

Prediction of age-structured model for SARS-CoV-2 in Seoul and Gyeonggi

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Data

1. Daily confirmed cases in Seoul and Gyeonggi
2. Vaccine
 - ▶ Daily number of vaccination for 1st dose (by age)
 - ▶ Daily number of vaccination for 2nd dose (by age)
 - ▶ Vaccine efficacy
3. Proportion of δ variant

Data processing

1. Daily number of vaccination for 1st dose (all ages)

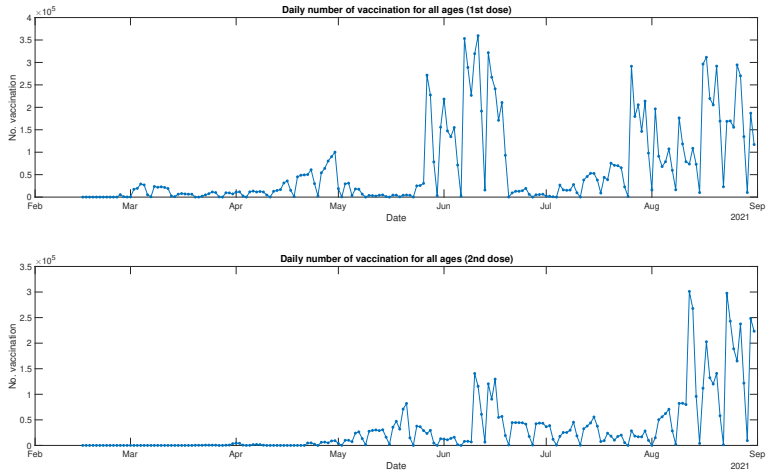


Figure 1: The daily number vaccination for 1st dose and 2nd dose from 2021/02/15 to 2021/09/01

Data processing

1. Daily number of vaccination for 1st dose (by age)

- ▶ The daily number of vaccination by age is generated by the ratio between ages of vaccinated people.
- ▶ The ratio is based on KDCA reports.

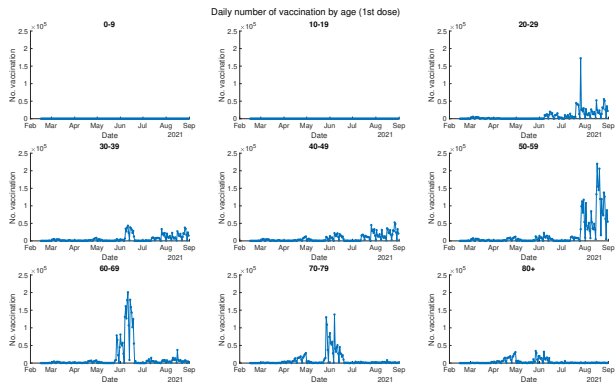


Figure 2: The daily number vaccination for 1st dose by age from 2021/02/15 to 2021/09/01

Data processing

2. Daily number of vaccination for 2nd dose (by age)

- ▶ The daily number of vaccination by age is generated by the ratio between ages of vaccinated people.
- ▶ The ratio is based on KDCA reports.

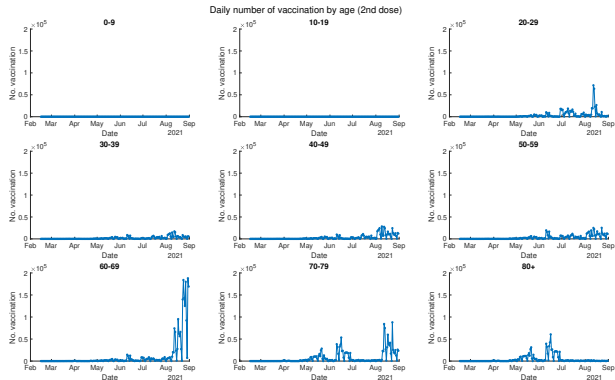


Figure 3: The daily number vaccination for 2nd dose by age from 2021/02/15 to 2021/09/01

3. Vaccine efficacy

- ▶ The vaccine efficacies for α variant and δ variant are different.¹
- ▶ We use weighted sum of vaccine efficacies where weights are based on proportion of δ variant

	Dose	Astrazeneca	Pfizer
α variant	1st dose	48.7%	47.5%
	2nd dose	74.5%	93.7%
δ variant	1st dose	30.0%	35.6%
	2nd dose	67%	88%

Table 1: The vaccine efficacies according to the vaccine type, variant and dose.

