Report: COVID19 Bayesian Epidemiological Model

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Model descriptions

- Model 1: The Imperial College model v3, with partial pooling of lockdown variable
- Model 2: Google Mobility and Oxford Binary Intervention indicators. Regression coefficients are assumed common for all countries (pooled alpha).
- Model 3: Google Mobility and Oxford Binary Intervention indicators. Regression coefficients are hierarchical and inform each other between countries. (hierarchical alpha)
- Model 4: Google Mobility and Oxford Binary Intervention indicators. Regression coefficients are estimated for each country. (local alpha)
- Model 5: Google Mobility, Oxford Binary Intervention indicators and b-spline. Regression coefficients are hierarchical and the b-spline is a local spline over t per country.

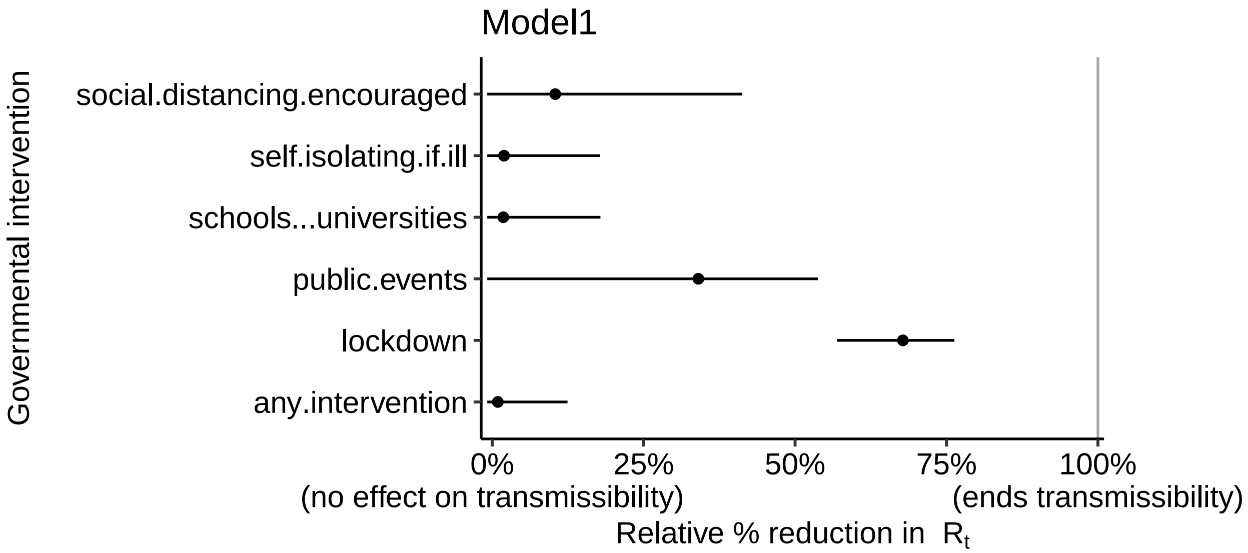
Oxford covariate descriptions

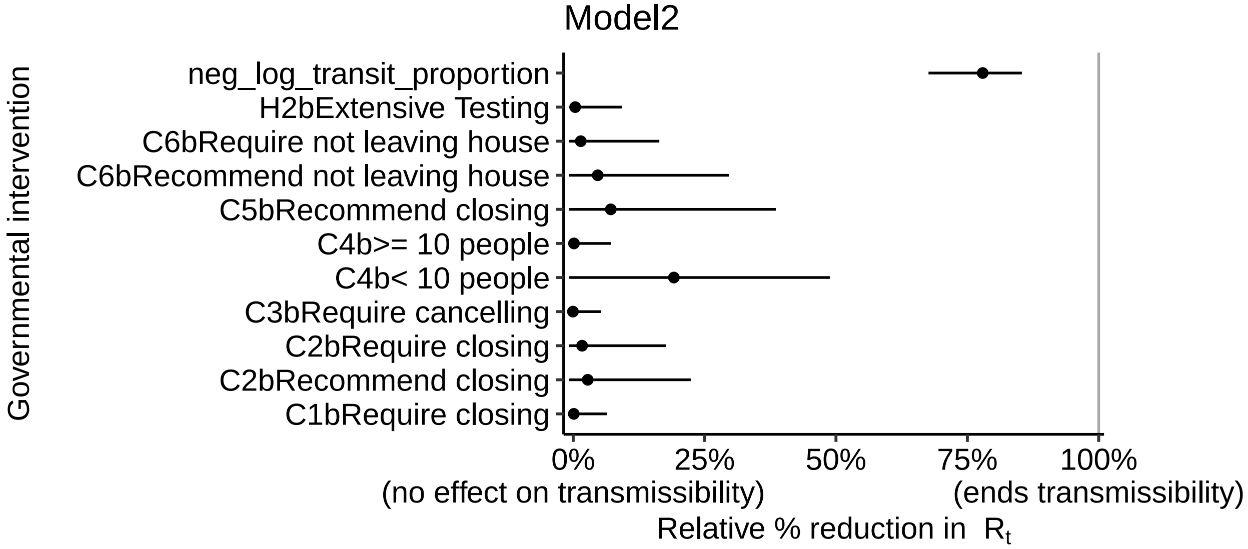
- C1: School closing
- C2: Workplace closing
- C3: Cancel public events
- C4: Restrictions on Gatherings
- C5: Close public transport
- C6: Stay at home requirements
- H2: Testing policy

Case study: The Sweden, Finland and Italy

All other countries are included in the Appendix.

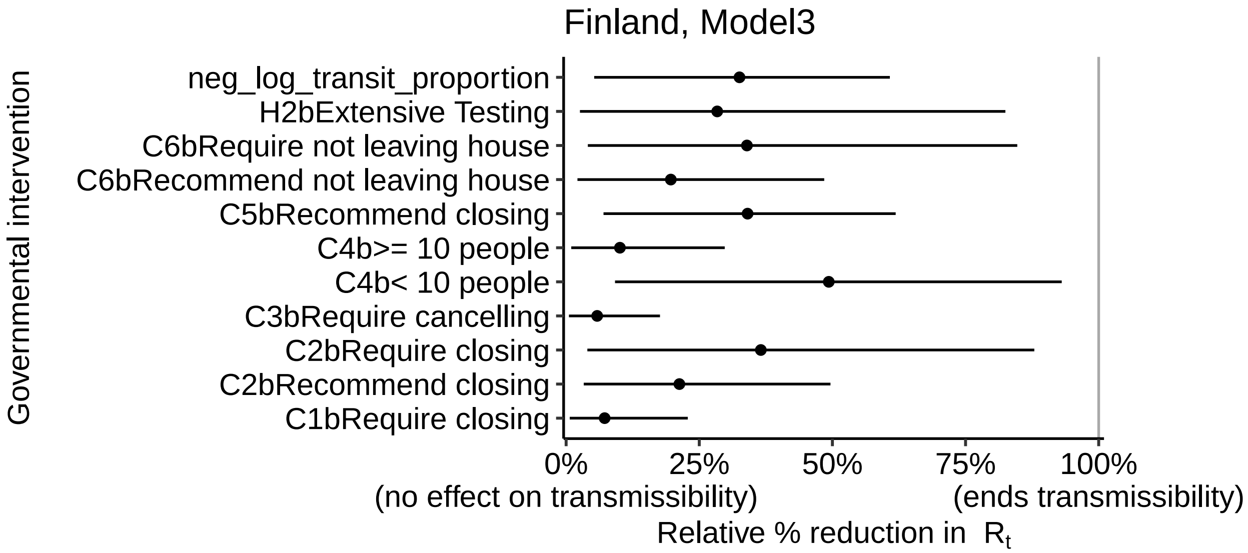
Global covariate effects (model 1 and 2)

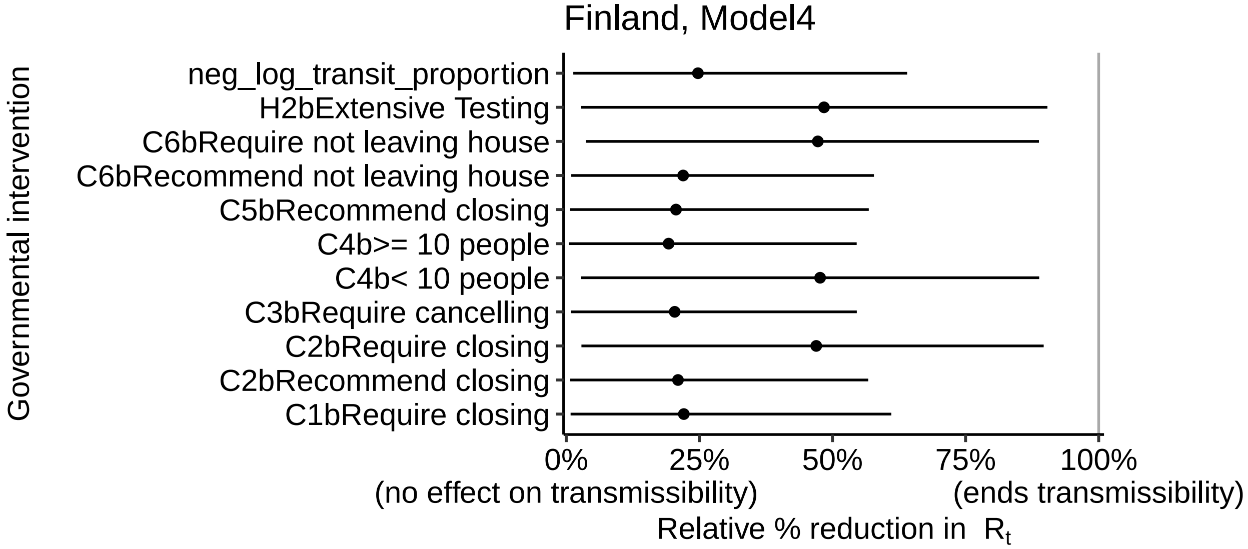




Country specific effects (model 3 and 4)

We see that the hierarchical model has an easier time to capture the general effect that mobility has a larger effect than the stringency index. Hence the actual mobility affects R_t more than the interventions.


Finland, Model3
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
0%
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t


Finland, Model4
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
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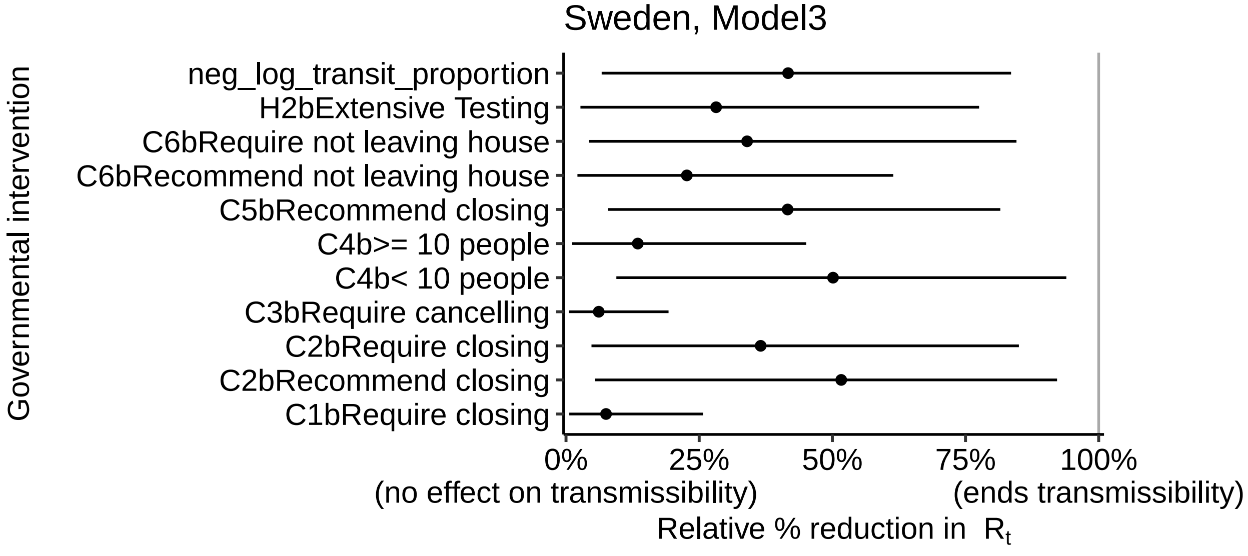
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t


Sweden, Model3
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
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C4b>= 10 people
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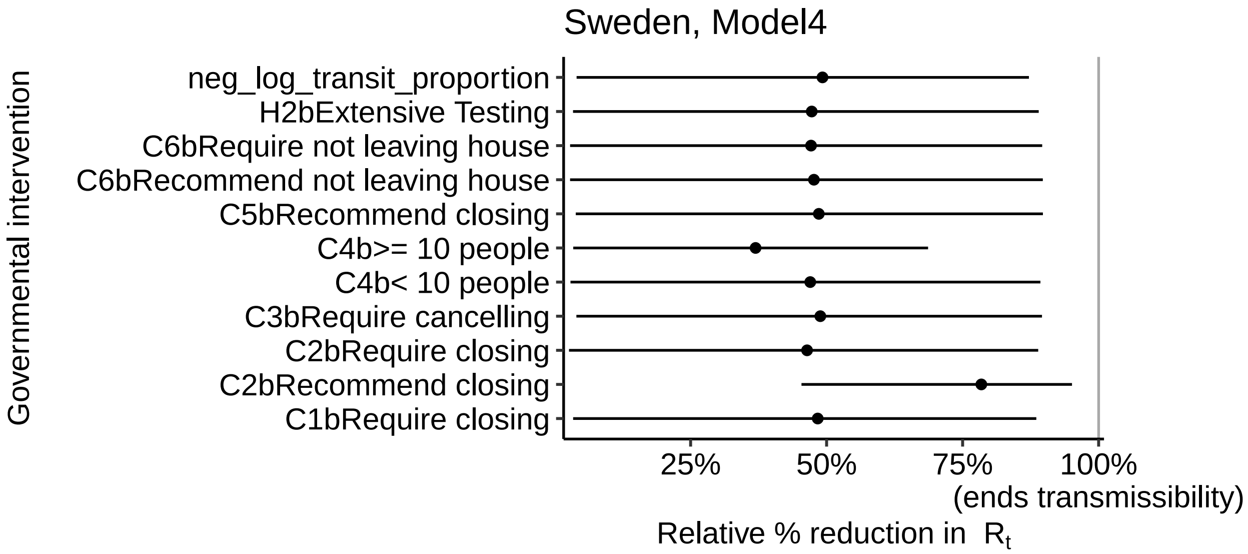
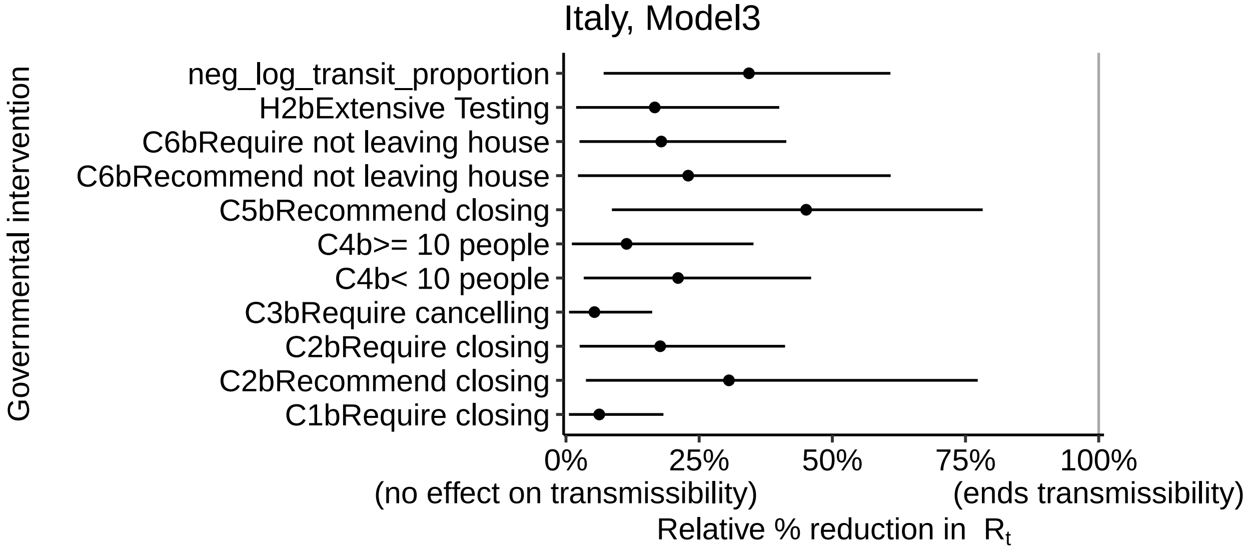
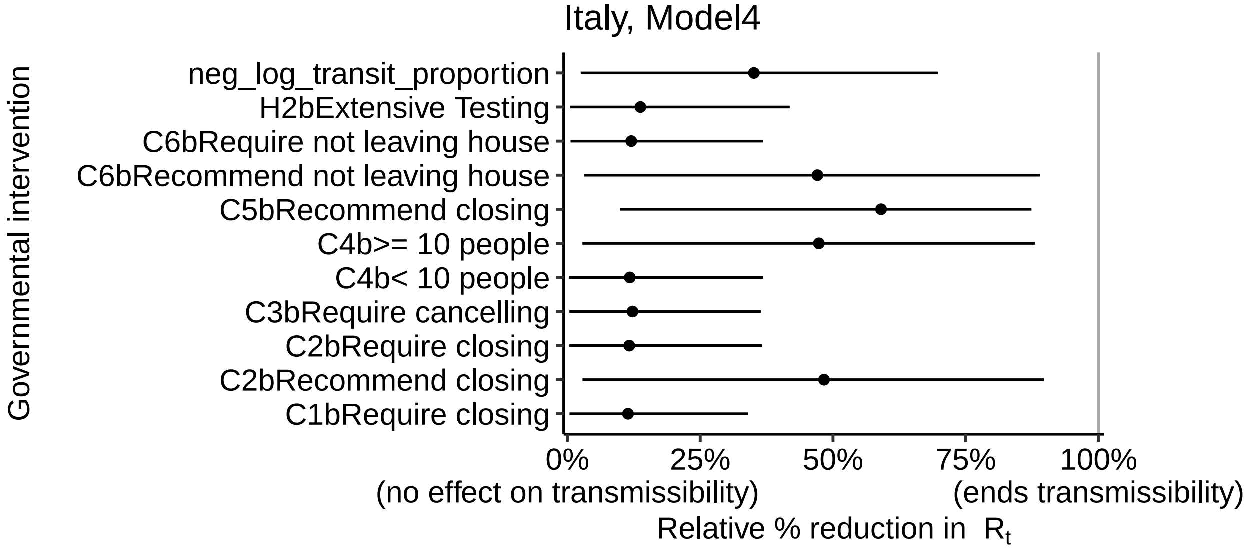
Relative % reduction in R_t

