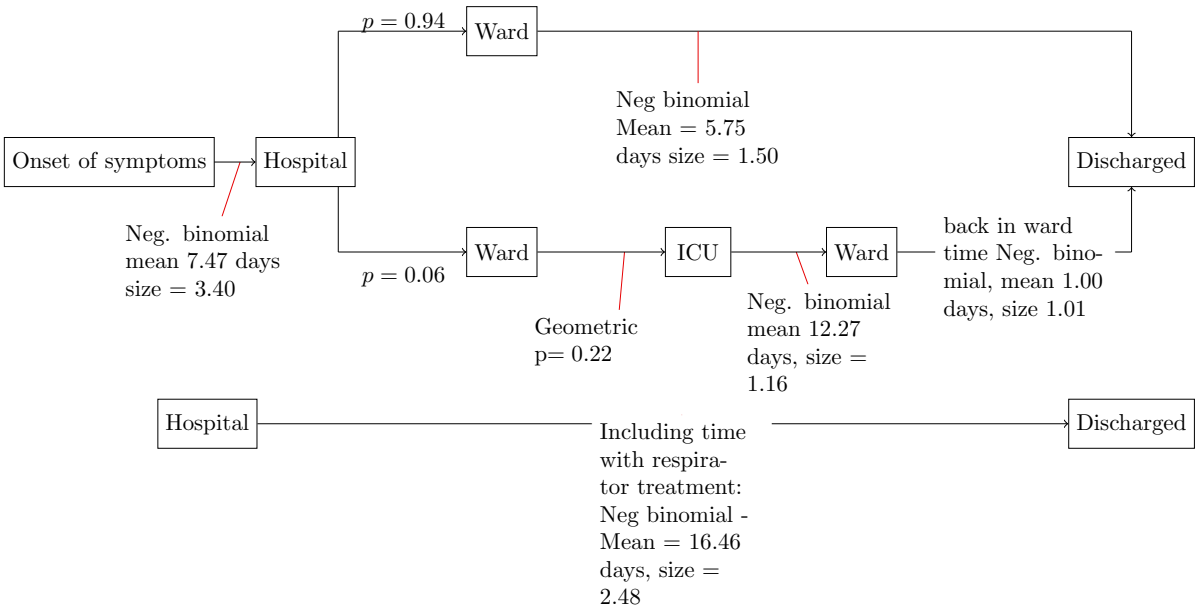


Figure 29: Hospital assumptions and parameters used after 1 August

Table 14: Estimated parameters

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Period
R0s	2.471	3.31	3.535	3.561	3.809	4.499	Until March 14
R1s	0.348	0.421	0.454	0.456	0.49	0.576	From March 15 to April 19
R2s	0.363	0.678	0.769	0.778	0.882	1.186	From April 20 until May 10
R3s	0.411	0.756	0.843	0.845	0.947	1.162	From May 11 until June 30
R4s	0.068	0.68	0.834	0.833	1.007	1.42	From July 1 until July 31
R5s	0.846	1.059	1.123	1.131	1.191	1.456	From Aug 1 until Aug 31
R6s	0.779	0.874	0.919	0.918	0.967	1.052	From Sept 1 to Sept 30
R7s	1.268	1.378	1.415	1.417	1.445	1.576	From October
AMPs	1.35	1.955	2.274	2.33	2.654	3.799	From February
π_0	-2.54	-1.691	-1.308	-1.355	-1.032	-0.097	-
π_1	2.1e-06	6.7e-05	8.9e-05	9.3e-05	1.2e-04	2.0e-04	-
delays	3	5	5	5.135	6	6	-