¹Jamie Lopez Bernal et al. (2021). “Effectiveness of Covid-19 vaccines against the B. 1.617. 2 (Delta) variant”.
In: *New England Journal of Medicine*

3. Vaccine efficacy

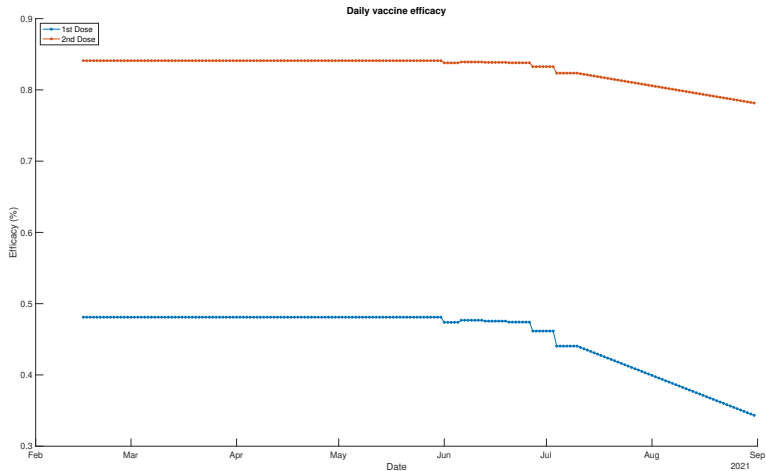


Figure 4: The estimated daily vaccine efficacy for 1st dose and 2nd dose.

4. Proportion of δ variant

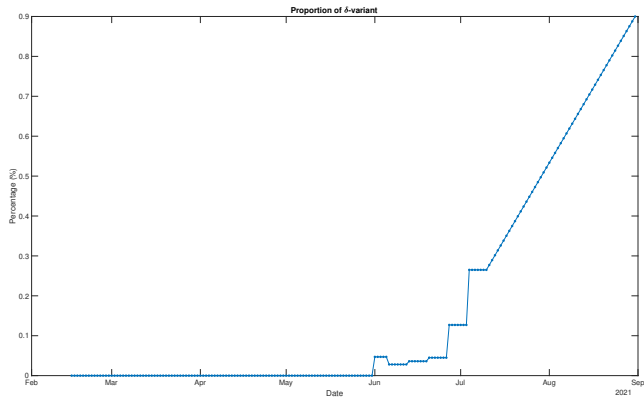
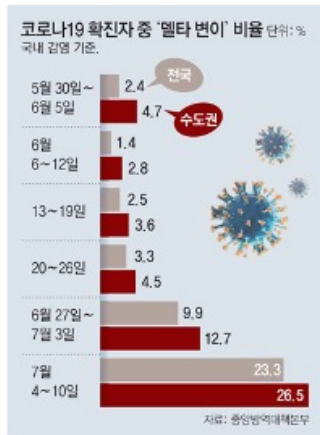


Figure 5: Estimates of proportion of δ variant.

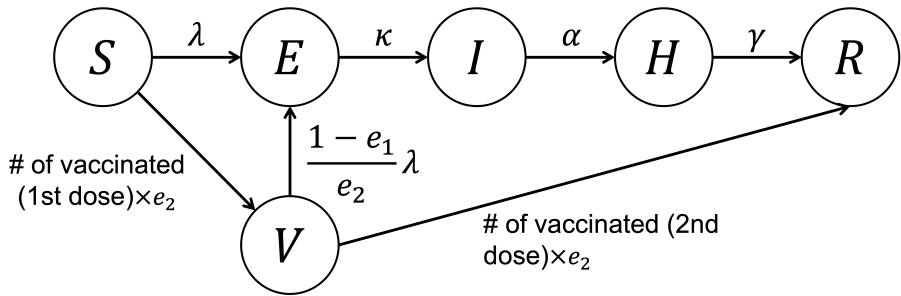


Figure 6: Diagram of age-structured model for SARS-CoV-2.