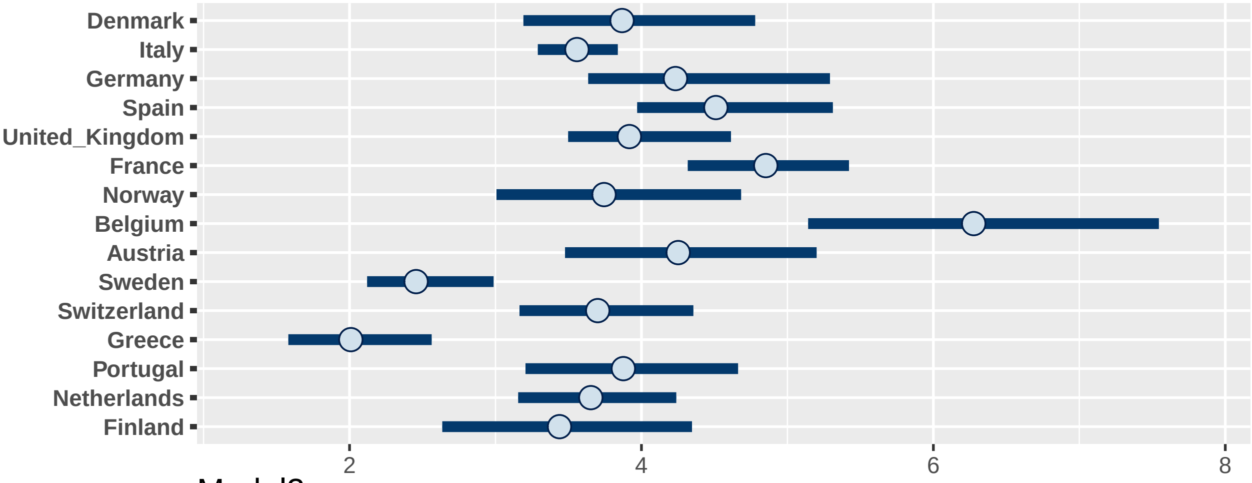

Sweden, Model4

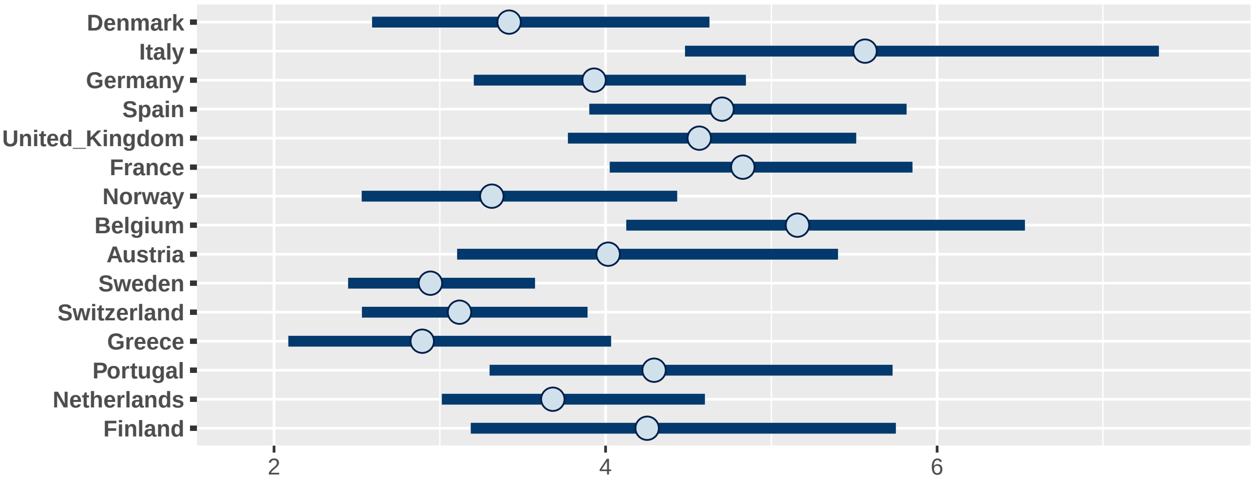

Italy, Model3

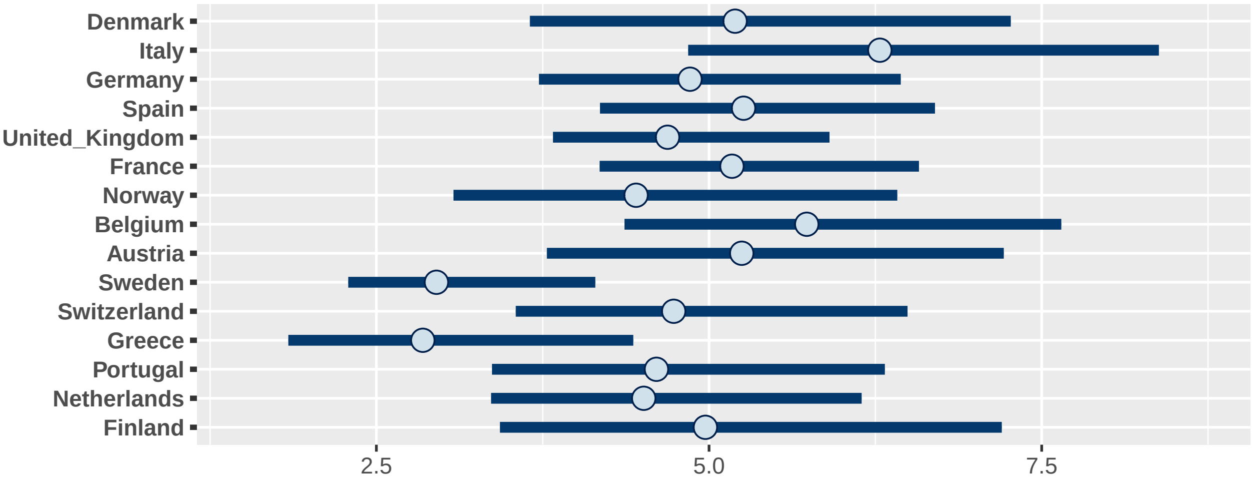

Italy, Model4

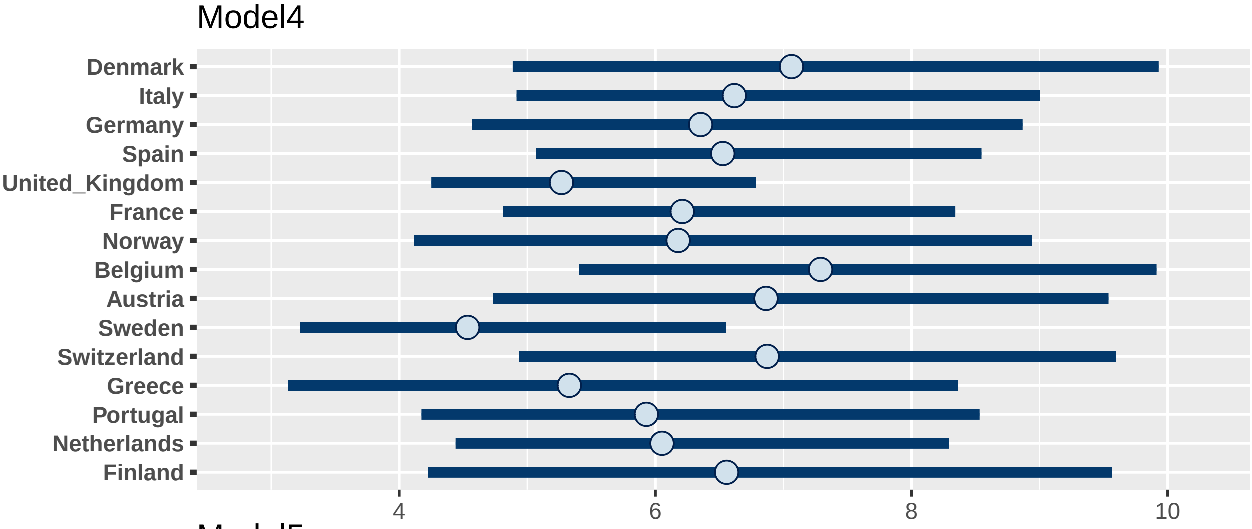
R0 for different countries

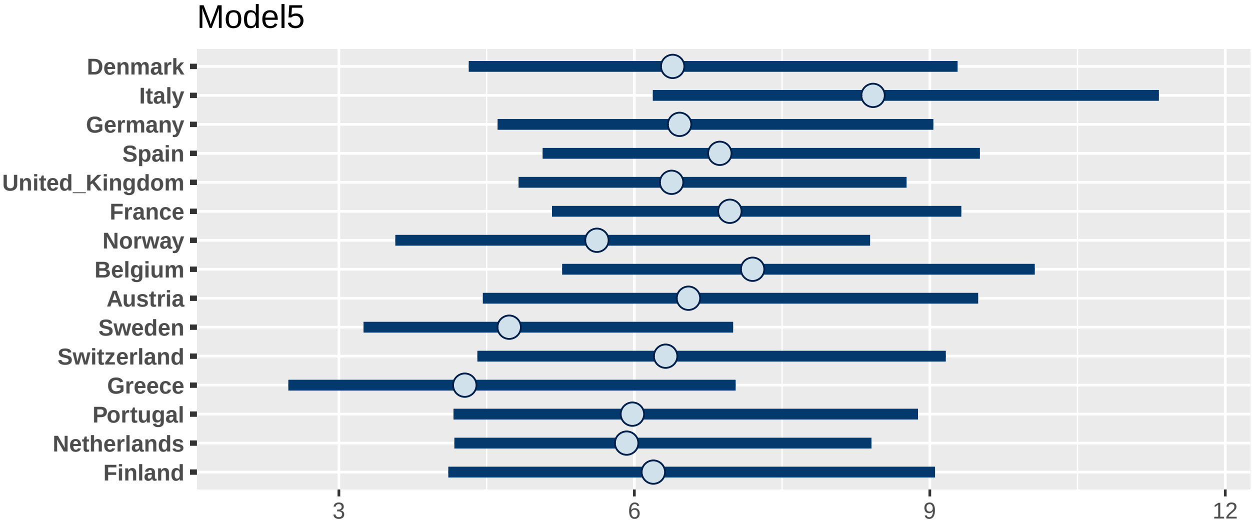
We can see that the different values for R0 vary much more between the countries when we use models with common regression coefficients.


Model1

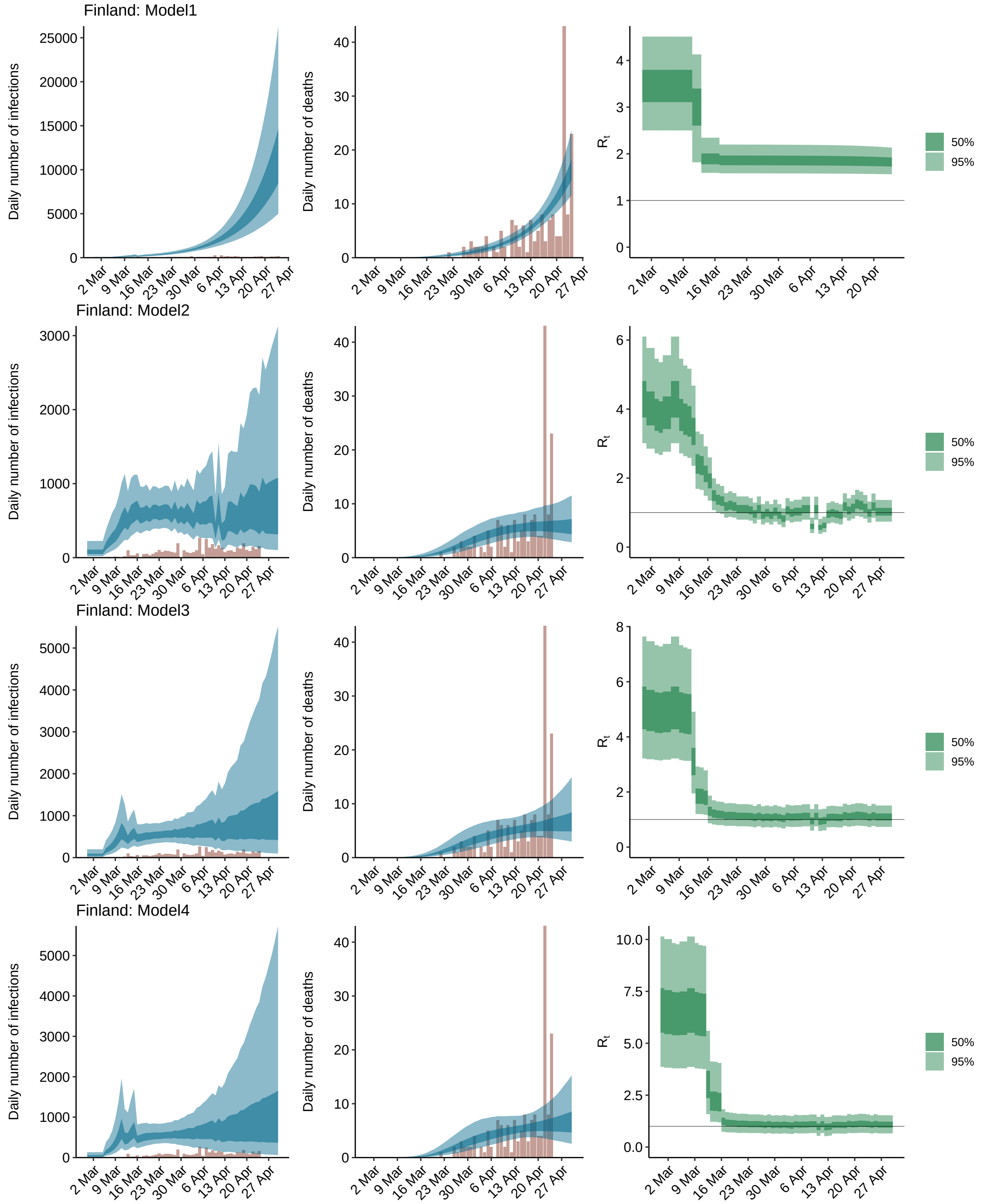

Model2

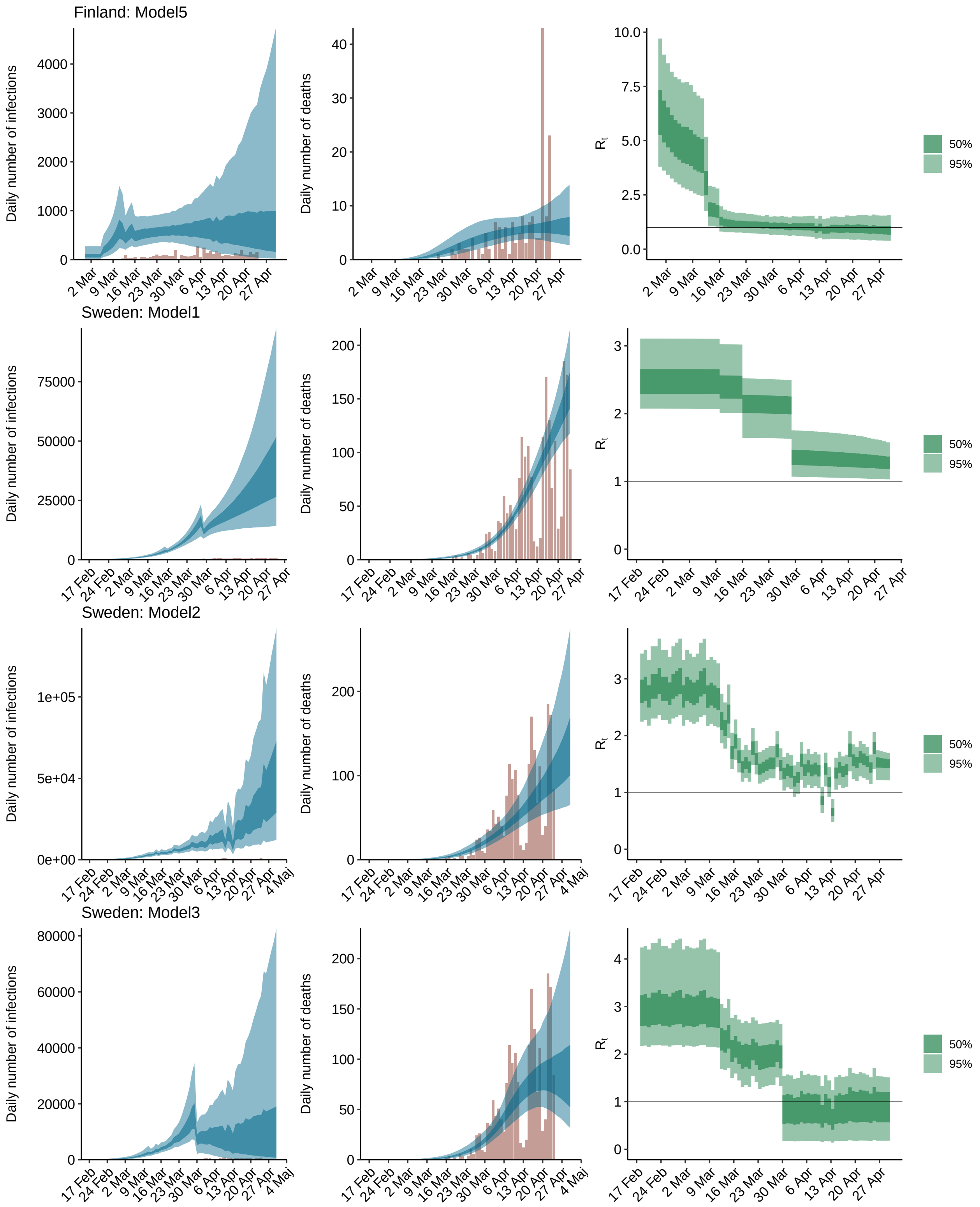

Model3

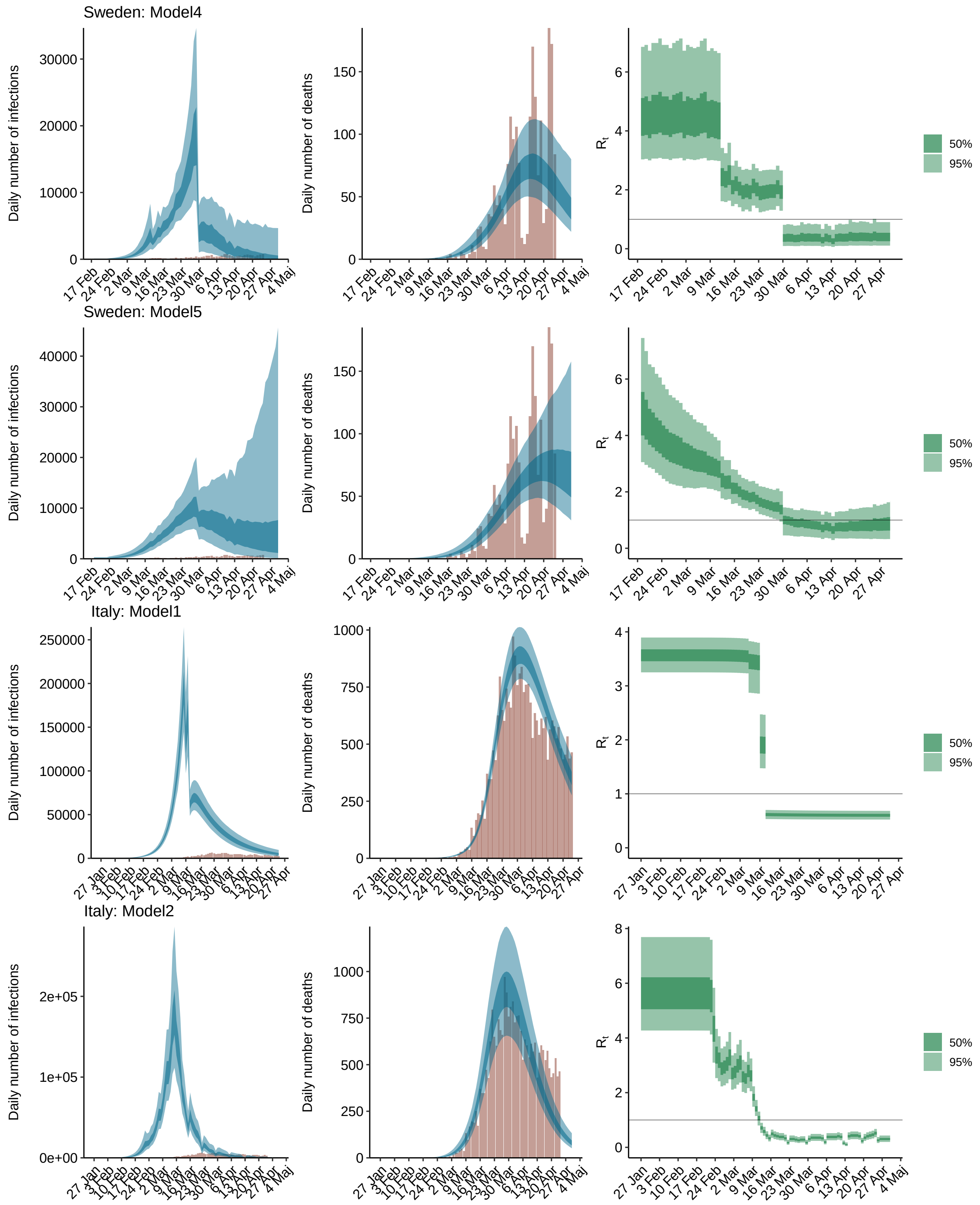

Model4
Denmark
Italy
Germany
Spain
United_Kingdom
France
Norway
Belgium
Austria
Sweden
Switzerland
Greece
Portugal
Netherlands
Finland
4
6
8
10

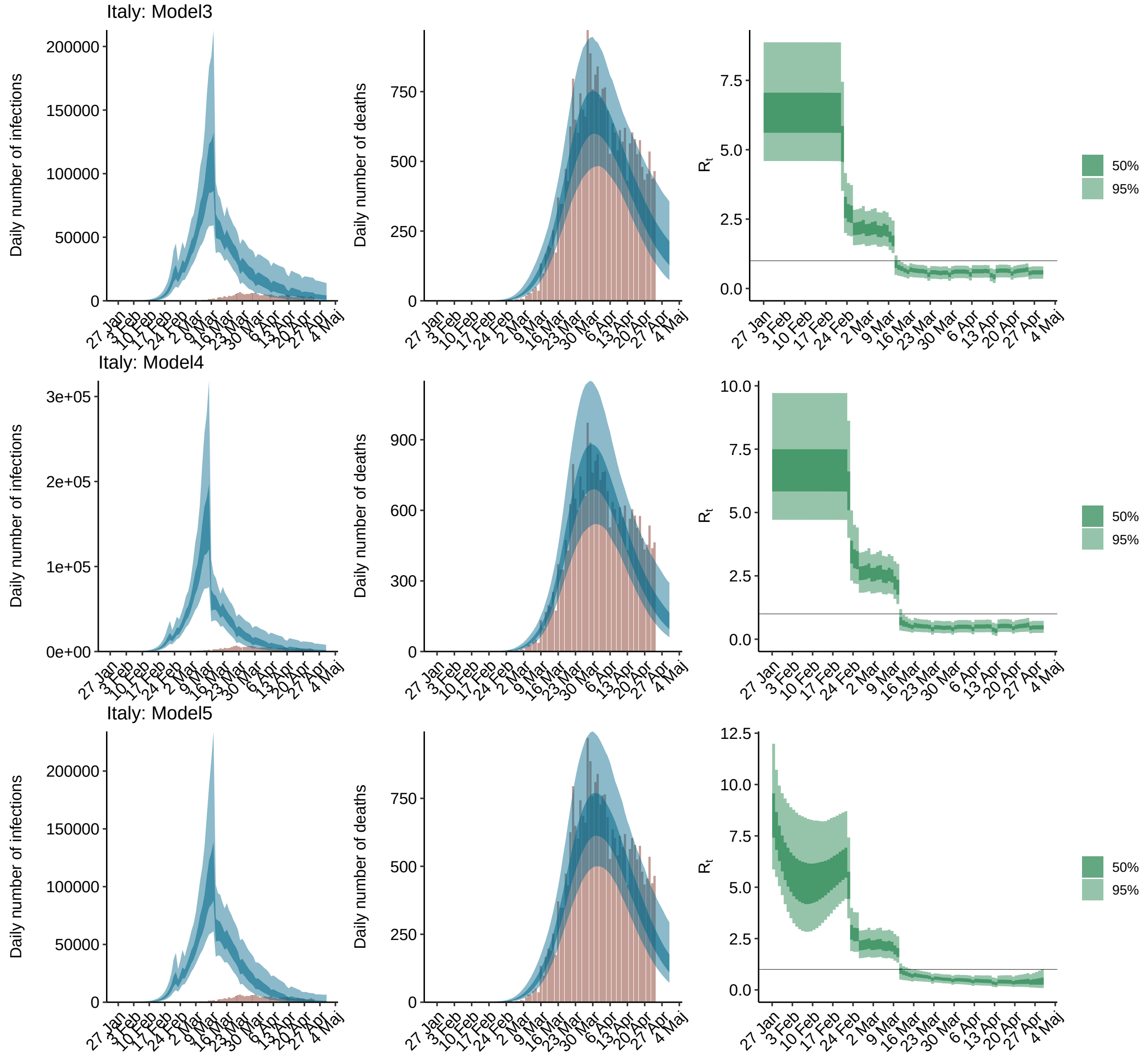

Model5
Denmark
Italy
Germany
Spain
United_Kingdom
France
Norway
Belgium
Austria
Sweden
Switzerland
Greece
Portugal
Netherlands
Finland
3
6
9
12