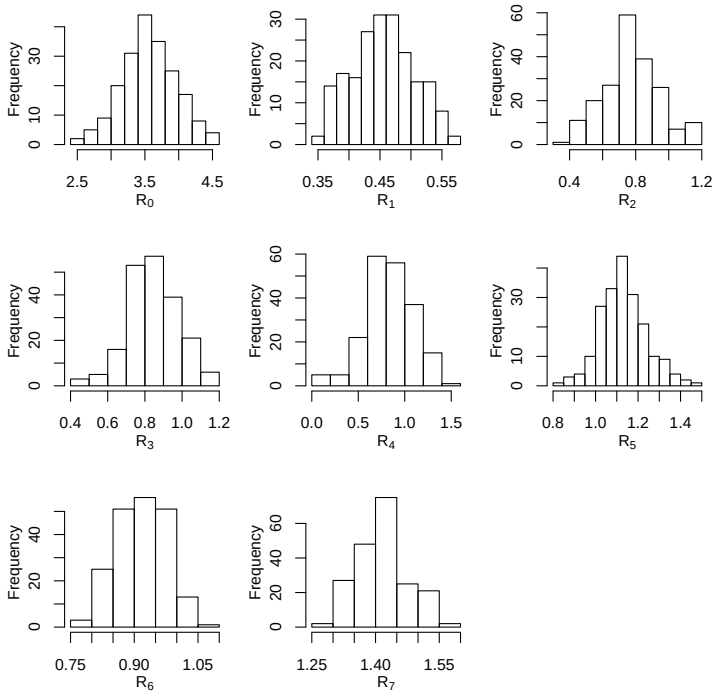


Figure 30: Estimated densities of the reproduction numbers. National model

Table 15

Mean (95% CI)	Parameter	County	From	To
3.89 (2.61-5.22)	R0	Oslo	2020-02-17	2020-03-14
3.59 (2.61-4.58)	R0	Rogaland	2020-02-17	2020-03-14
2.48 (0.54-4.61)	R0	Møre og Romsdal	2020-02-17	2020-03-14
4.54 (2.38-6.74)	R0	Nordland	2020-02-17	2020-03-14
3.99 (2.45-5.36)	R0	Viken	2020-02-17	2020-03-14
3.88 (2.56-5.12)	R0	Innlandet	2020-02-17	2020-03-14
3.12 (1.59-4.62)	R0	Vestfold og Telemark	2020-02-17	2020-03-14
3.33 (1.97-4.96)	R0	Agder	2020-02-17	2020-03-14
3.8 (2.04-5.48)	R0	Vestland	2020-02-17	2020-03-14
4.4 (2.59-6.08)	R0	Trøndelag	2020-02-17	2020-03-14
3.19 (1.8-4.54)	R0	Troms og Finnmark	2020-02-17	2020-03-14
0.98 (0.65-1.19)	R1	Oslo	2020-03-15	2020-04-19
0.67 (0.39-0.93)	R2	Oslo	2020-04-20	2020-06-19
1.27 (0.84-1.63)	R3	Oslo	2020-06-20	2020-08-31
1.18 (0.79-1.67)	R4	Oslo	2020-09-01	2020-09-30
1.64 (1.35-1.89)	R5	Oslo	2020-10-01	
0.4 (0.06-0.72)	R1	Rogaland	2020-03-15	2020-04-19
0.65 (0.28-1.03)	R2	Rogaland	2020-04-20	2020-08-31
0.93 (0.31-1.51)	R3	Rogaland	2020-09-01	2020-09-30
1.13 (0.63-1.61)	R4	Rogaland	2020-10-01	
0.78 (0.41-1.09)	R1	Møre og Romsdal	2020-03-15	2020-04-19
0.74 (0.54-0.98)	R2	Møre og Romsdal	2020-04-20	2020-08-31
0.77 (0.14-1.37)	R3	Møre og Romsdal	2020-09-01	2020-09-30
0.83 (0.23-1.4)	R4	Møre og Romsdal	2020-10-01	
0.58 (0.25-0.95)	R1	Nordland	2020-03-15	2020-04-19
1.09 (0.92-1.24)	R2	Nordland	2020-04-20	2020-08-31
1.1 (0.53-1.75)	R3	Nordland	2020-09-01	2020-09-30
0.96 (0.25-1.67)	R4	Nordland	2020-10-01	

Table 16

Mean (95% CI)	Parameter	County	From	To
0.64 (0.44-0.81)	R1	Viken	2020-03-15	2020-04-19
0.38 (0.08-0.81)	R2	Viken	2020-04-20	2020-06-19
1.19 (0.78-1.48)	R3	Viken	2020-06-20	2020-08-31
0.9 (0.42-1.36)	R4	Viken	2020-09-01	2020-09-30
1.39 (1.15-1.62)	R5	Viken	2020-10-01	
0.52 (0.16-0.88)	R1	Innlandet	2020-03-15	2020-04-19
0.46 (0.1-0.81)	R2	Innlandet	2020-04-20	2020-08-31
1.12 (0.36-1.86)	R3	Innlandet	2020-09-01	2020-09-30
0.64 (0.11-1.21)	R4	Innlandet	2020-10-01	
0.68 (0.39-1)	R1	Vestfold og Telemark	2020-03-15	2020-04-19
0.93 (0.7-1.19)	R2	Vestfold og Telemark	2020-04-20	2020-08-31
0.35 (0.03-0.82)	R3	Vestfold og Telemark	2020-09-01	
0.63 (0.19-1.03)	R1	Agder	2020-03-15	2020-04-19
0.64 (0.4-0.92)	R2	Agder	2020-04-20	2020-08-31
1.1 (0.75-1.46)	R3	Agder	2020-09-01	
0.53 (0.21-0.82)	R1	Vestland	2020-03-15	2020-04-19
0.55 (0.07-1.04)	R2	Vestland	2020-04-20	2020-08-16
1.39 (0.6-2.16)	R3	Vestland	2020-08-17	2020-09-09
0.83 (0.13-1.45)	R4	Vestland	2020-09-10	2020-09-30
1.28 (0.67-1.8)	R5	Vestland	2020-10-01	
0.54 (0.17-0.97)	R1	Trøndelag	2020-03-15	2020-04-19
0.75 (0.47-1.02)	R2	Trøndelag	2020-04-20	2020-08-31
1.33 (0.86-1.76)	R3	Trøndelag	2020-09-01	2020-09-30
0.5 (0.05-1)	R4	Trøndelag	2020-10-01	
1 (0.64-1.34)	R1	Troms og Finnmark	2020-03-15	2020-04-19
0.52 (0.08-0.85)	R2	Troms og Finnmark	2020-04-20	2020-08-31
0.72 (0.1-1.49)	R3	Troms og Finnmark	2020-09-01	2020-09-30
0.94 (0.29-1.57)	R4	Troms og Finnmark	2020-10-01	
1.6 (1.06-2.23)	AMP factor	All		