Notation	Interpretation
S	Susceptibles
E	Exposed
I	Infectious
H	Hospitalized
R	Removed (or recovered)
V	Vaccinated (between 1st dose and 2nd dose)
λ	Force of infection
κ	Latent period
α	Infectious period
γ	Hospitalization period
e_1	Vaccine efficacy for 1st dose
e_2	Vaccine efficacy for 2nd dose

Table 2: Definition of states and parameters.

Social distance level

- ▶ 0.5단계 감소: transmission rate 전단계 대비 41.61% 증가
- ▶ 0.5단계 증가: transmission rate 전단계 대비 30% 감소

Date	Social distancing level	Change of transmission rate
2021/02/15-2021/06/30	2	
2021/07/01-2021/07/11	1.5	$\beta \times 1.4161$
2021/07/12-2021/09/26	Assumed as 2	$\beta \times 1.4161 \times 0.699$
2021/09/27-2021/12/31 ²	-	-

Table 3: The change of transmission rate according to the social distancing level from 2021/02/15 to 2021/09/01.

²It will be changed according to the experiments.

School opening effect

- ▶ The school opening effect only affects the contact rate between teenagers.
- ▶ We assumed that the contact number of teenagers reduces by 85.86%.
- ▶ We assumed that the school opening effect is applied since 2021/09/02.

Assumption	Increment of contact rate (%)
원격수업	0
33% 등교	91.95
50% 등교	165.93
66% 등교	268.44
전면 등교	607.21

Table 4: The increment of contact rate of teenagers for the corresponding assumptions.

Definition of λ

Motivation

- ▶ In general, $\lambda(t)$ is defined by $W \times I(t)$ where W is the WAIFW matrix, and $I(t)$ is the number of infectious at time t .
- ▶ To reflect the non-pharmaceutical intervention, we consider time-dependent $W(t)$.

Definition of WAIFW matrix

Let $p(t)$ and $SD(t)$ be the proportion of δ variant and proportionate of the corresponding social distancing level at time t . Let $C(t)$ be the contact rate at time t .

- ▶ $W(t) = ((1 - p(t) + p(t)\delta) \times \beta \times SD(t) \times C(t)$

Order of experiment

		School opening				
		원격수업	33% 등교	50% 등교	66% 등교	전면 등교
SD ³	2단계	1	2	3	4	5
	1.5단계	6	7	8	9	10

Table 5: The experiment numbers according to the social distancing level and school opening.

³Abbreviation of "Social Distancing".

Parameter estimation results

► $\hat{\beta} = 0.0432$

Parameter	Initial	Estimate
δ	1.0000e+00	1.2532e+00
Cost	1.9417e+04	1.2841e+04
Time	0.0000e+00	2.6832e+01

Table 6: Parameter estimates obtained by maximum likelihood estimation.

Parameter estimation results

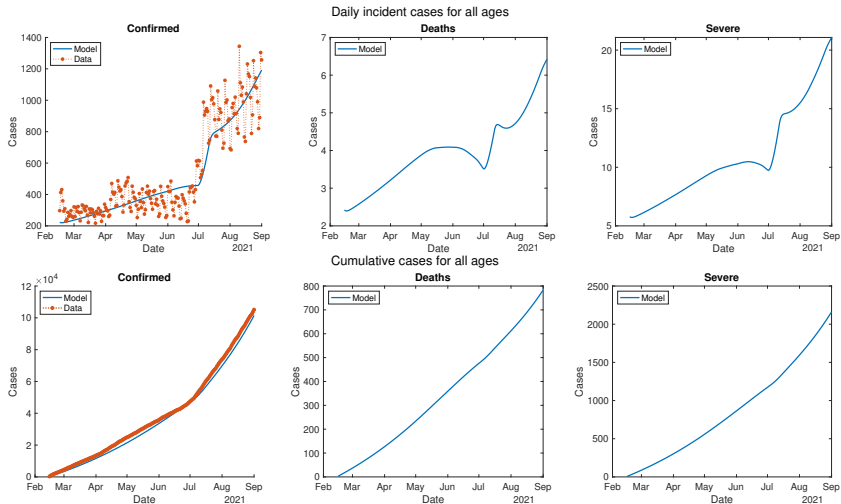


Figure 7: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Parameter estimation results