Infections, cases, deaths and Rt by country and model




Finland: Model5
Daily number of infections
0
1000
2000
3000
4000
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Daily number of deaths
0
10
20
30
40
R_t
0.0
2.5
5.0
7.5
10.0
50%
95%
Sweden: Model1
Daily number of infections
0
25000
50000
75000
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Daily number of deaths
0
50
100
150
200
R_t
0
1
2
3
50%
95%
Sweden: Model2
Daily number of infections
0e+00
5e+04
1e+05
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
100
200
R_t
0
1
2
3
50%
95%
Sweden: Model3
Daily number of infections
0
20000
40000
60000
80000
Daily number of deaths
0
50
100
150
200
R_t
0
1
2
3
4
50%
95%


Sweden: Model4
Daily number of infections
0
10000
20000
30000
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
50
100
150
R_t
0
2
4
6
50%
95%
Sweden: Model5
Daily number of infections
0
10000
20000
30000
40000
Daily number of deaths
0
50
100
150
R_t
0
2
4
6
50%
95%
Italy: Model1
Daily number of infections
0
50000
100000
150000
200000
250000
27 Jan
3 Feb
10 Feb
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Daily number of deaths
0
250
500
750
1000
R_t
0
1
2
3
4
50%
95%
Italy: Model2
Daily number of infections
0e+00
1e+05
2e+05
27 Jan
3 Feb
10 Feb
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
250
500
750
1000
R_t
0
2
4
6
8
50%
95%

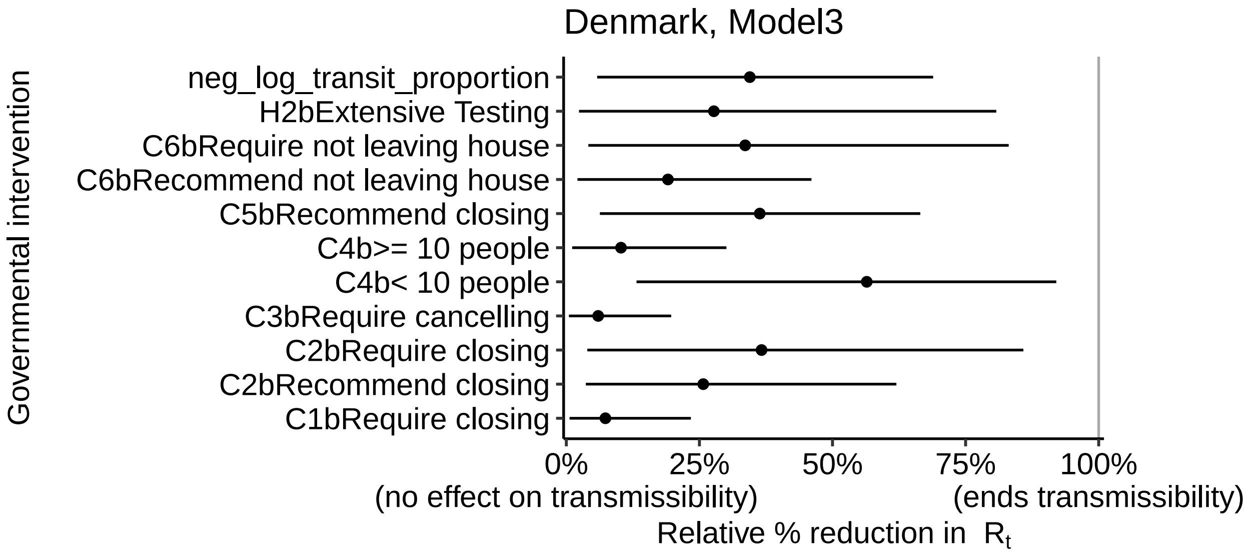


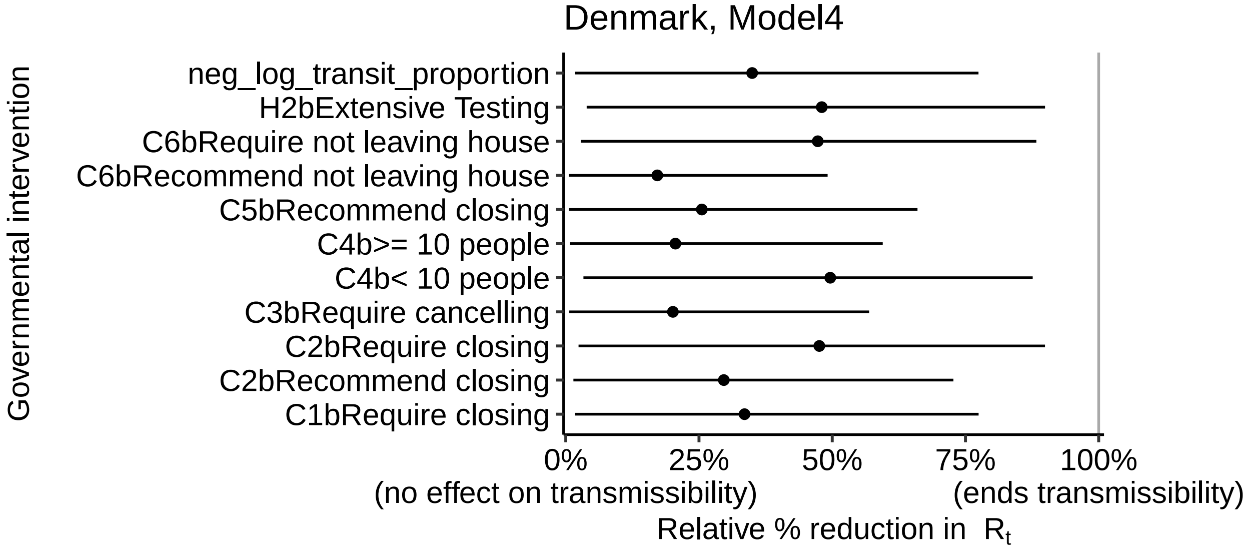
Stan code

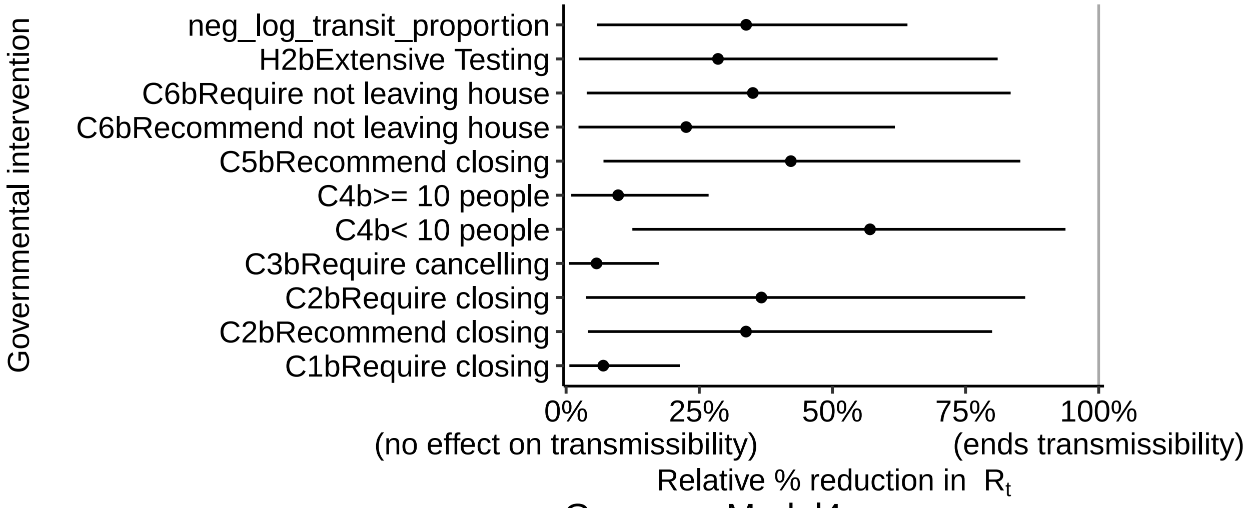
```
## S4 class stanmodel 'base' coded as follows:
## data {
##   int <lower=1> M; // number of countries
##   int <lower=1> P; // number of covariates
##   int <lower=1> N0; // number of days for which to impute infections
##   int<lower=1> N[M]; // days of observed data for country m. each entry must be <= N2
##   int<lower=1> N2; // days of observed data + # of days to forecast
##   int cases[N2,M]; // reported cases
##   int deaths[N2, M]; // reported deaths -- the rows with i > N contain -1 and should be ignored
##   matrix[N2, M] f; // h * s
##   matrix[N2, P] X[M]; // features matrix
##   int EpidemicStart[M];
##   real pop[M];
##   real SI[N2]; // fixed pre-calculated SI using emprical data from Neil
## }
##
## transformed data {
##   vector[N2] SI_rev; // SI in reverse order
##   vector[N2] f_rev[M]; // f in reversed order
##
##   for(i in 1:N2)
##     SI_rev[i] = SI[N2-i+1];
##
##   for(m in 1:M){
##     for(i in 1:N2) {
##      f_rev[m, i] = f[N2-i+1,m];
##     }
##   }
## }
##
##
## parameters {
##   real<lower=0> mu[M]; // intercept for Rt
##   real<lower=0> alpha_hier[P]; // sudo parameter for the hier term for alpha
##   real<lower=0> gamma;
##   vector[M] lockdown;
##   real<lower=0> kappa;
##   real<lower=0> y[M];
##   real<lower=0> phi;
##   real<lower=0> tau;
##   real <lower=0> ifr_noise[M];
## }
##
## transformed parameters {
##     vector[P] alpha;
##     matrix[N2, M] prediction = rep_matrix(0,N2,M);
##     matrix[N2, M] E_deaths  = rep_matrix(0,N2,M);
##     matrix[N2, M] Rt = rep_matrix(0,N2,M);
##     matrix[N2, M] Rt_adj = Rt;
##
##     {
##       matrix[N2,M] cumm_sum = rep_matrix(0,N2,M);
##       for(i in 1:P){
##         alpha[i] = alpha_hier[i] - ( log(1.05) / 6.0 );
##       }
##       for (m in 1:M){
##         prediction[1:N0,m] = rep_vector(y[m],N0); // learn the number of cases in the first N0 days
##         cumm_sum[2:N0,m] = cumulative_sum(prediction[2:N0,m]);
##
##         Rt[,m] = mu[m] * exp(-X[m] * alpha - X[m][,5] * lockdown[m]);
##         Rt_adj[1:N0,m] = Rt[1:N0,m];
##         for (i in (N0+1):N2) {
##           real convolution = dot_product(sub_col(prediction, 1, m, i-1), tail(SI_rev, i-1));
##           cumm_sum[i,m] = cumm_sum[i-1,m] + prediction[i-1,m];
##           Rt_adj[i,m] = ((pop[m]-cumm_sum[i,m]) / pop[m]) * Rt[i,m];
##           prediction[i, m] = Rt_adj[i,m] * convolution;
##         }
##         E_deaths[1, m]= 1e-15 * prediction[1,m];
##         for (i in 2:N2){
##           E_deaths[i,m] = ifr_noise[m] * dot_product(sub_col(prediction, 1, m, i-1), tail(f_rev[m], i
##         }
##       }
##     }
## }
## model {
##   tau ~ exponential(0.03);
##   for (m in 1:M){
##       y[m] ~ exponential(1/tau);
##   }
##   gamma ~ normal(0,.2);
##   lockdown ~ normal(0,gamma);
##   phi ~ normal(0,5);
##   kappa ~ normal(0,0.5);
##   mu ~ normal(3.28, kappa); // citation: https://academic.oup.com/jtm/article/27/2/taaa021/5735319
##   alpha_hier ~ gamma(.1667,1);
##   ifr_noise ~ normal(1,0.1);
##   for(m in 1:M){
##     deaths[EpidemicStart[m]:N[m], m] ~ neg_binomial_2(E_deaths[EpidemicStart[m]:N[m], m], phi);
##    }
## }
##
## generated quantities {
##     matrix[N2, M] prediction0 = rep_matrix(0,N2,M);
##     matrix[N2, M] E_deaths0  = rep_matrix(0,N2,M);
##
##     {
##       matrix[N2,M] cumm_sum0 = rep_matrix(0,N2,M);
##       for (m in 1:M){
##          for (i in 2:N0){
##           cumm_sum0[i,m] = cumm_sum0[i-1,m] + y[m];
##         }
##         prediction0[1:N0,m] = rep_vector(y[m],N0);
##         for (i in (N0+1):N2) {
##           real convolution0 = dot_product(sub_col(prediction0, 1, m, i-1), tail(SI_rev, i-1));
##           cumm_sum0[i,m] = cumm_sum0[i-1,m] + prediction0[i-1,m];
##           prediction0[i, m] = ((pop[m]-cumm_sum0[i,m]) / pop[m]) * mu[m] * convolution0;
##         }
##         E_deaths0[1, m]= 1e-15 * prediction0[1,m];
##         for (i in 2:N2){
##           E_deaths0[i,m] = ifr_noise[m] * dot_product(sub_col(prediction0, 1, m, i-1), tail(f_rev[m]
##         }
##       }
##     }
## }
##
```

Appendix

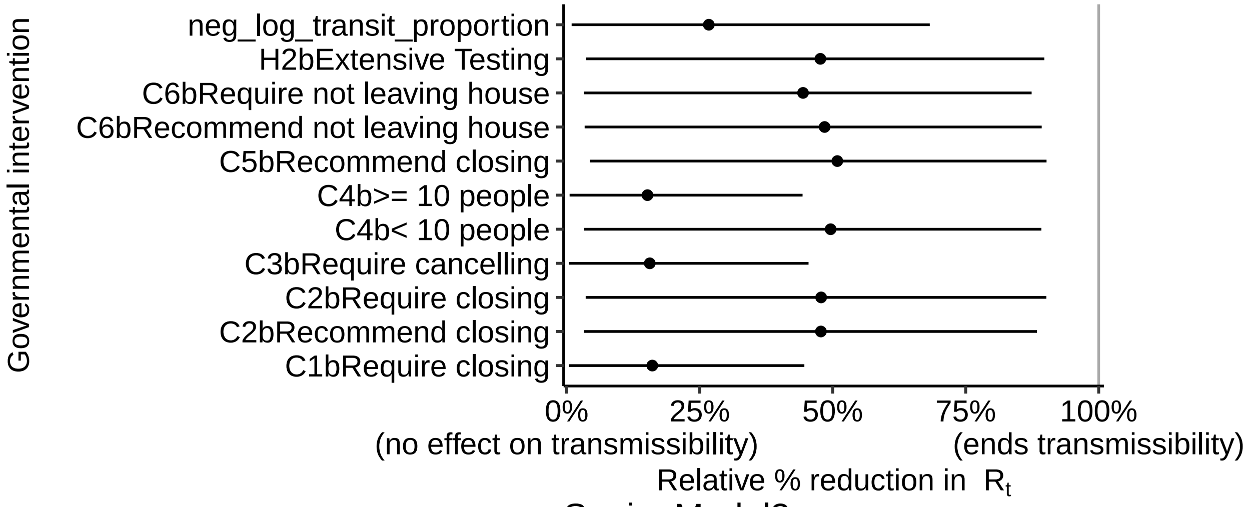
Country specific effects (model 3 to 4)