Table 17: Hospitalisation probabilities (1/2)

	Until 2020-05-01	Until 2020-06-01	Until 2020-07-01	Until 2020-08-01
0-9 years	0.0001	0.0005	0.001	0.0004
10 - 19 years	0.0004	0.001	0.001	0.001
20 - 29 years	0.006	0.007	0.009	0.009
30 - 39 years	0.013	0.019	0.015	0.018
40 - 49 years	0.018	0.015	0.016	0.017
50 - 59 years	0.043	0.032	0.025	0.030
60 - 69 years	0.059	0.031	0.039	0.035
70 - 79 years	0.087	0.047	0.026	0.029
80+ years	0.317	0.129	0.127	0.025

Table 18: Hospitalisation probabilities (2/2)

	Until 2020-09-01	Until 2020-10-01	From 2020-10-01
0-9 years	0.0004	0.0004	0.0003
10 - 19 years	0.001	0.001	0.001
20 - 29 years	0.014	0.011	0.011
30 - 39 years	0.014	0.015	0.015
40 - 49 years	0.013	0.014	0.017
50 - 59 years	0.025	0.023	0.029
60 - 69 years	0.015	0.030	0.031
70 - 79 years	0.028	0.032	0.033
80+ years	0.042	0.089	0.069

Table 19: Assumptions I

Assumptions	Mean	Distribution	Reference
Seeding			
Telenor coverage	48%		https://ekomstatistikken.nkom.no/
Model parameters			
Exposed period ($1/\lambda_1$)	3 days	Exponential	Feretti et al 2020
Pre-symptomatic period ($1/\lambda_2$)	2 days	Exponential	Feretti et al 2020
Symptomatic infectious period ($1/\gamma$)	5 days	Exponential	Feretti et al 2020
Asymptomatic, infectious period ($1/\gamma$)	5 days	Exponential	Feretti et al 2020
Infectiousness asympt. (r_{I_a})	0.1	Fixed	Feretti et al 2020
Infectiousness presymp (r_{E_2})	1.25	Fixed	guided by Feretti et al 2020
Prob. asymptomatic infection (p_a)	0.4		Feretti et al 2020
Healthcare			
Time sympt. onset to hospitalisation	9 days	Neg. binomial	
Fraction asymptomatic infections	40%	Fixed	Mizumoto et al 2020 20% for the old population, Diamond Princess
% symptomatic and asymptomatic infections requiring hospitalization: 0-9 years 10 - 19 years 20 - 29 years 30 - 39 years 40 - 49 years 50 - 59 years 60 - 69 years 70 - 79 years 80+ years	 0.1% 0.1% 0.5% 1.1% 1.4% 2.9% 5.8% 9.3% 22.3%	Fixed	Saljie et al 2020 corrected for: % of elderly living in elderly homes in Norway (last two age groups) and corrected for presence among positive tested since May 1. Corrected values available in tables 17 and 18
% hospitalized patients requiring ICU Feb - July August -	 16% 6%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Overall hospitalization risk	2.26%	Fixed	Corrected Saljie et al 2020 (adapted to Norwegian population and adapted to positive tested)
Probability that an admission has been reported on Monday From Sunday From Saturday From Friday From Thursday	 32% 49% 68% 86%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Probability that an admission has been reported From one day before From two days before From three days before From four days before	 53% 77% 82% 91%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Probability that a positive laboratory test has been reported From one day before From two days before From three days before From four days before	 10% 66% 90% 97%	Fixed	Estimated from MSIS
Probability that a negative laboratory test has been reported From one day before From two days before From three days before From four days before	 16% 74% 92% 98%	Fixed	Estimated from MSIS
Mobile phone mobility			
Until November 7th	Measured Telenor mobility		
Data used in the predictions	November 6th	Fixed	Corrected to preserve population