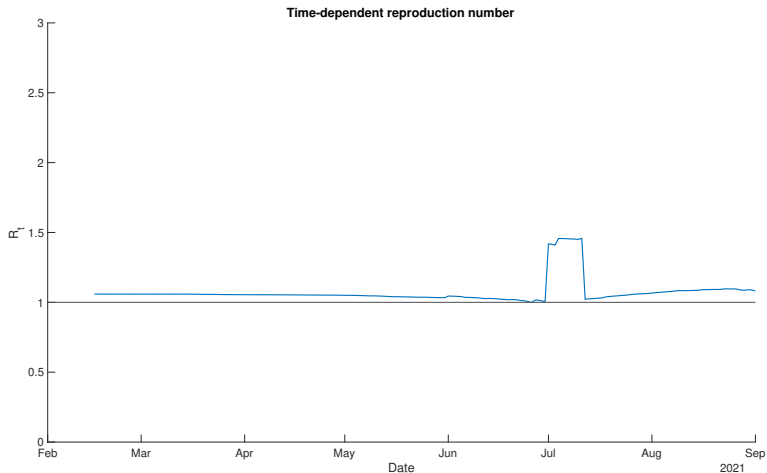


Figure 8: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 1

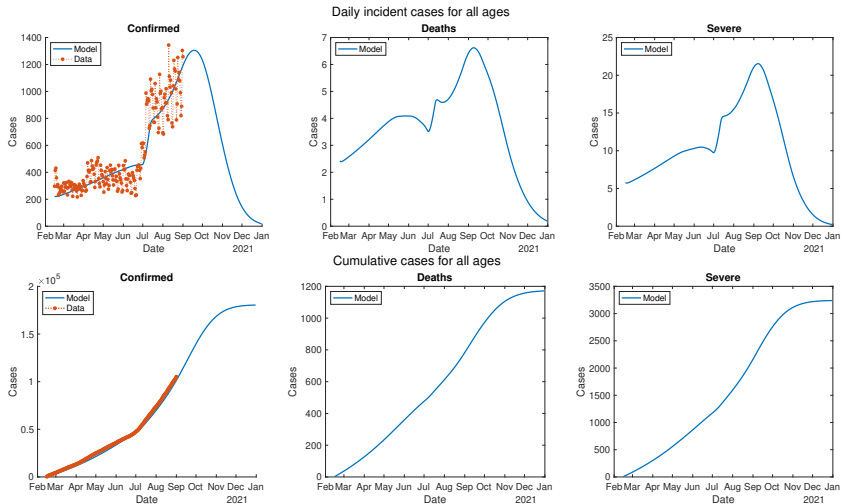


Figure 9: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 1

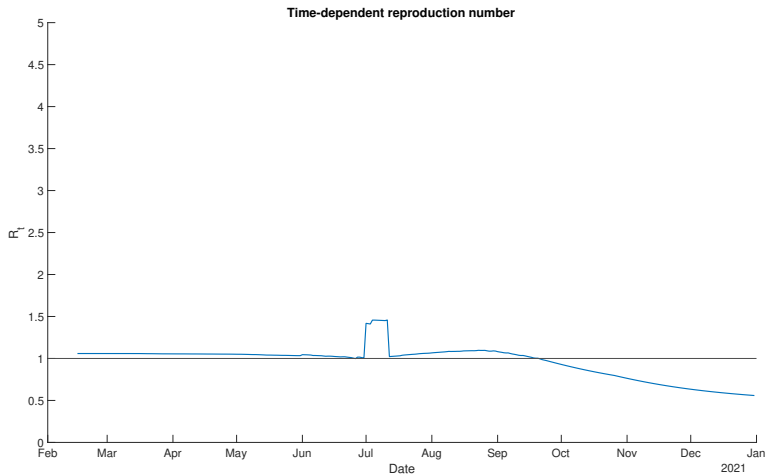


Figure 10: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 2

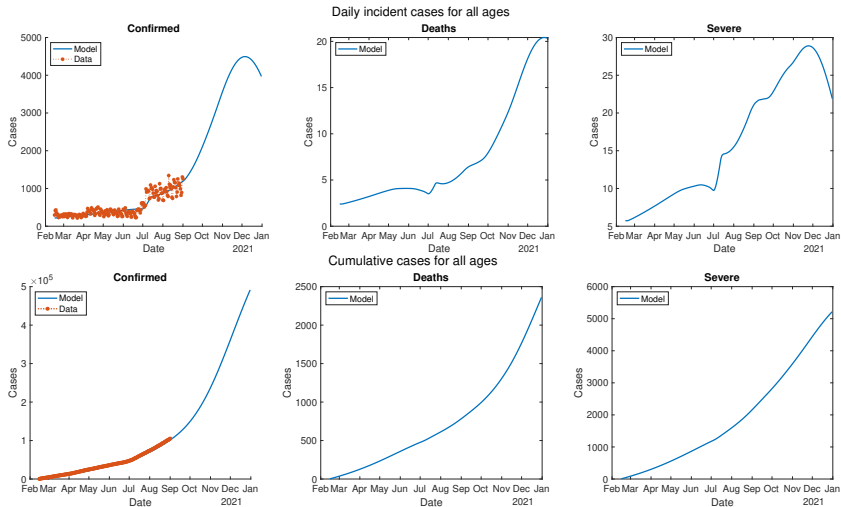