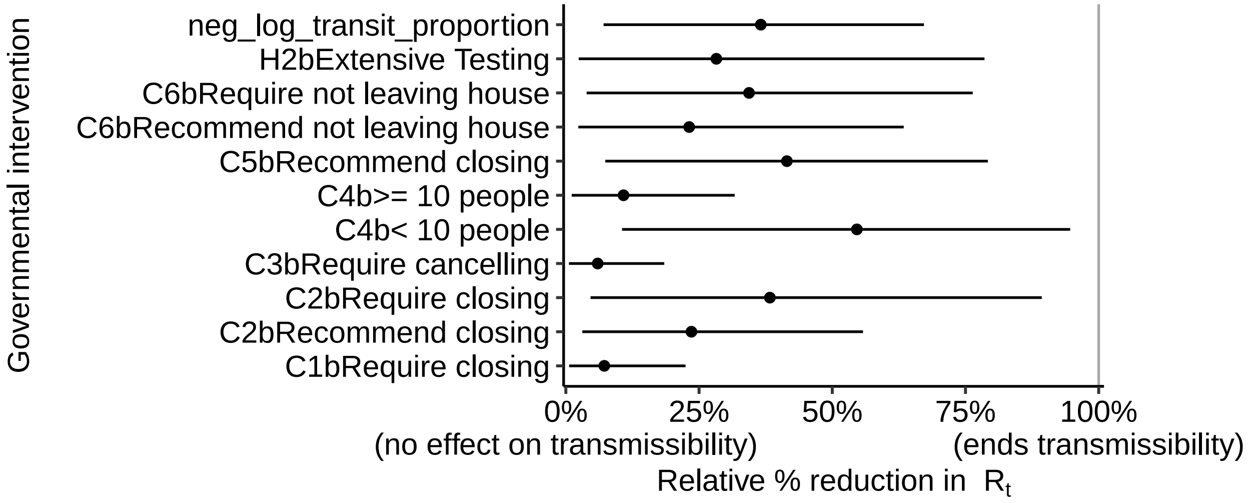




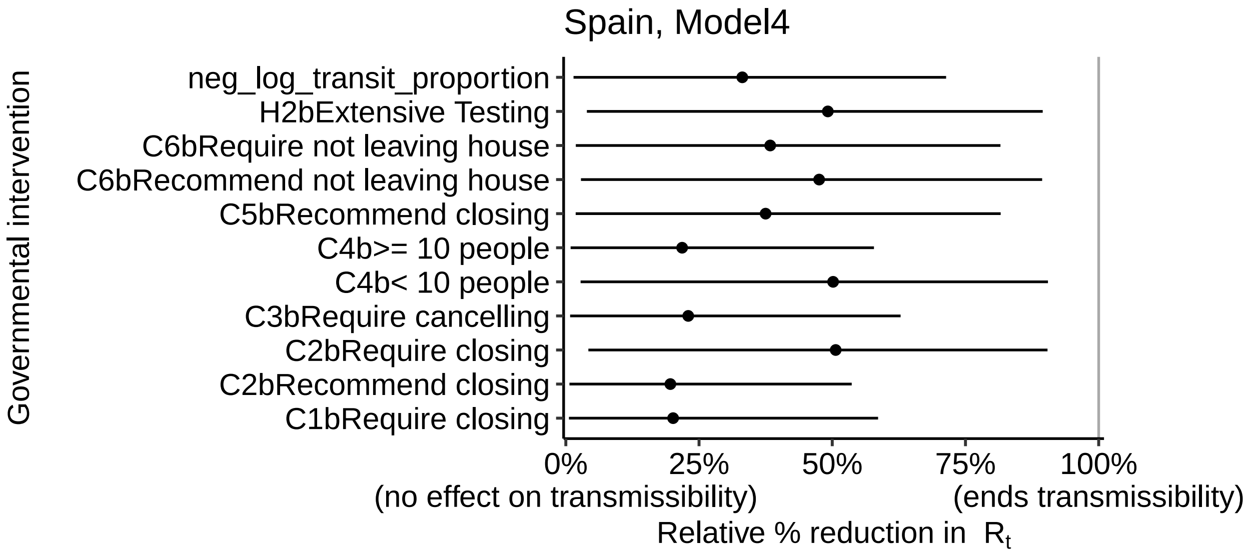
Germany, Model3



Germany, Model4



Spain, Model3


Spain, Model4
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
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C4b>= 10 people
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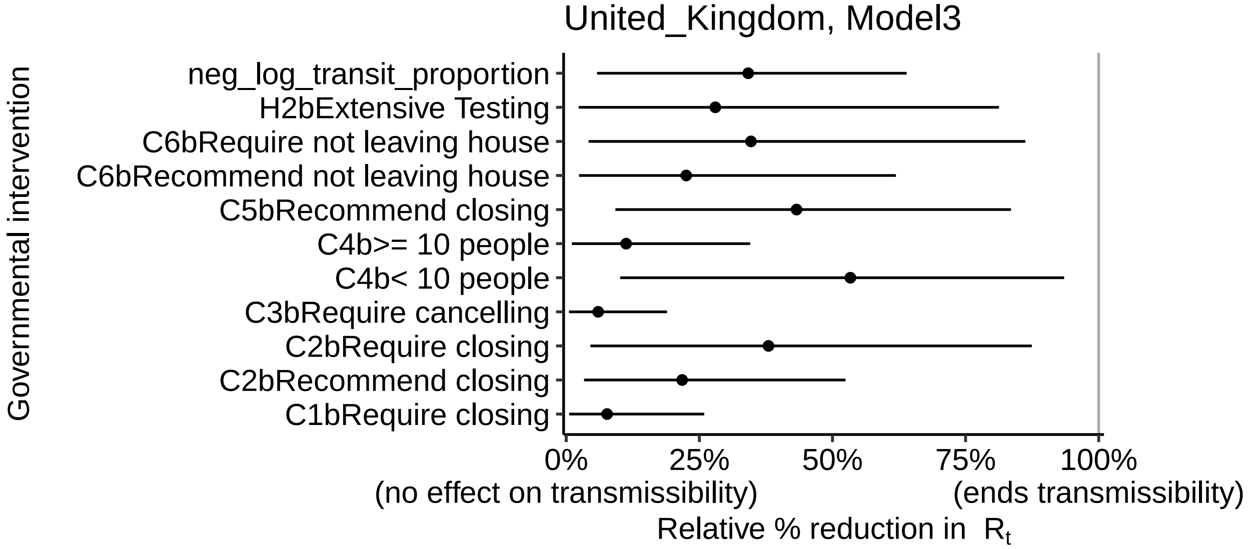
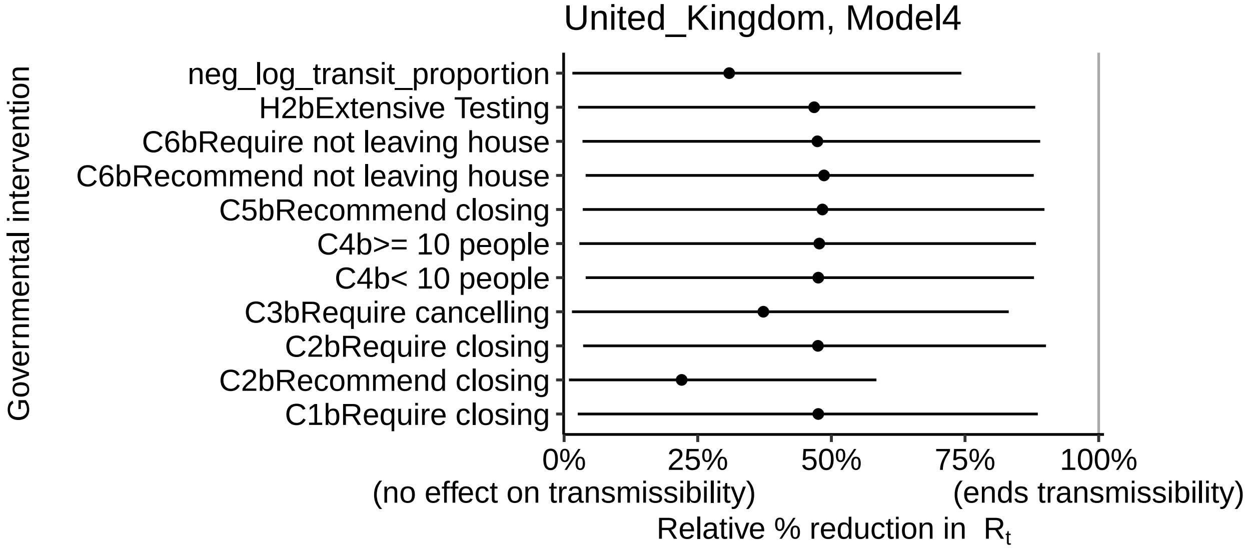
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t


United_Kingdom, Model3
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
0%
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t


United_Kingdom, Model4
Governmental intervention
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C2bRecommend closing
C1bRequire closing
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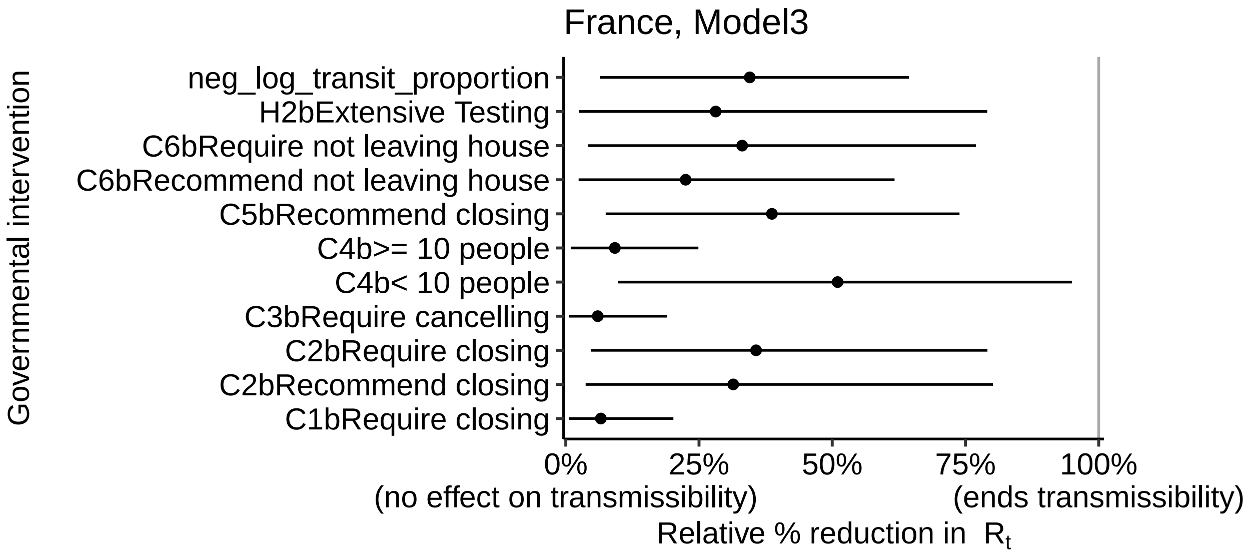
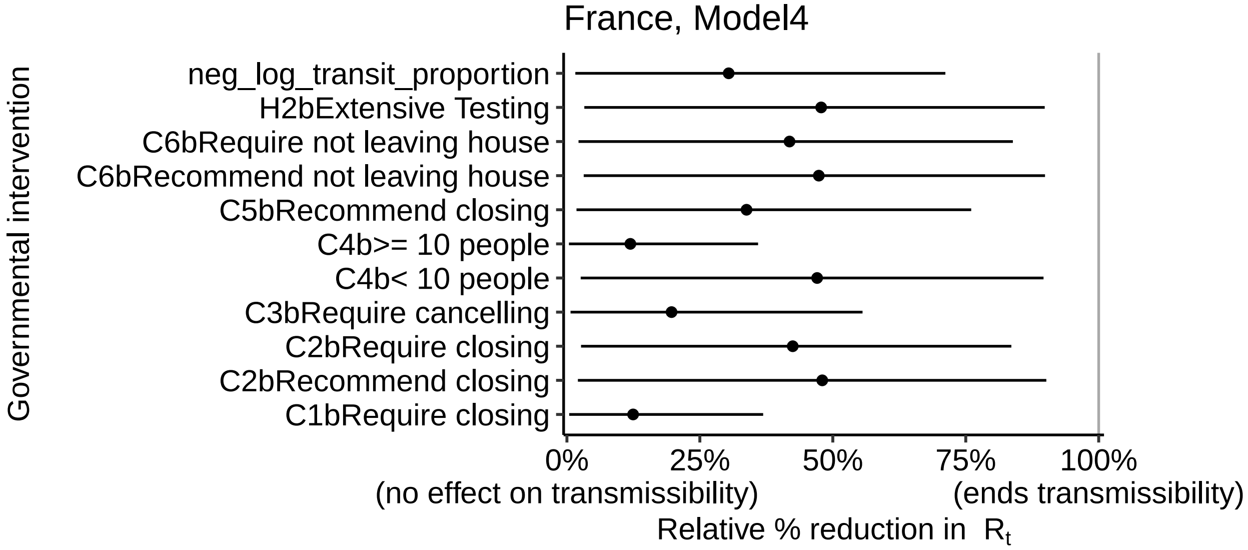
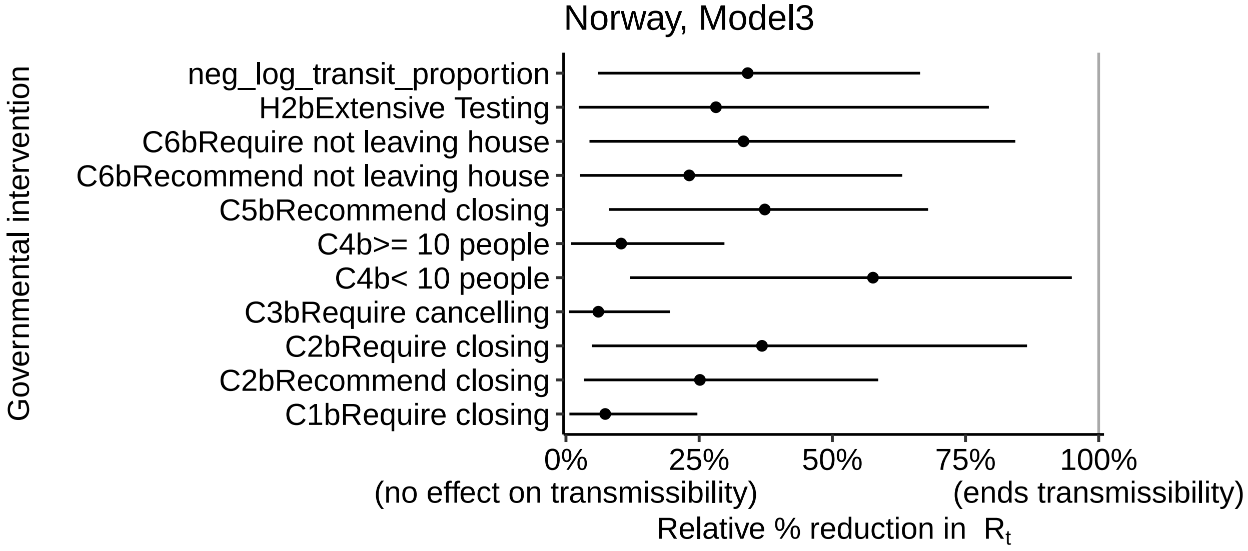
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t