Supplementary analysis: EpiEstim estimation of reproduction number based on laboratory-confirmed cases

To complement the results of the metapopulation model, we present estimates of the temporal evolution of the reproduction number in Norway based on an analysis of laboratory-confirmed cases. The primary purpose of this analysis is to provide a more comprehensive perspective on the epidemic situation, taking into account several data sources.
The hospitalisation data are a less biased information source for the number of infections compared to case data because the testing criteria in Norway has changed. For this reason, the present results should be interpreted with caution. During the early part of the period, testing of individuals was mainly based on travel history to areas with an ongoing outbreak. Since the middle of March, testing is recommended for people with an acute respiratory infection. From early May, the testing criteria have been expanded to include less severe symptoms. The analysis of laboratory-confirmed cases does not take into account the effect of imported cases during the early outbreak in Norway; the early results are less reliable than later results when the impact of importations is negligible.

EpiEstim method and assumptions: We estimate the instantaneous reproduction number using the procedure outlined in Thompson et al. (2019). This method, implemented in the EpiEstim R-package, uses a Bayesian approach to estimate the instantaneous reproduction number smoothed over a sliding window of 5 days, see figure 31. For the results to be comparable to those of the metapopulation model, we use the same natural history parameters. We estimate the date of infection for each confirmed case by first estimating the date of symptom onset and then subtracting 5 days for the incubation period. We estimate the date of symptom onset from the empirical delay between onset and testing in the first reported cases. For each case, we draw 100 possible onset dates from the delay distribution; this gives us 100 epi-curves that we use to estimate the reproduction number. The displayed results are the combined results from all these 100 simulated epi-curves. The serial interval was assumed to be 5 days with uncertainty; the serial interval refers to the time between symptom onset between successive cases in a chain of transmission (see https://www.medrxiv.org/content/10.1101/2020.02.03.20019497v2). To account for censoring of observations with onset dates in the last few days we correct the observed data by the mean of a negative binomial distribution with observation probability given by the empirical cumulative distribution of the onset to reporting date distributions. Due to this correction, the results from the last few days are uncertain, as indicated by increasing credible intervals.

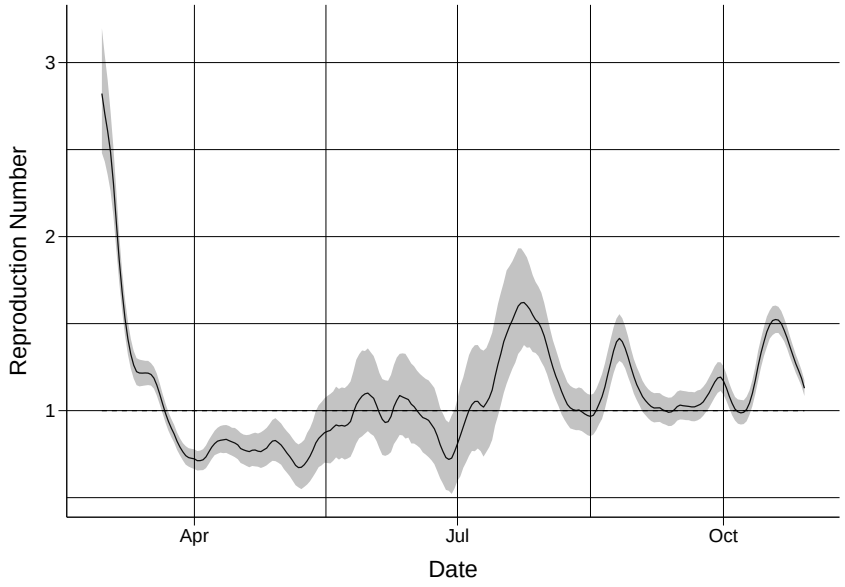


Figure 31: Reproduction number estimated using the R package EpiEstim.

FHI COVID-19 modelling team:

- **Birgitte Freiesleben de Blasio** - Department of Method Development and Analytics. Norwegian Institute of Public Health and Oslo Centre for Biostatistics and Epidemiology, University of Oslo.
- **Francesco Di Ruscio** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Gunnar Øyvind Isaksson Rø** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Solveig Engebretsen** - Norsk Regnesentral.
- **Arnoldo Frigessi** - Oslo Centre for Biostatistics and Epidemiology, University of Oslo and Oslo University Hospital.
- **Alfonso Diz-Lois Palomares** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **David Swanson** - Oslo Centre for Biostatistics and Epidemiology, Oslo University Hospital.
- **Magnus Nygård Osnes** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Anja Bråthen Kristoffersen** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Kenth Engø-Monsen** - Telenor Research.
- **Louis Yat Hin Chan** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Jonas Christoffer Lindstrøm** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Richard White** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Gry Marysol Grøneng** - Department of Method Development and Analytics. Norwegian Institute of Public Health.