Figure 11: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 2

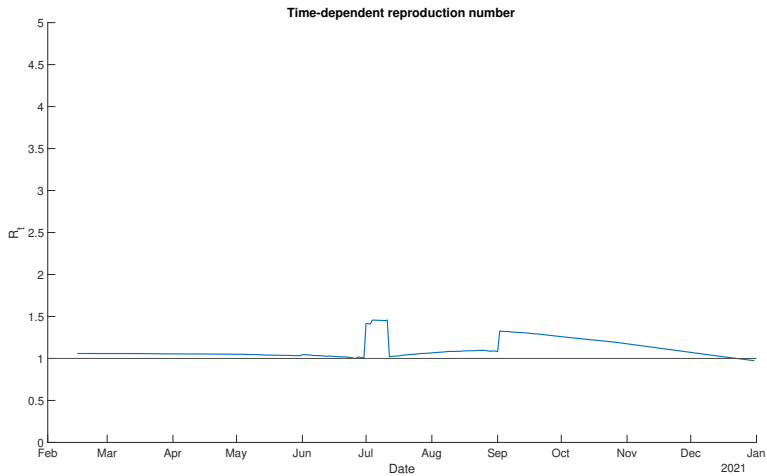


Figure 12: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 3

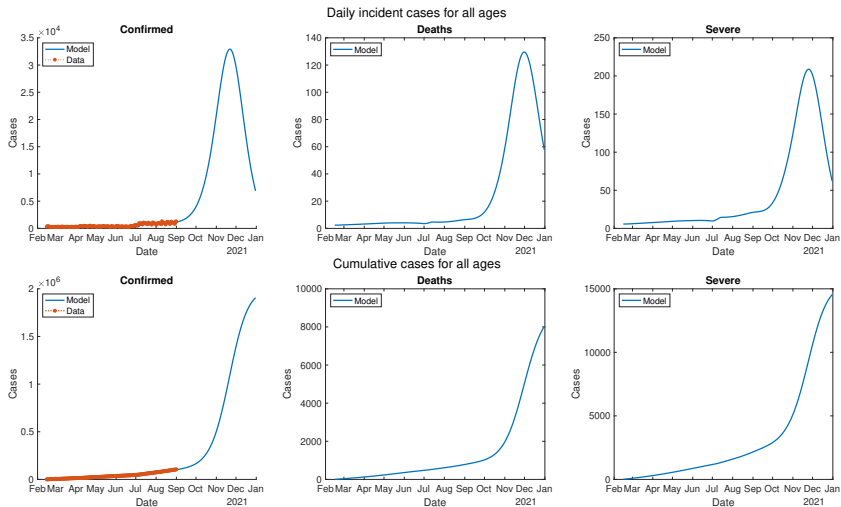


Figure 13: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 3

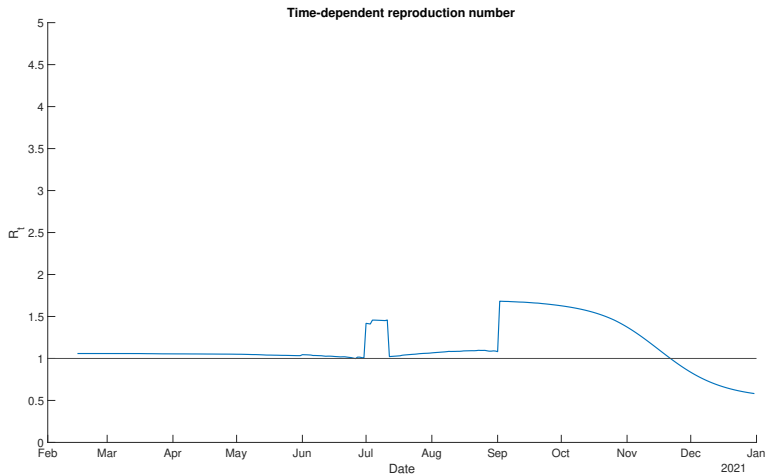