France, Model3

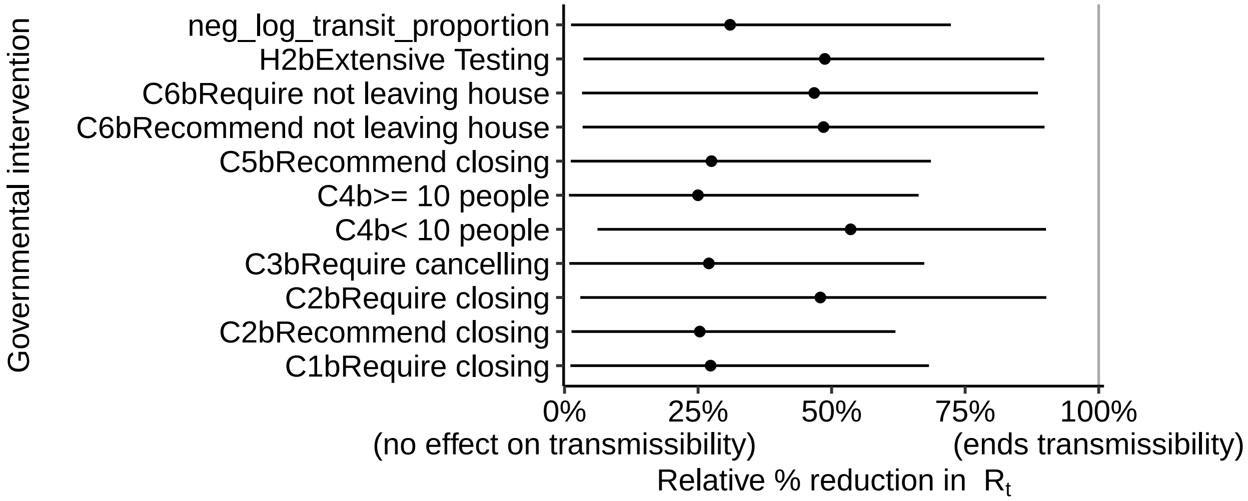


France, Model4

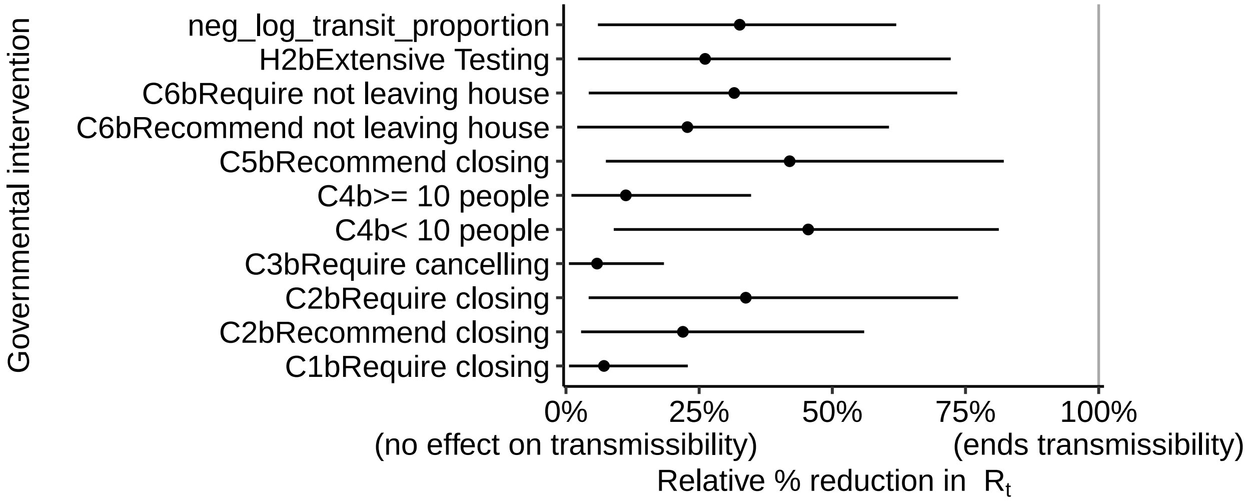


Norway, Model3

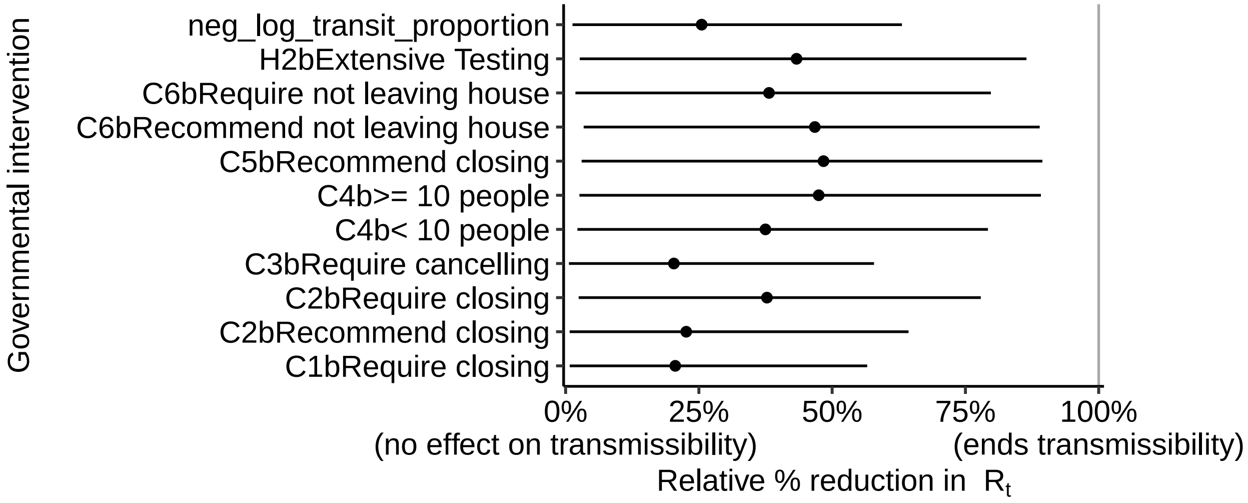
Norway, Model4

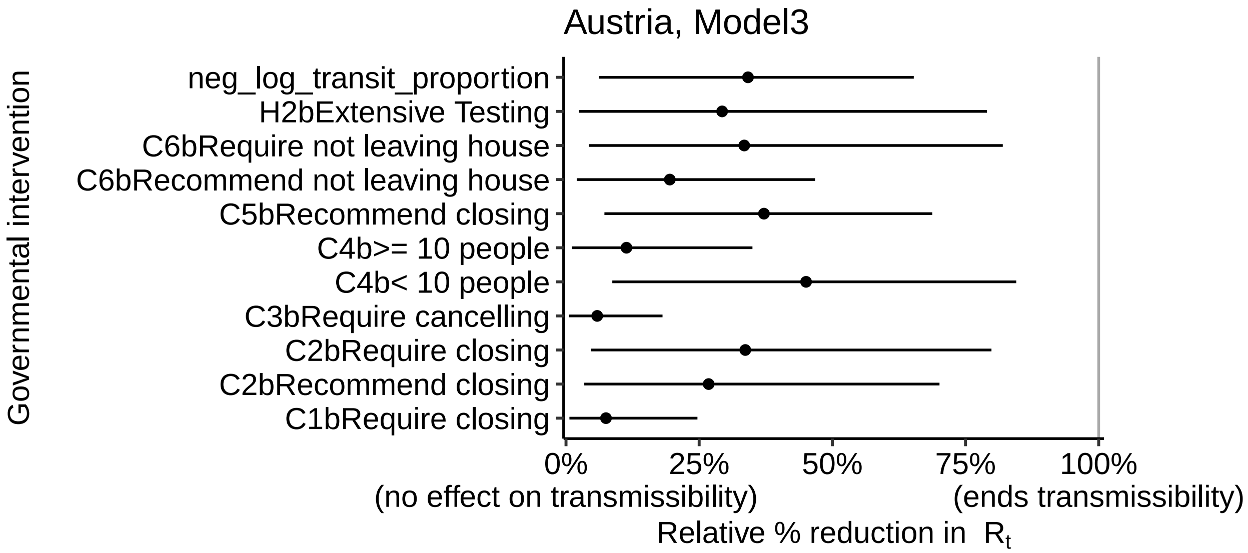


Belgium, Model3



Belgium, Model4




Austria, Model3
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
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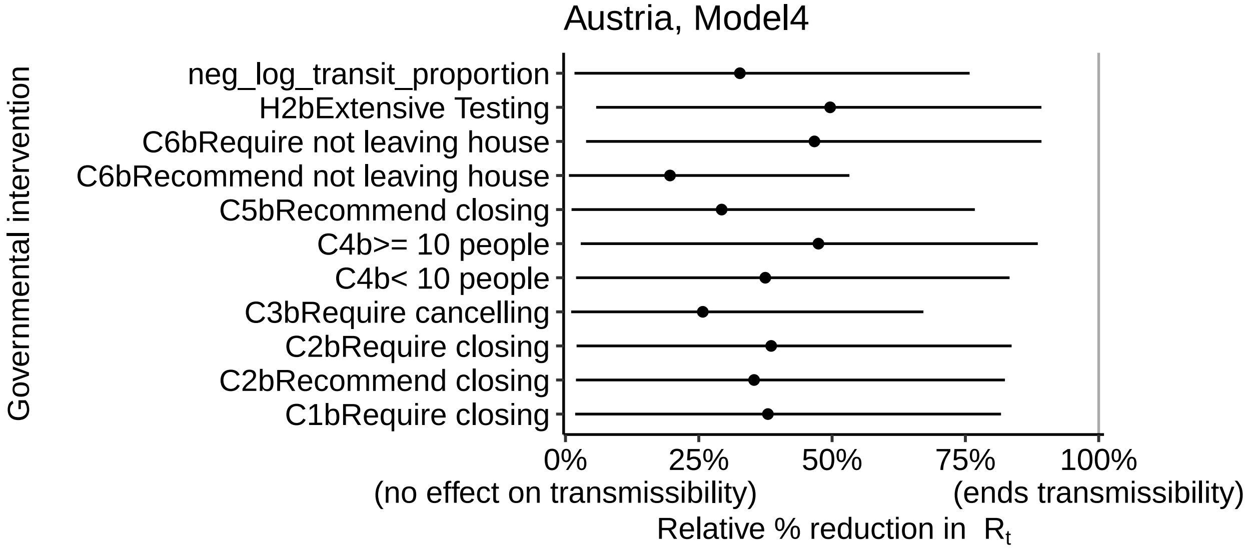
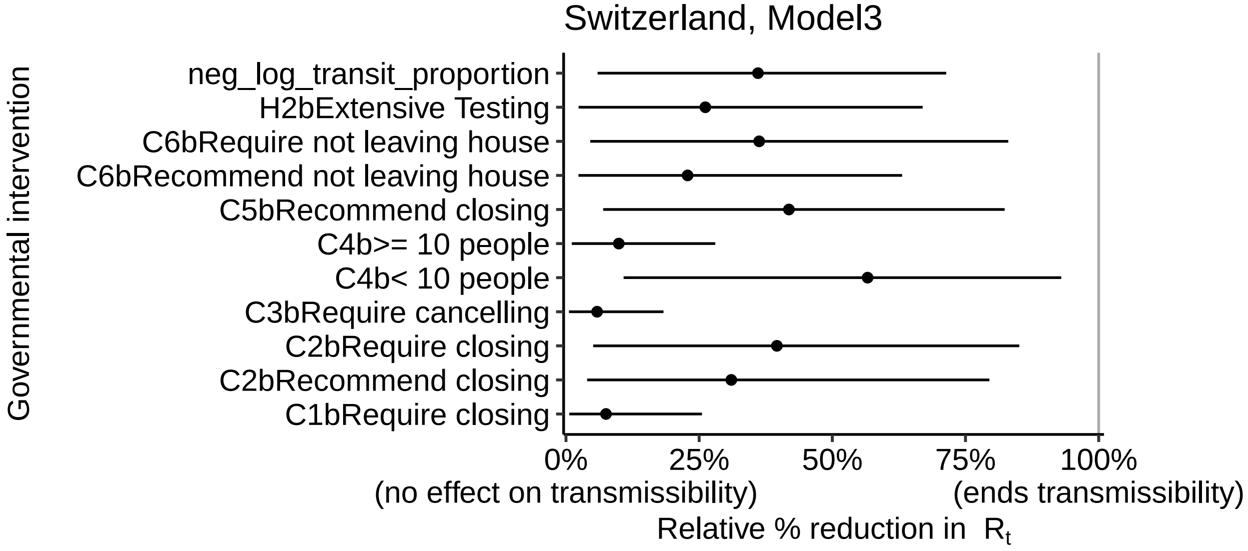
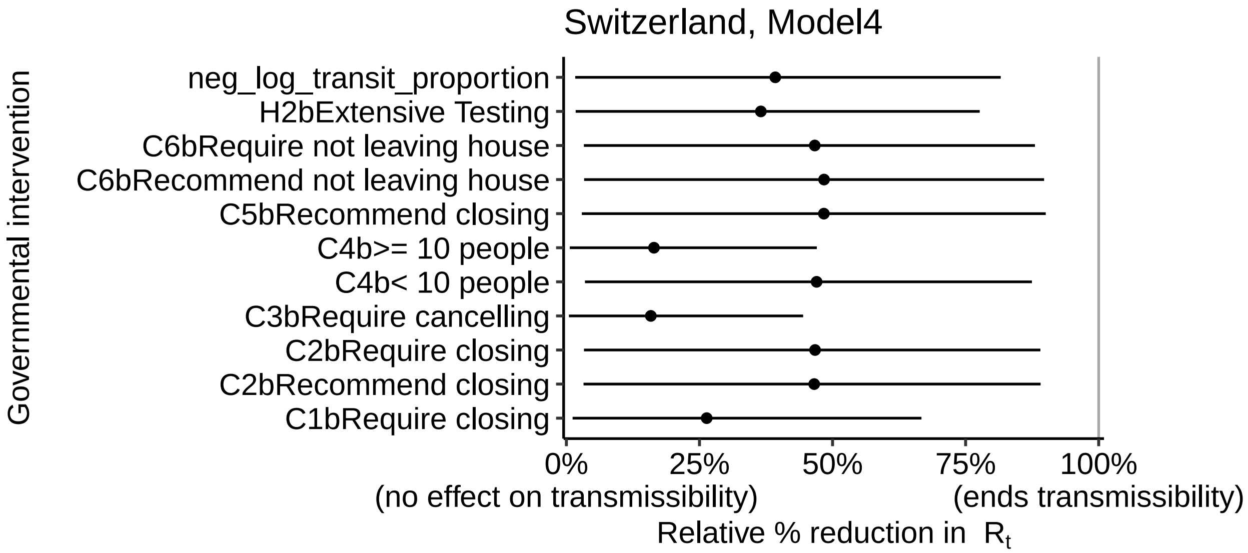
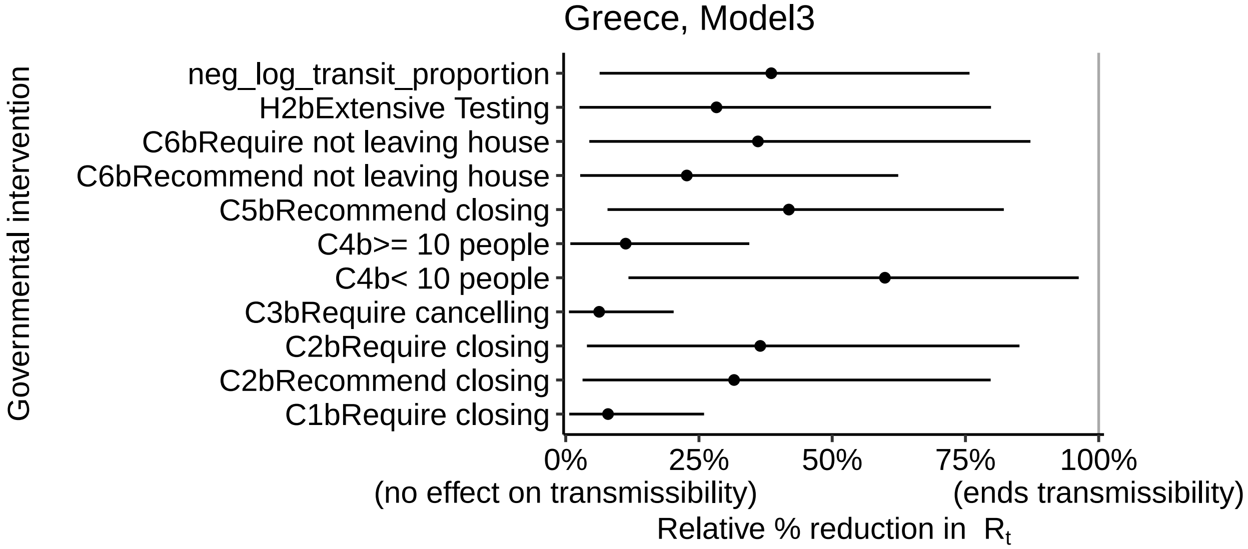
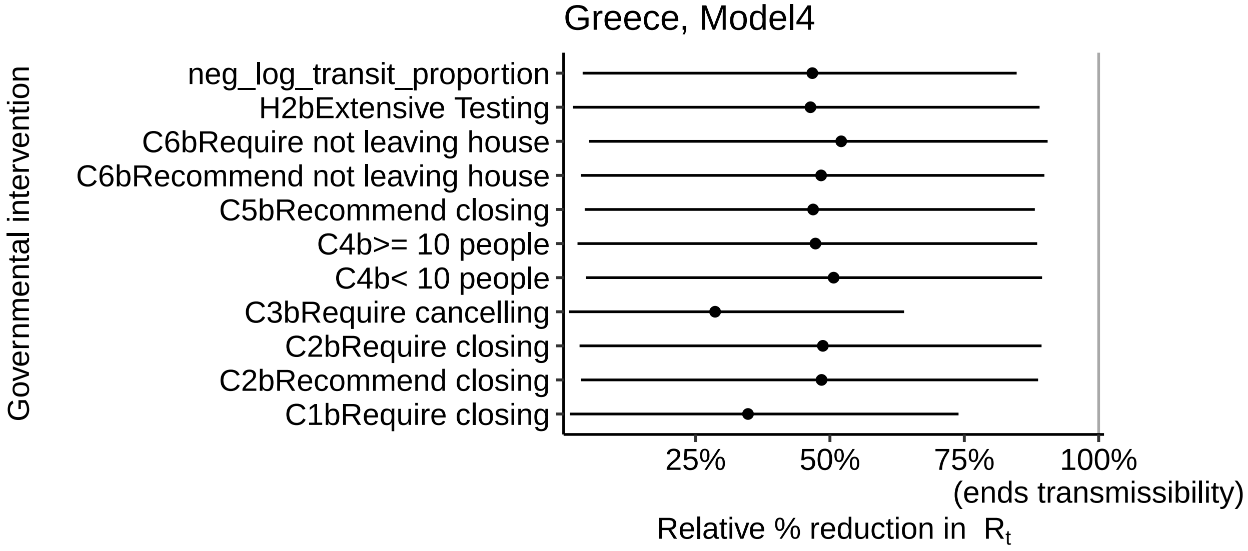
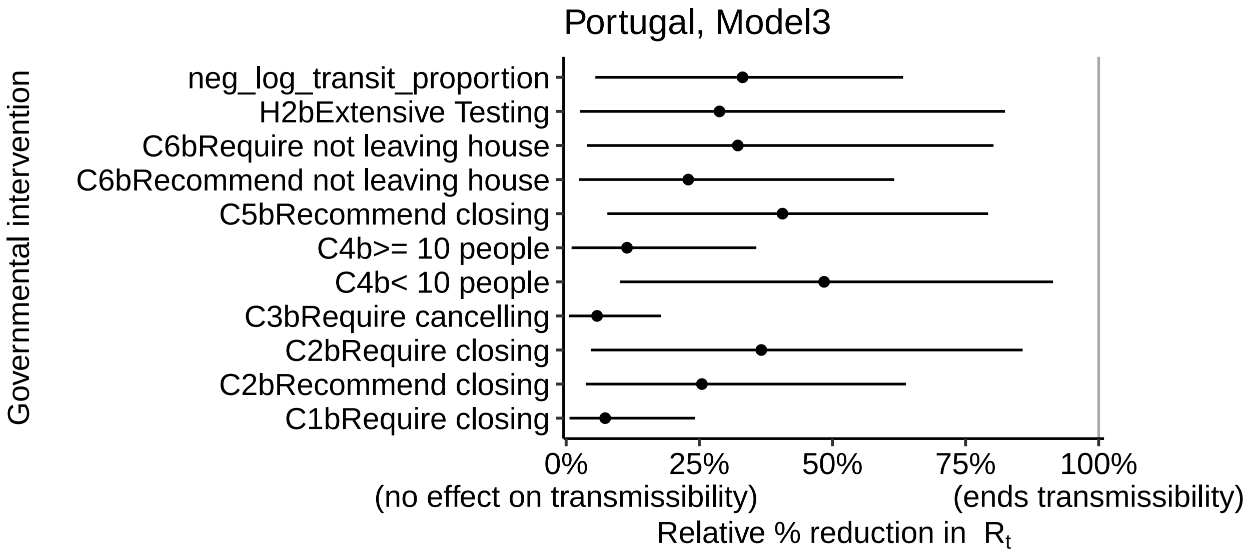

Austria, Model4
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
0%
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t

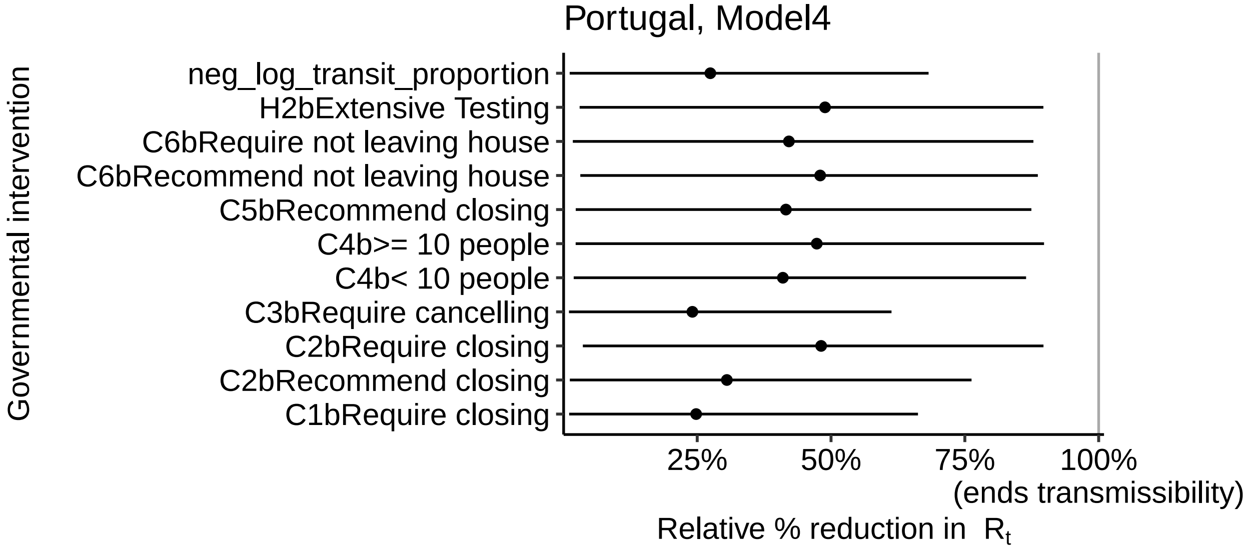

Switzerland, Model3
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
0%
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t

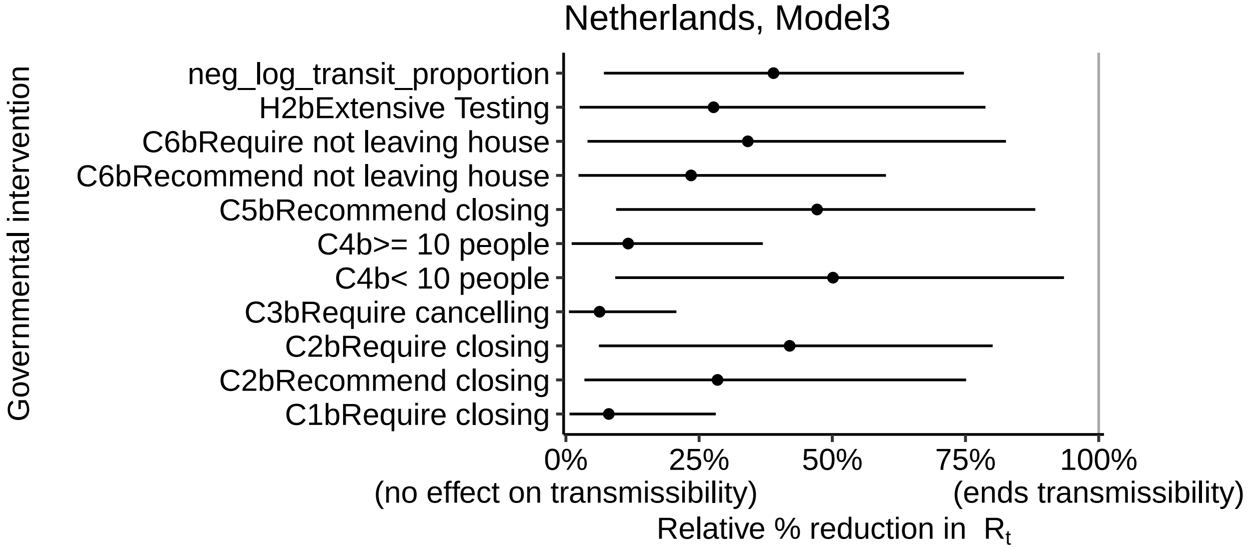

Switzerland, Model4
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
0%
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t

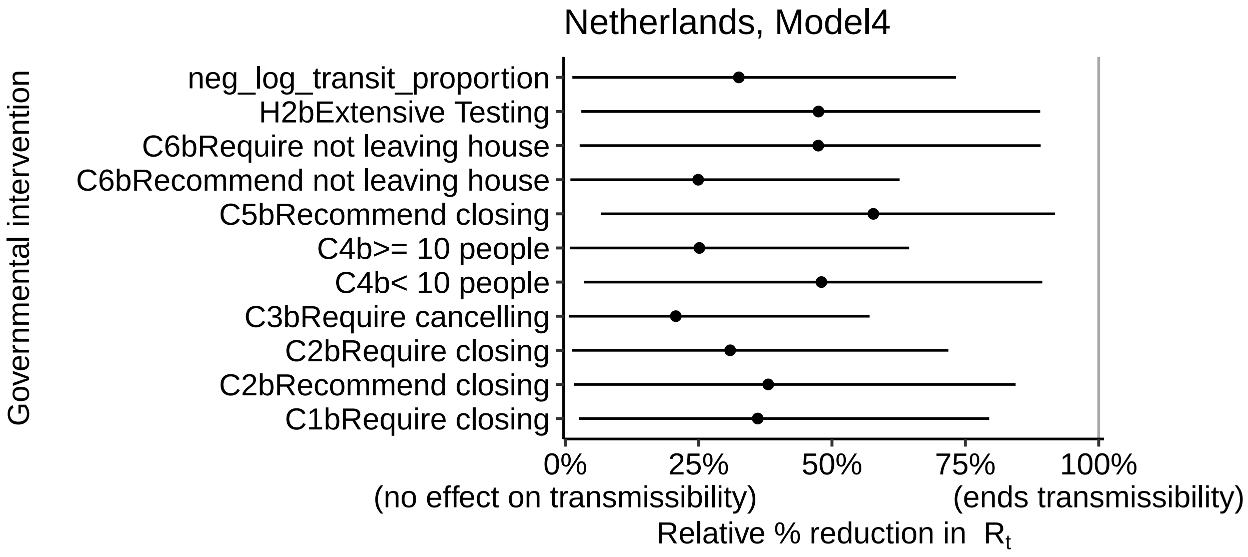

Greece, Model3
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
0%
25%
50%
75%
100%
(no effect on transmissibility)
(ends transmissibility)
Relative % reduction in R_t


Greece, Model4
Governmental intervention
neg_log_transit_proportion
H2bExtensive Testing
C6bRequire not leaving house
C6bRecommend not leaving house
C5bRecommend closing
C4b>= 10 people
C4b< 10 people
C3bRequire cancelling
C2bRequire closing
C2bRecommend closing
C1bRequire closing
25%
50%
75%
100%
(ends transmissibility)
Relative % reduction in R_t

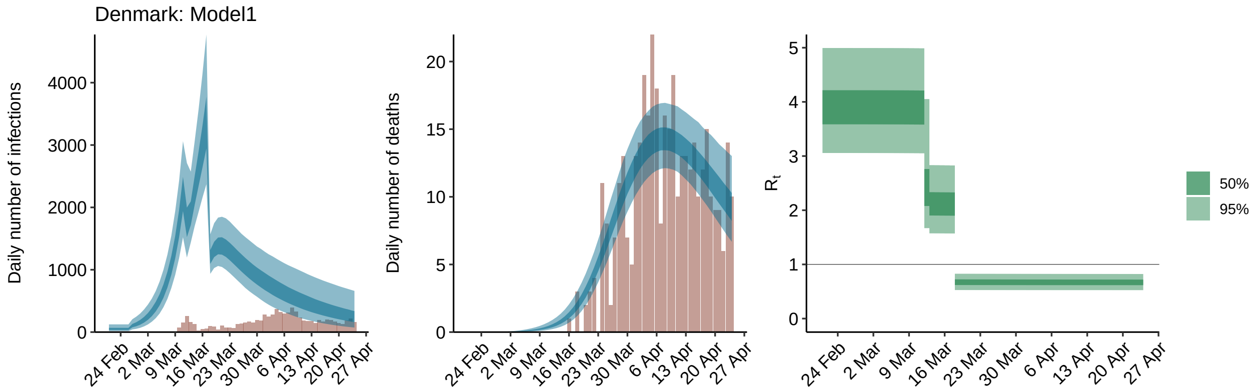

Portugal, Model3

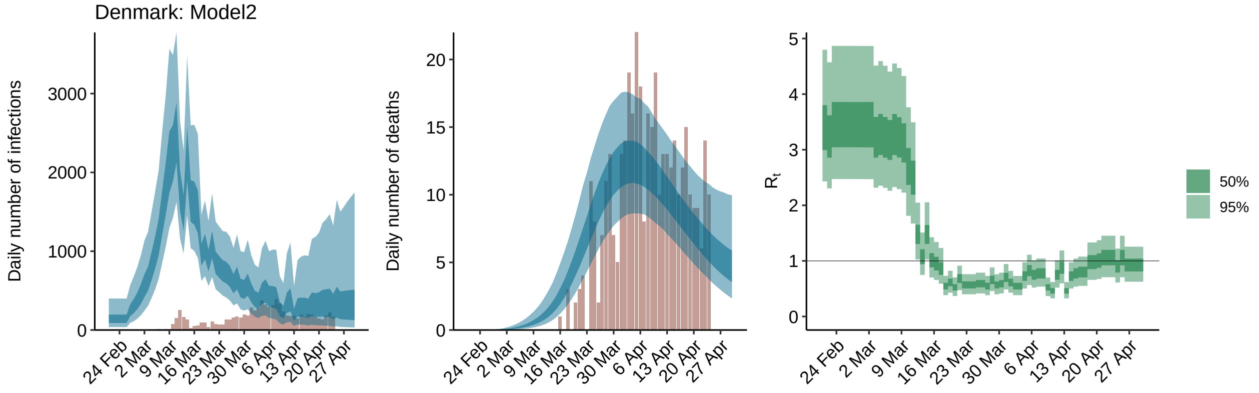

Portugal, Model4

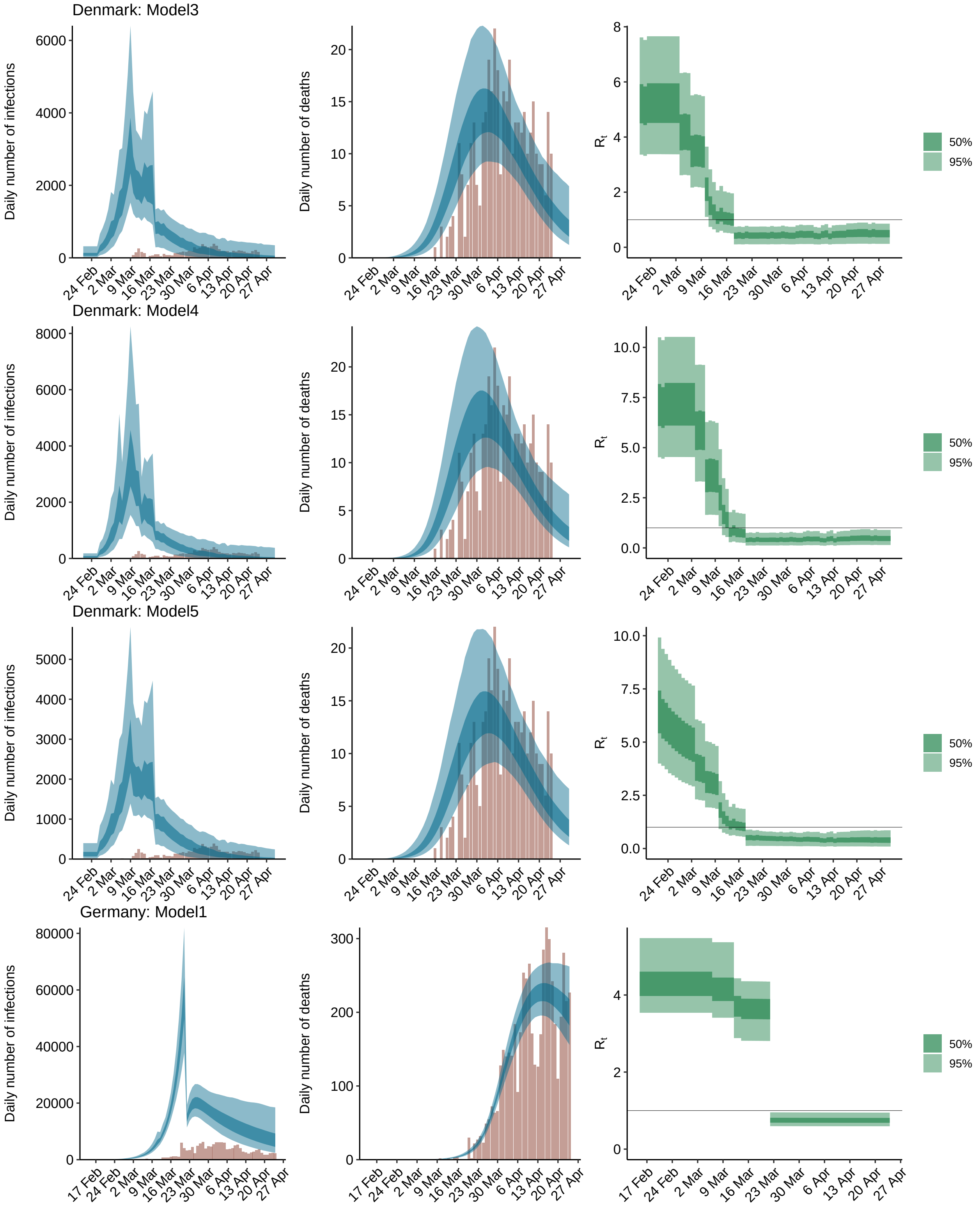

Netherlands, Model3

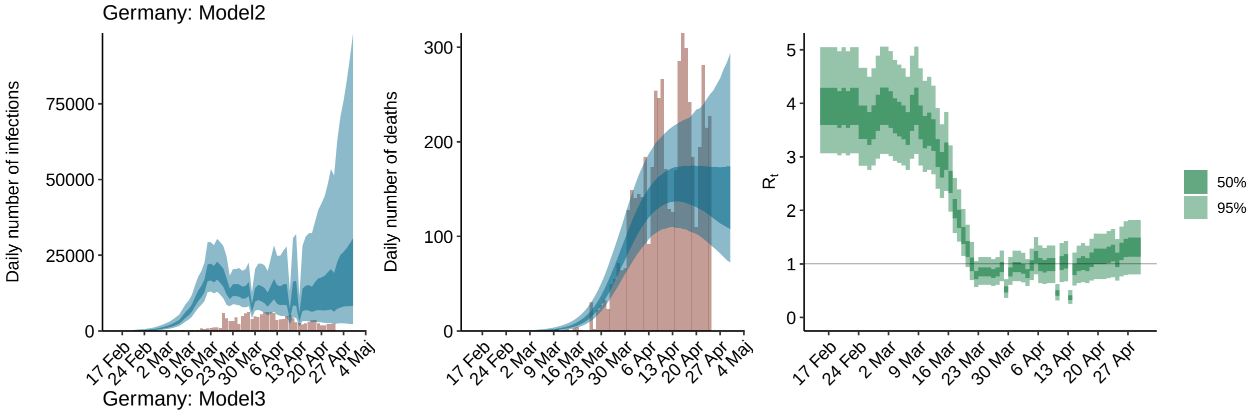


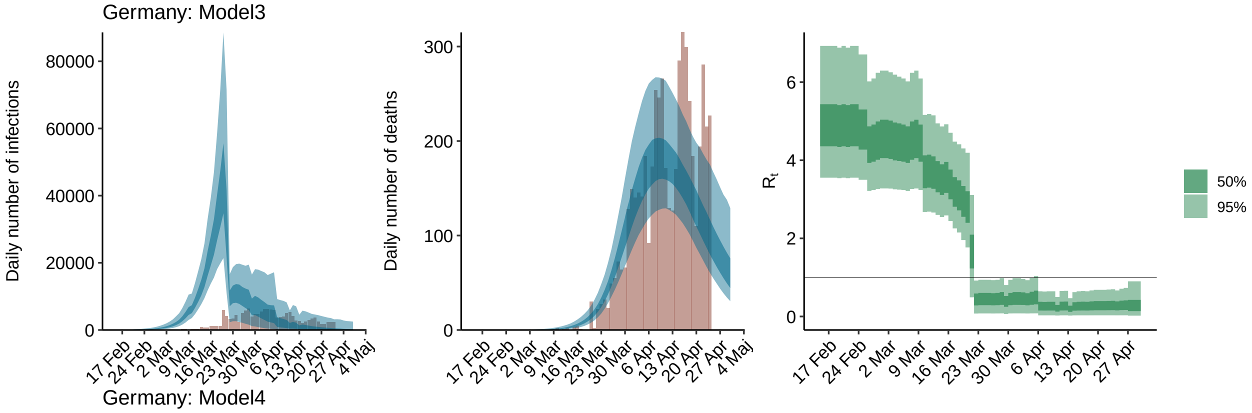
Infections, cases, deaths and Rt by country and model

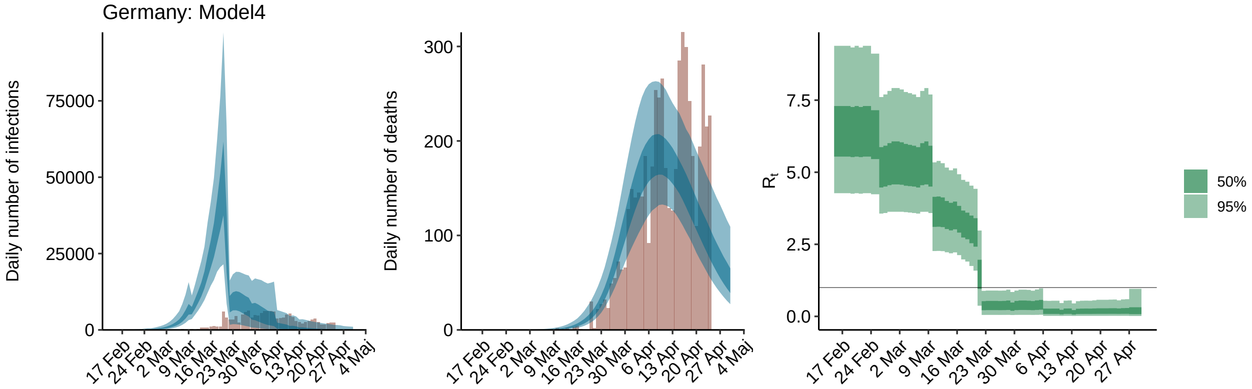


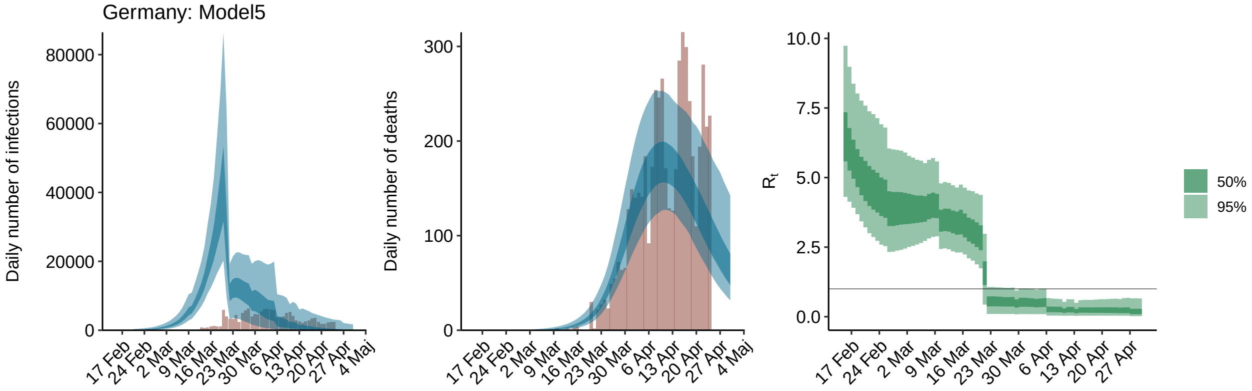


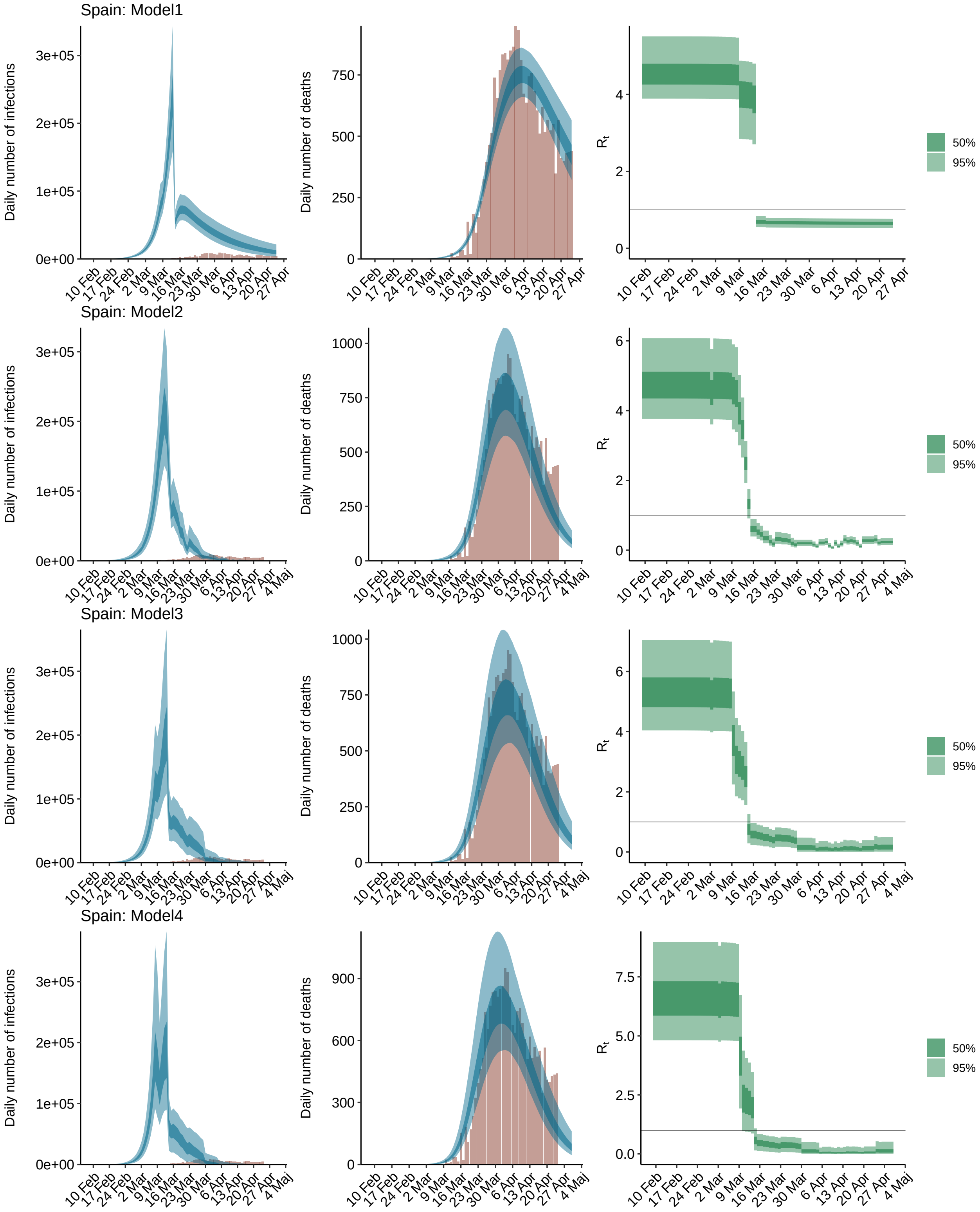

Denmark: Model3
Daily number of infections
0
2000
4000
6000
Daily number of deaths
0
5
10
15
20
R_t
0
2
4
6
8
50%
95%
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Denmark: Model4
0
2000
4000
6000
8000
0.0
2.5
5.0
7.5
10.0
Denmark: Model5
1000
2000
3000
4000
5000
Germany: Model1
20000
40000
60000
80000
100
200
300
17 Feb


Germany: Model2
Daily number of infections
0
25000
50000
75000
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
100
200
300
R_t
0
1
2
3
4
5
50%
95%


Germany: Model3
Daily number of infections
0
20000
40000
60000
80000
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
100
200
300
R_t
0
2
4
6
50%
95%


Germany: Model4
Daily number of infections
0
25000
50000
75000
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
100
200
300
R_t
0.0
2.5
5.0
7.5
50%
95%


Germany: Model5
Daily number of infections
0
20000
40000
60000
80000
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
100
200
300
R_t
0.0
2.5
5.0
7.5
10.0
50%
95%