Figure 14: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 4

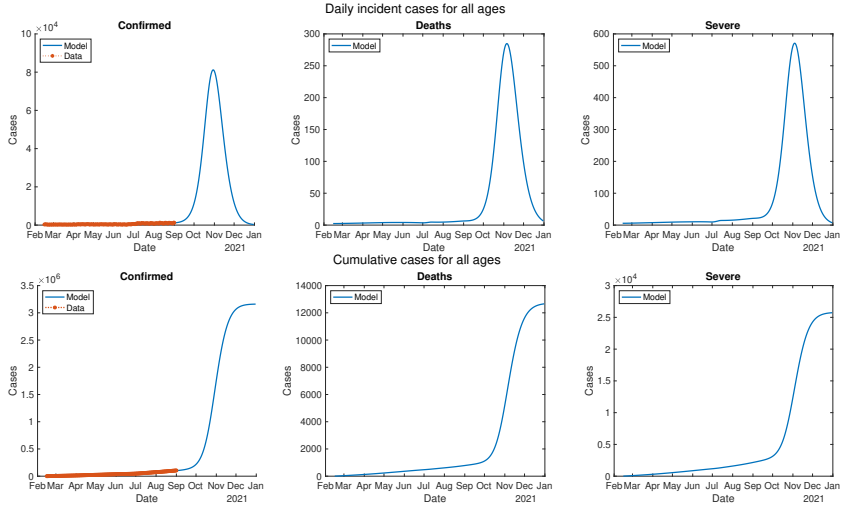


Figure 15: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 4

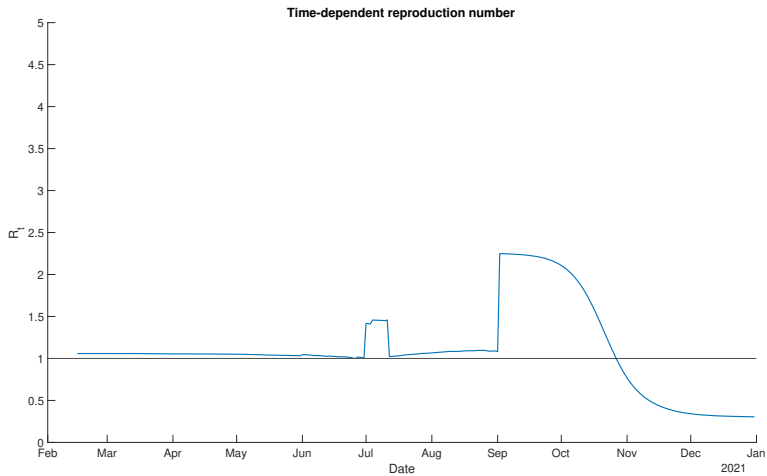


Figure 16: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 5

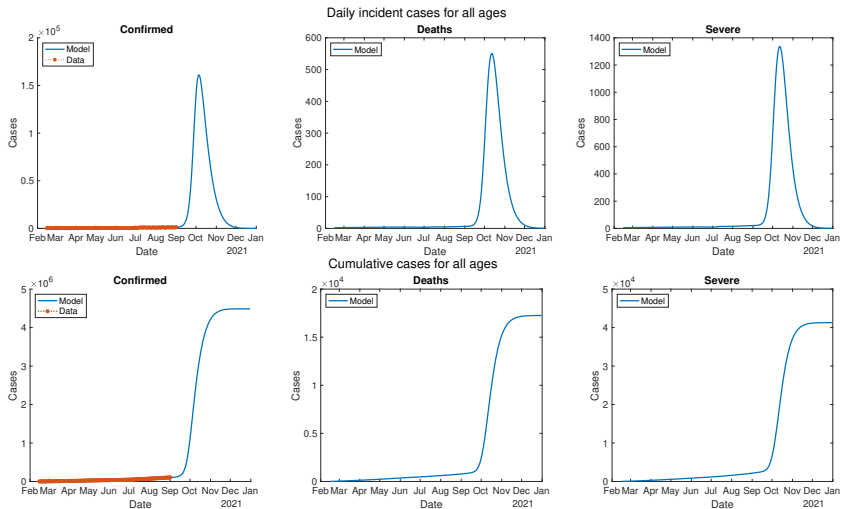