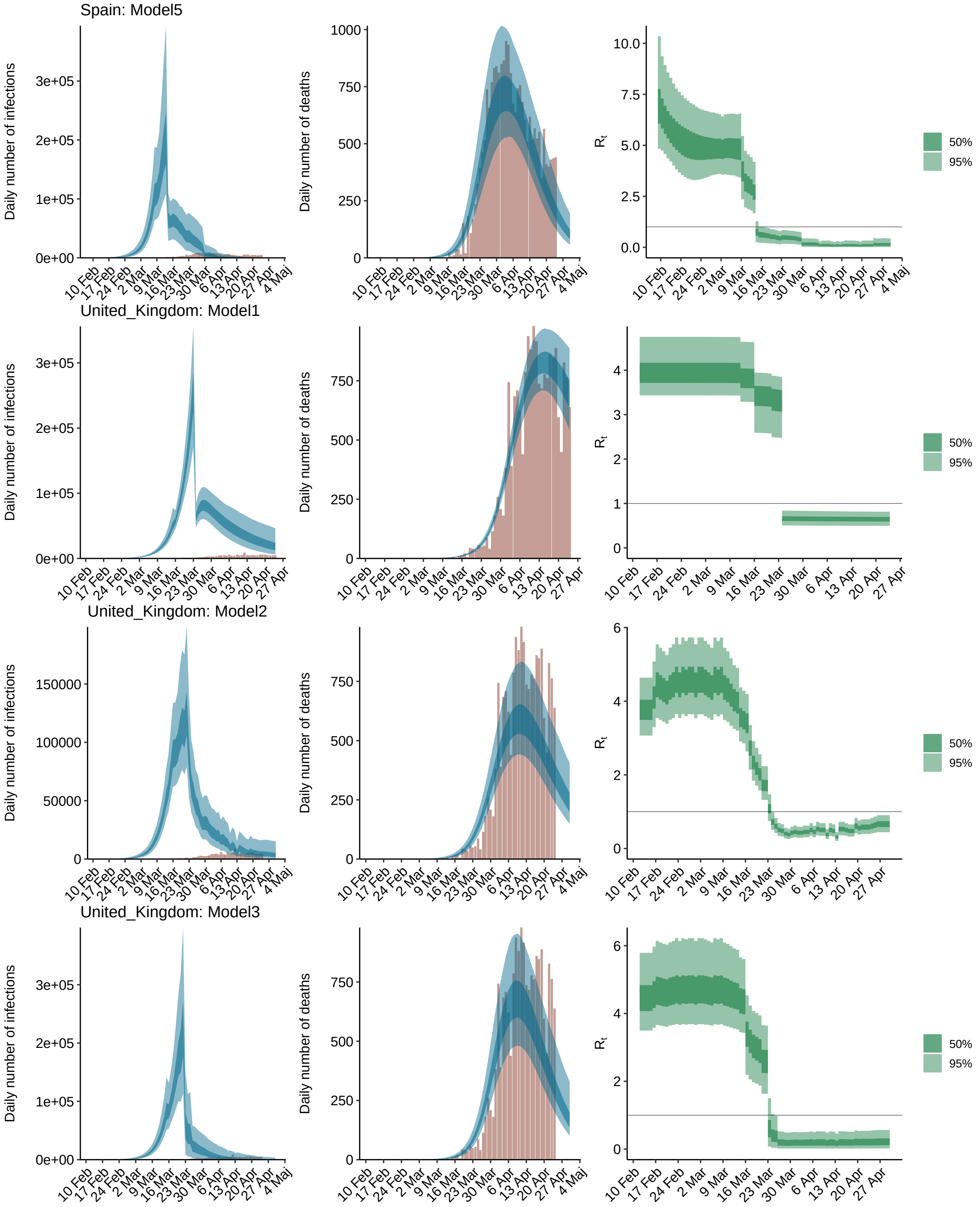


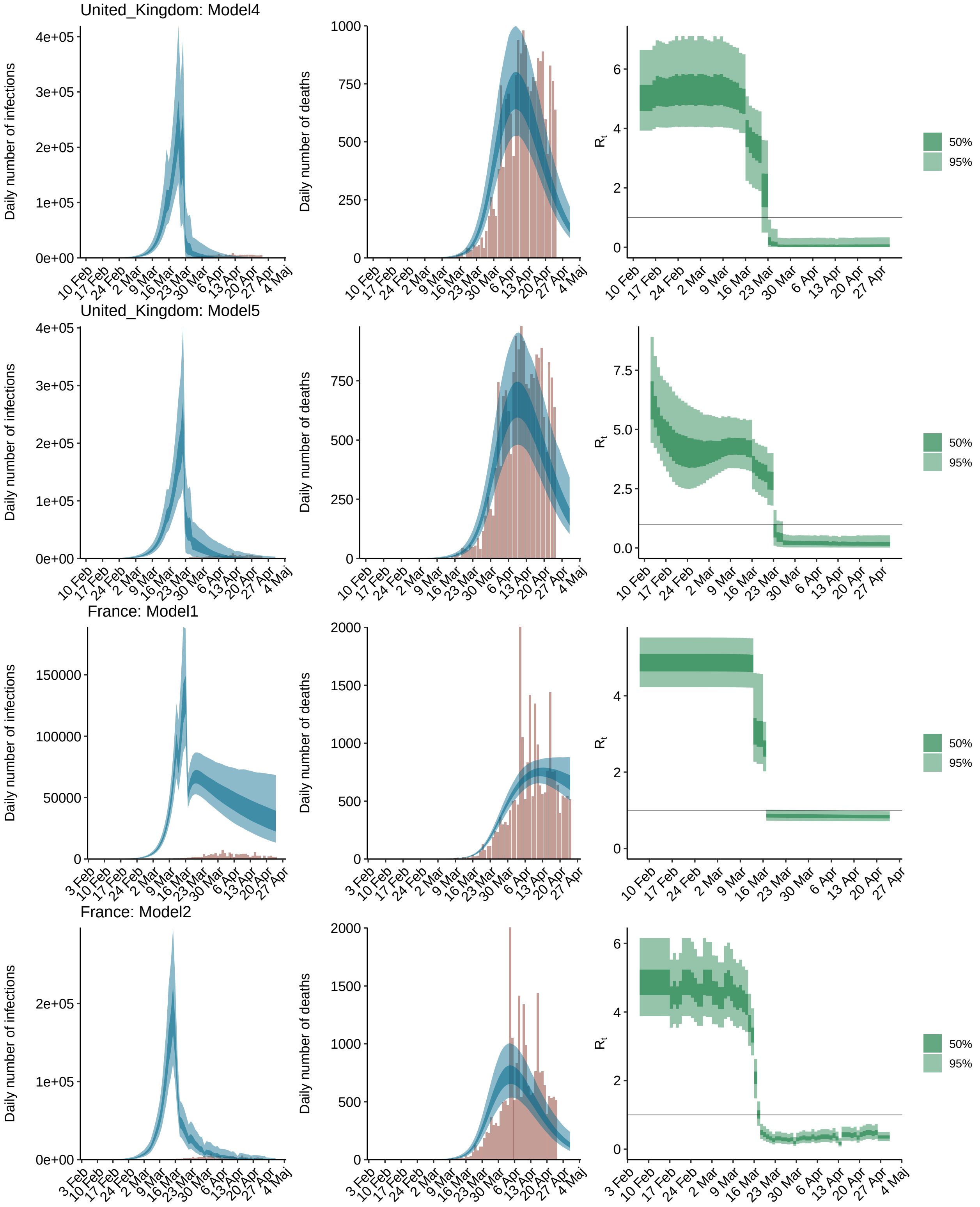
Spain: Model1

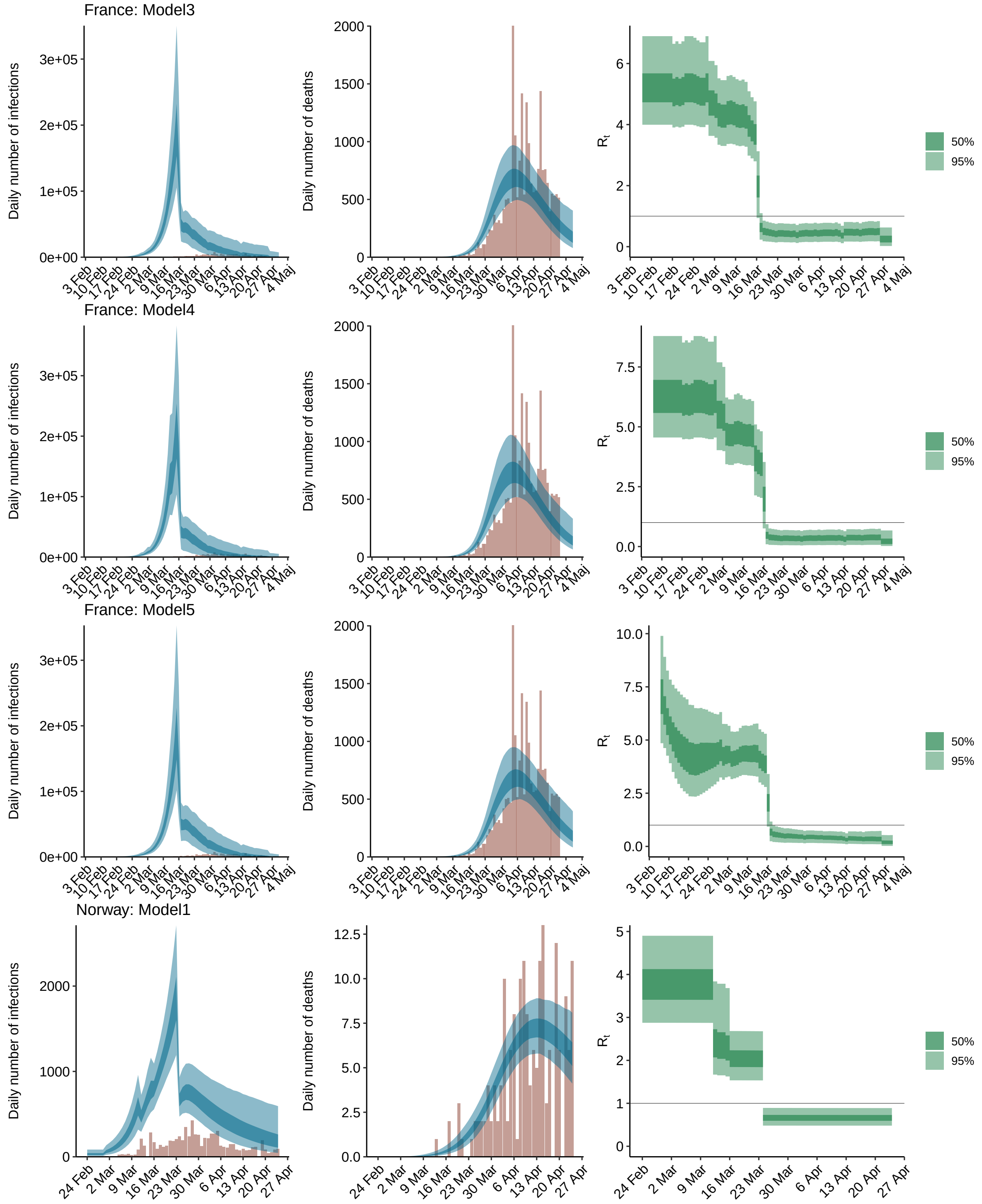
Spain: Model2

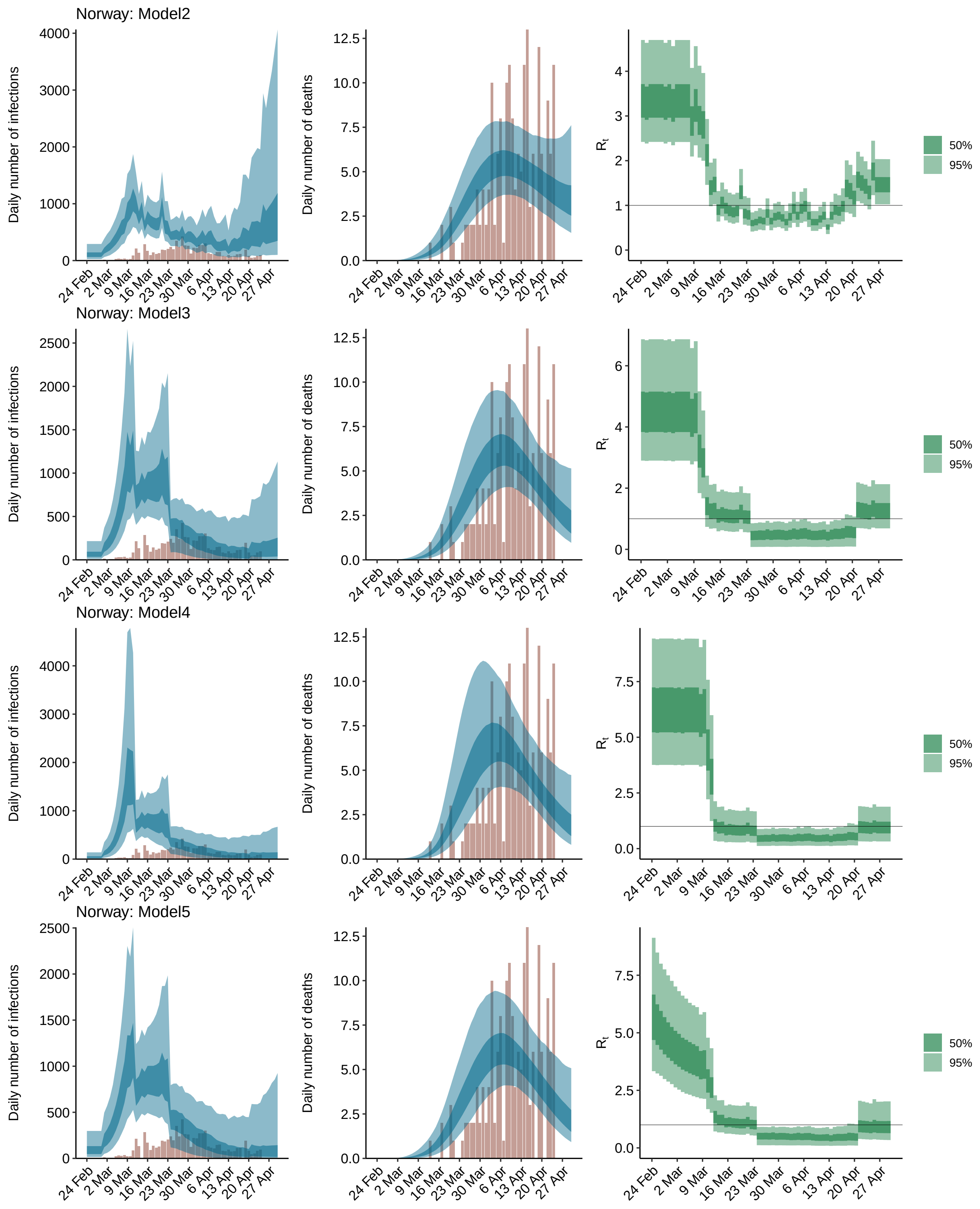
Spain: Model3

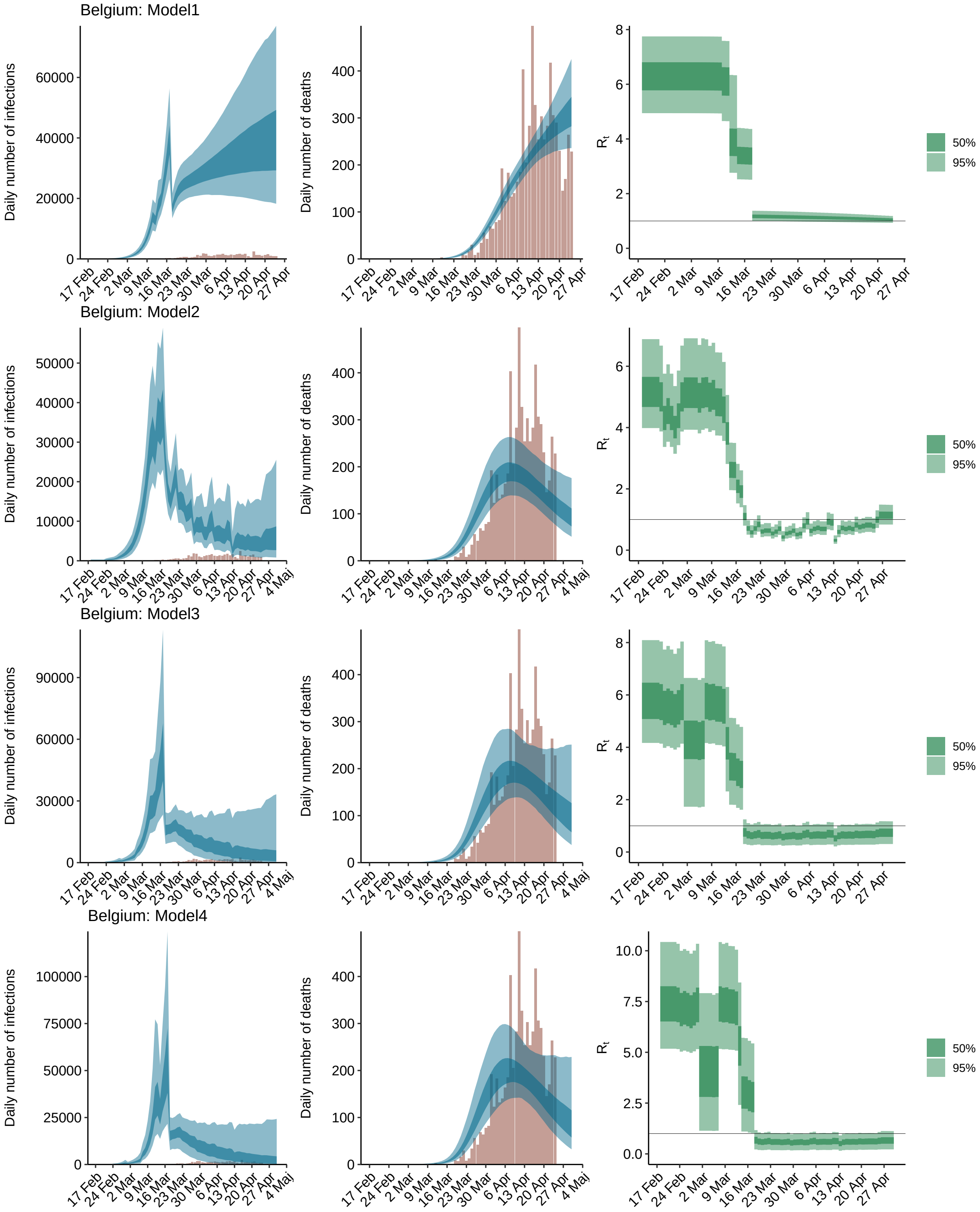
Spain: Model4

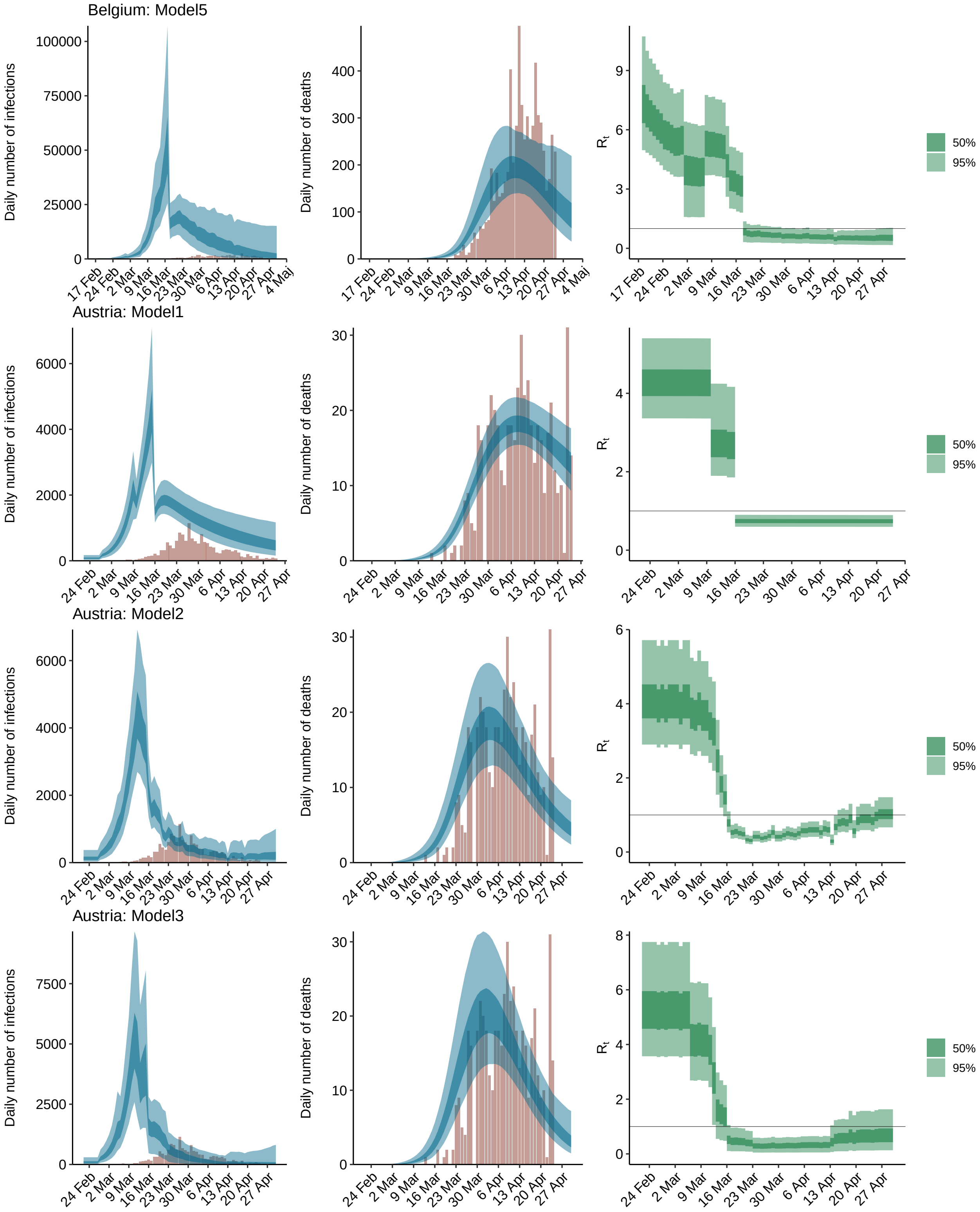

Spain: Model5
Daily number of infections
0e+00
1e+05
2e+05
3e+05
Daily number of deaths
0
250
500
750
1000
Rt
0.0
2.5
5.0
7.5
10.0
50%
95%
10 Feb
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
United_Kingdom: Model1
Daily number of infections
0e+00
1e+05
2e+05
3e+05
Daily number of deaths
0
250
500
750
Rt
0
1
2
3
4
50%
95%
United_Kingdom: Model2
Daily number of infections
0
50000
100000
150000
Daily number of deaths
0
250
500
750
Rt
0
2
4
6
50%
95%
United_Kingdom: Model3
Daily number of infections
0e+00
1e+05
2e+05
3e+05
Daily number of deaths
0
250
500
750
Rt
0
2
4
6
50%
95%

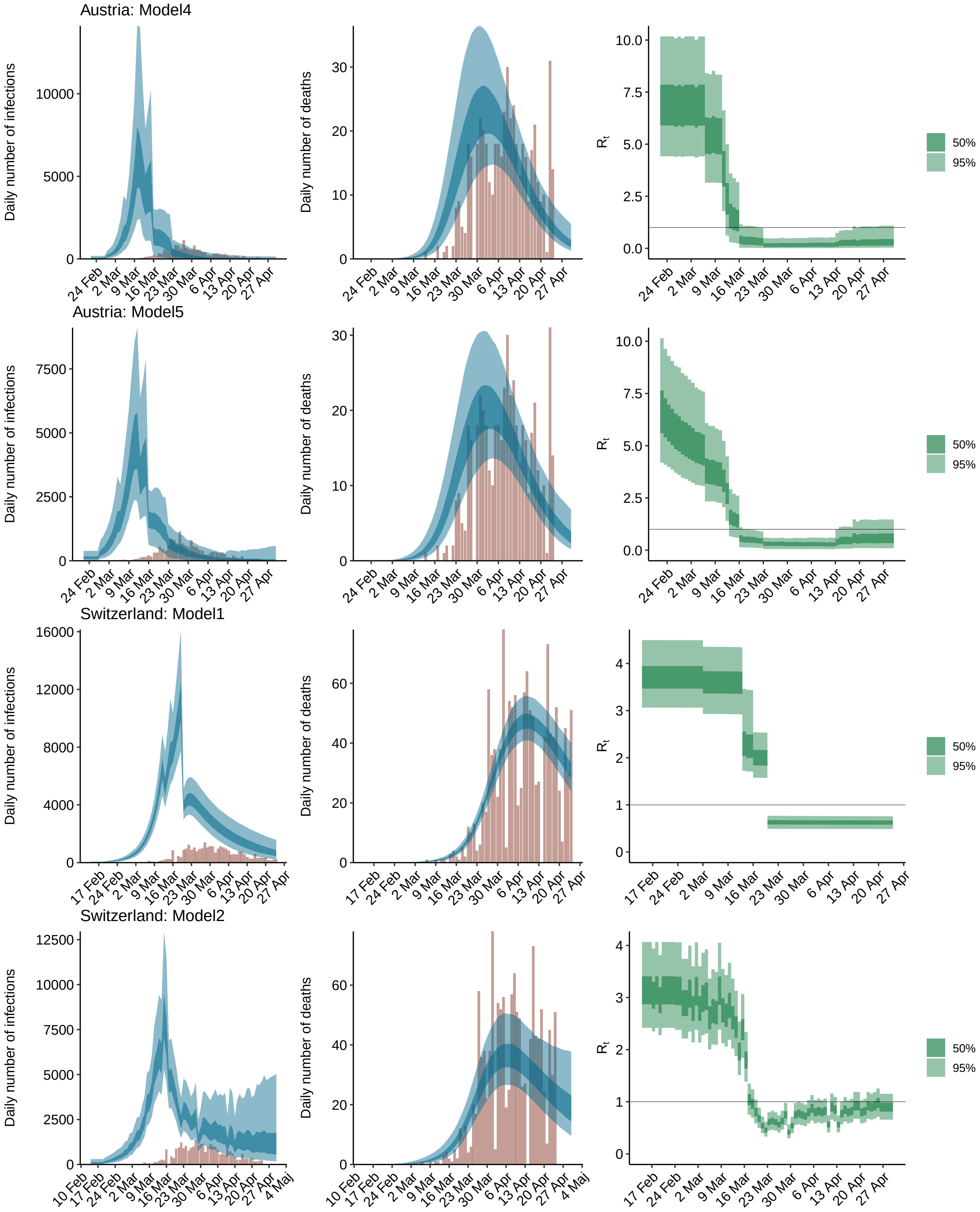

United_Kingdom: Model4
Daily number of infections
4e+05
3e+05
2e+05
1e+05
0e+00
10 Feb
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
1000
750
500
250
0
R_t
6
4
2
0
50%
95%
United_Kingdom: Model5
7.5
5.0
2.5
0.0
France: Model1
150000
100000
50000
2000
1500
1000
500
3 Feb
France: Model2
2e+05
1e+05


France: Model3
France: Model4
France: Model5
Norway: Model1
Daily number of infections
Daily number of deaths
Rt
0e+00
1e+05
2e+05
3e+05
0
500
1000
1500
2000
0
2
4
6
0.0
2.5
5.0
7.5
10.0
1000
2000
12.5
1
3
5
50%
95%
3 Feb
10 Feb
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj


Norway: Model2
Norway: Model3
Norway: Model4
Norway: Model5
Daily number of infections
Daily number of deaths
R_t
50%
95%
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
0
500
1000
1500
2000
2500
3000
4000
0.0
2.5
5.0
7.5
10.0
12.5
0
1
2
3
4
6


Belgium: Model1
Daily number of infections
0
20000
40000
60000
Daily number of deaths
0
100
200
300
400
Rt
0
2
4
6
8
50%
95%
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Belgium: Model2
Daily number of infections
0
10000
20000
30000
40000
50000
Daily number of deaths
0
100
200
300
400
Rt
0
2
4
6
50%
95%
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Belgium: Model3
Daily number of infections
0
30000
60000
90000
Daily number of deaths
0
100
200
300
400
Rt
0
2
4
6
8
50%
95%
Belgium: Model4
Daily number of infections
0
25000
50000
75000
100000
Daily number of deaths
0
100
200
300
400
Rt
0.0
2.5
5.0
7.5
10.0
50%
95%


Belgium: Model5
Daily number of infections
100000
75000
50000
25000
0
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
400
300
200
100
0
R_t
9
6
3
0
50%
95%
Austria: Model1
6000
4000
2000
30
20
10
4
2
Austria: Model2
6
Austria: Model3
7500
5000
2500
8