Figure 17: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 5

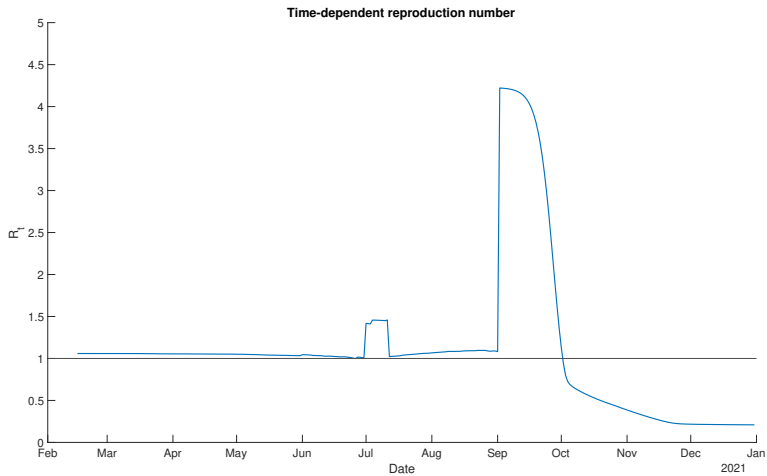


Figure 18: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 6

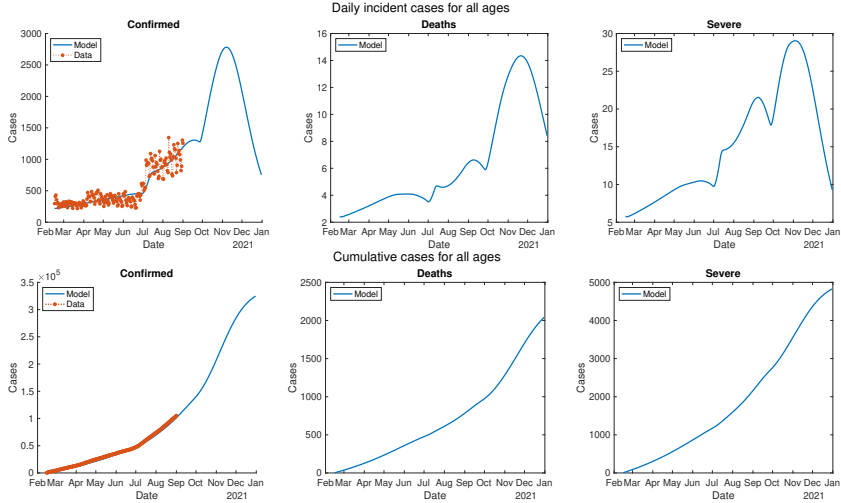


Figure 19: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 6

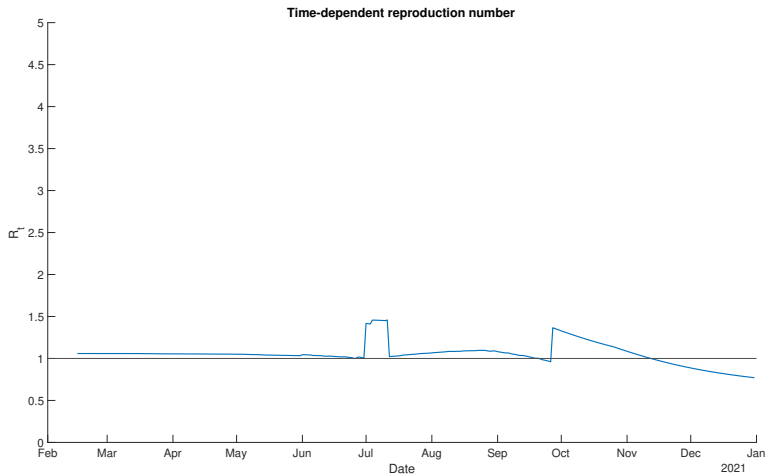


Figure 20: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 7