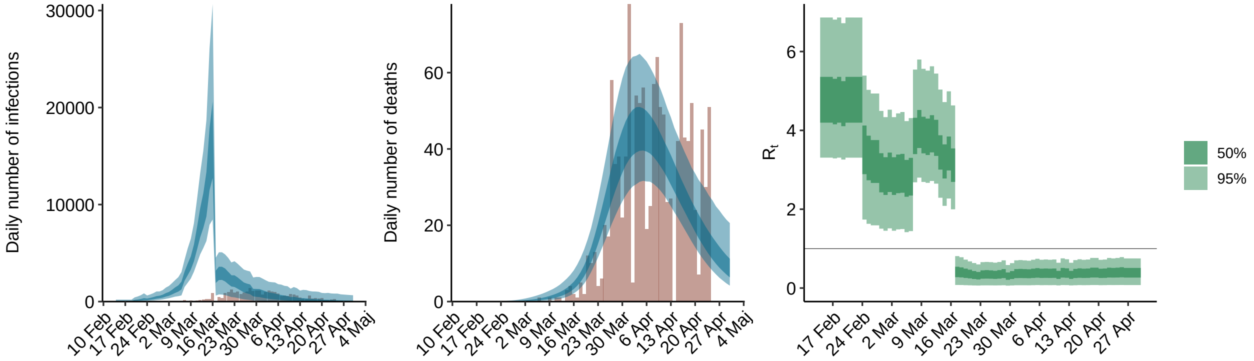

Austria: Model4

Austria: Model5

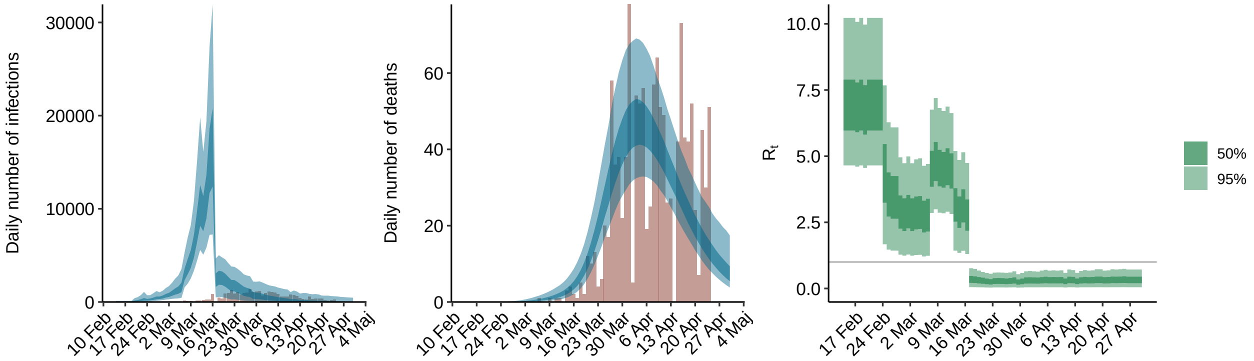
Switzerland: Model1

Switzerland: Model2

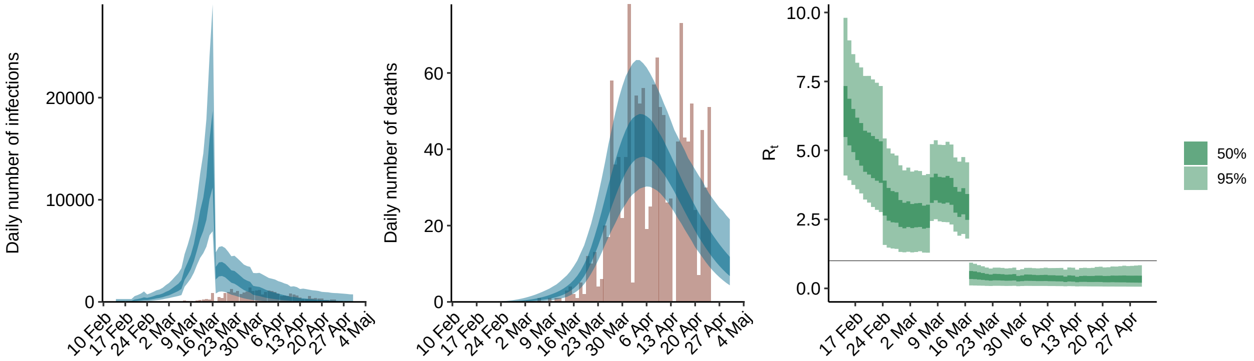
Switzerland: Model3



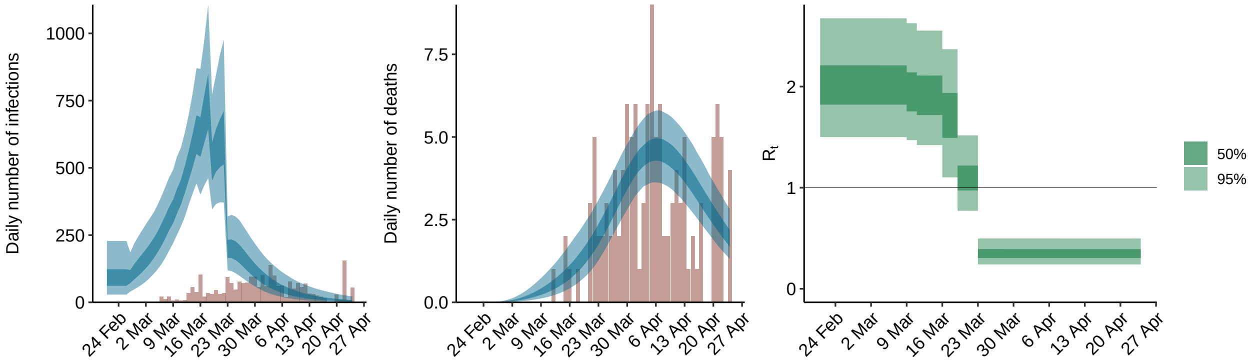
Switzerland: Model4

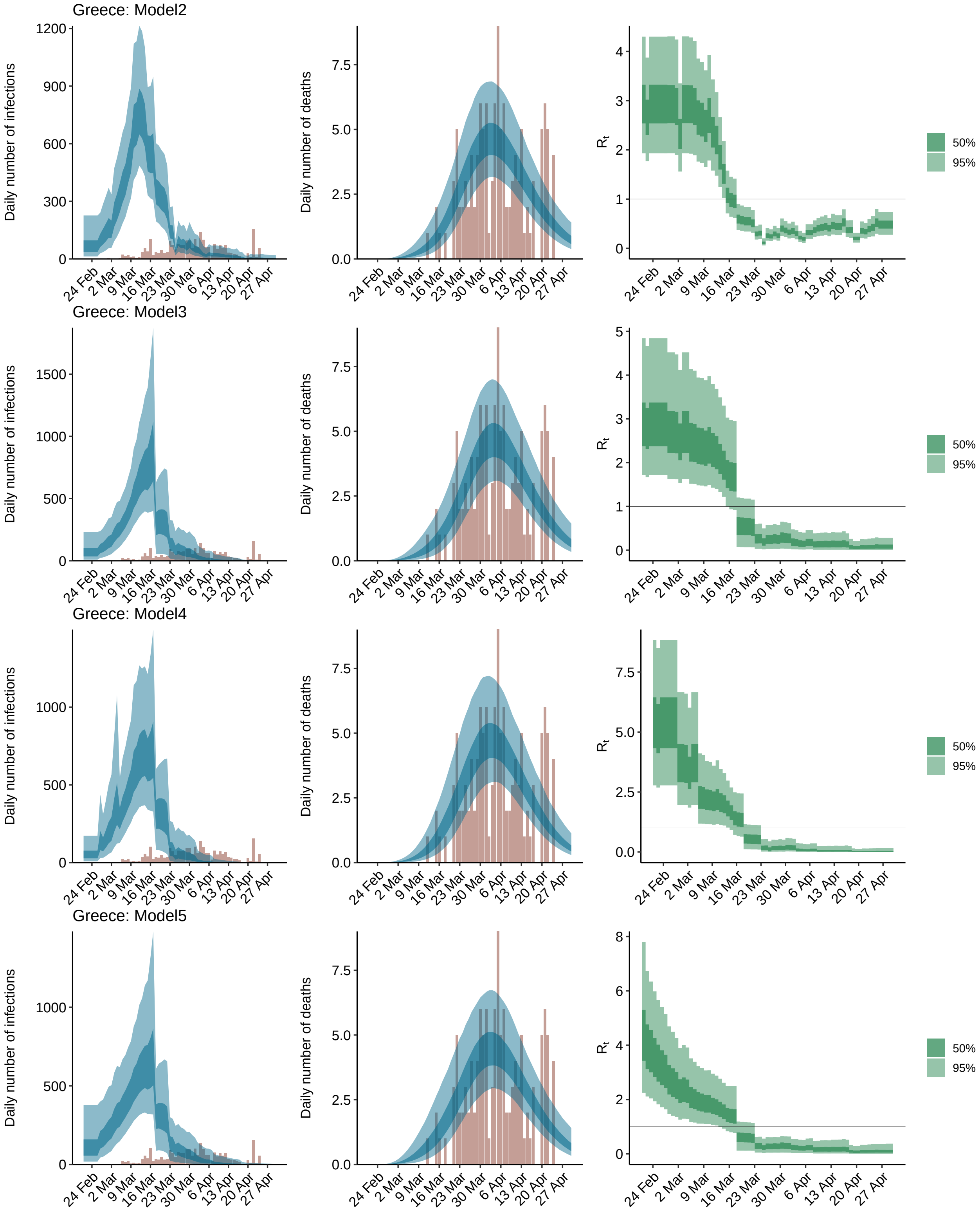


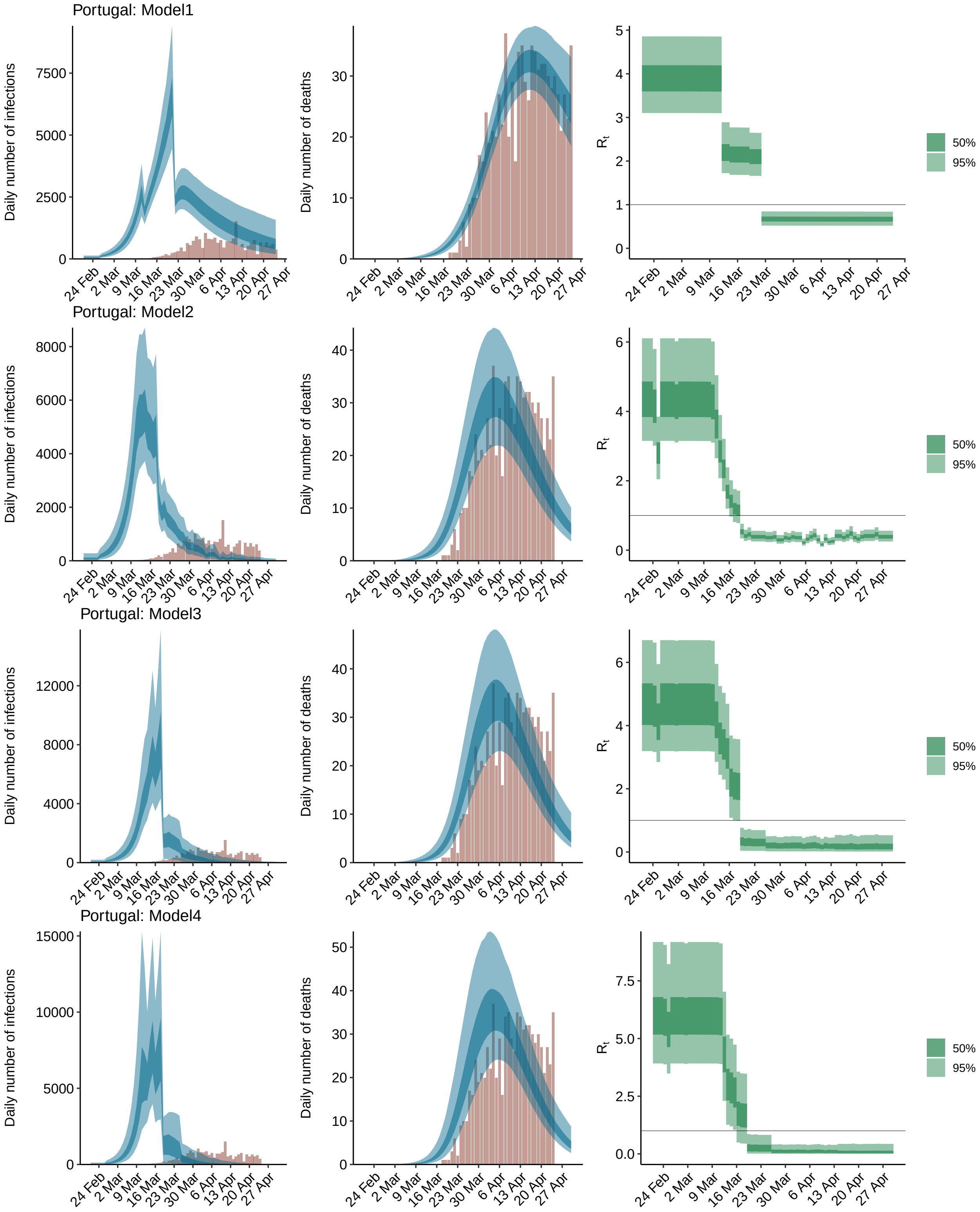
Switzerland: Model5



Greece: Model1




Greece: Model2
Daily number of infections
0
300
600
900
1200
Daily number of deaths
0.0
2.5
5.0
7.5
Rt
0
1
2
3
4
50%
95%
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Greece: Model3
Daily number of infections
0
500
1000
1500
Daily number of deaths
0.0
2.5
5.0
7.5
Rt
0
1
2
3
4
5
50%
95%
Greece: Model4
Daily number of infections
0
500
1000
Daily number of deaths
0.0
2.5
5.0
7.5
Rt
0.0
2.5
5.0
7.5
50%
95%
Greece: Model5
Daily number of infections
0
500
1000
Daily number of deaths
0.0
2.5
5.0
7.5
Rt
0
2
4
6
8
50%
95%

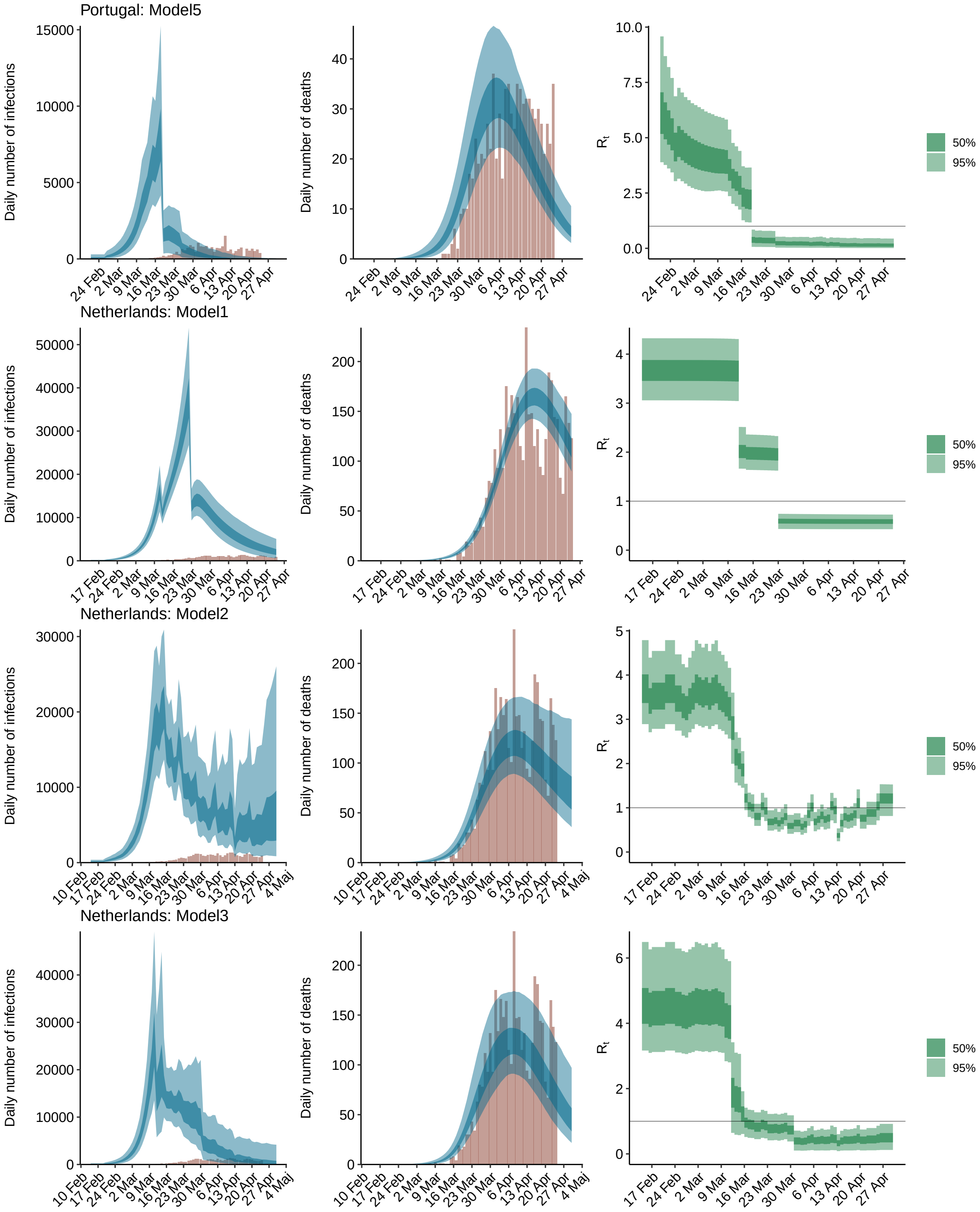


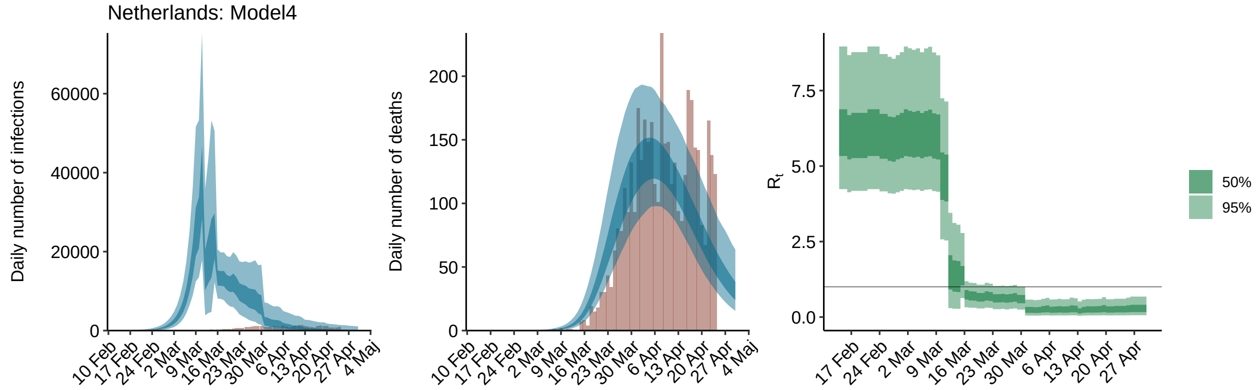
Portugal: Model1

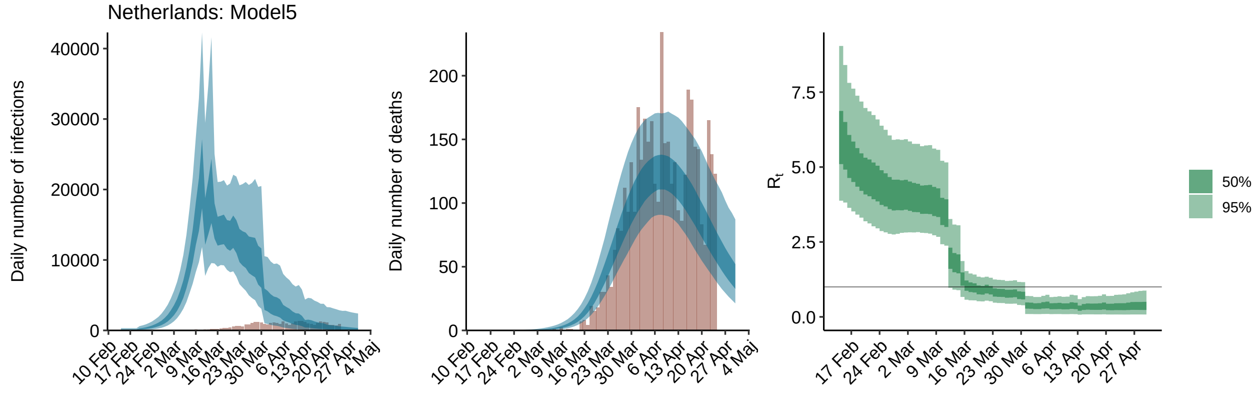
Portugal: Model2

Portugal: Model3

Portugal: Model4


Portugal: Model5
Daily number of infections
0
5000
10000
15000
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Daily number of deaths
0
10
20
30
40
Rt
0.0
2.5
5.0
7.5
10.0
50%
95%
Netherlands: Model1
Daily number of infections
0
10000
20000
30000
40000
50000
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
Daily number of deaths
0
50
100
150
200
Rt
0
1
2
3
4
50%
95%
Netherlands: Model2
Daily number of infections
0
10000
20000
30000
10 Feb
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
50
100
150
200
Rt
0
1
2
3
4
5
50%
95%
Netherlands: Model3
Daily number of infections
0
10000
20000
30000
40000
10 Feb
17 Feb
24 Feb
2 Mar
9 Mar
16 Mar
23 Mar
30 Mar
6 Apr
13 Apr
20 Apr
27 Apr
4 Maj
Daily number of deaths
0
50
100
150
200
Rt
0
2
4
6
50%
95%





Reproducibility

Report git hash:

```
## 4473e0191f3b40756192ec0cf1bac62b027dbc78
```