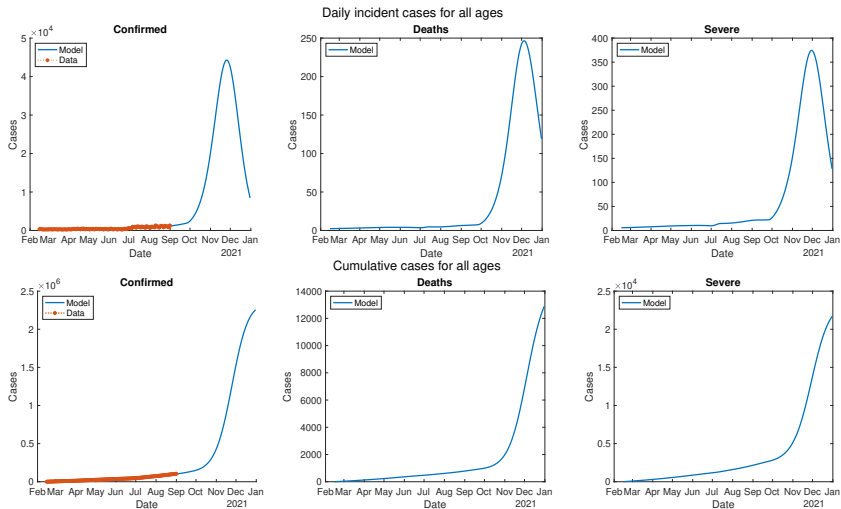


Figure 21: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 7

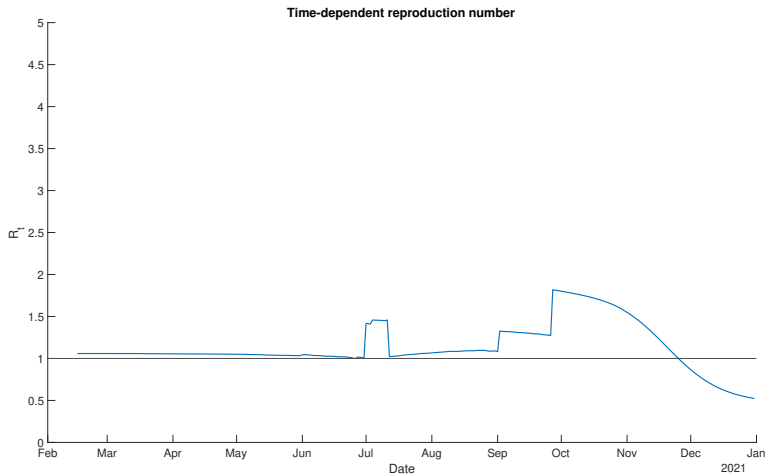


Figure 22: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 8

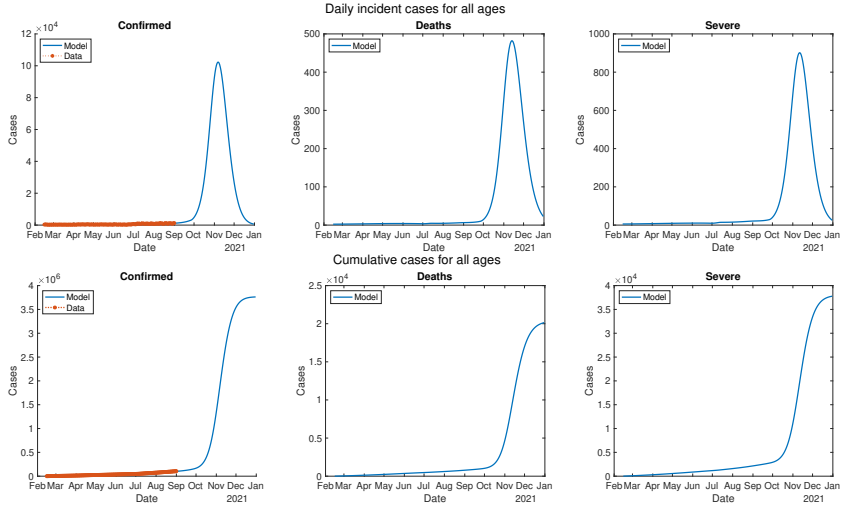


Figure 23: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 8

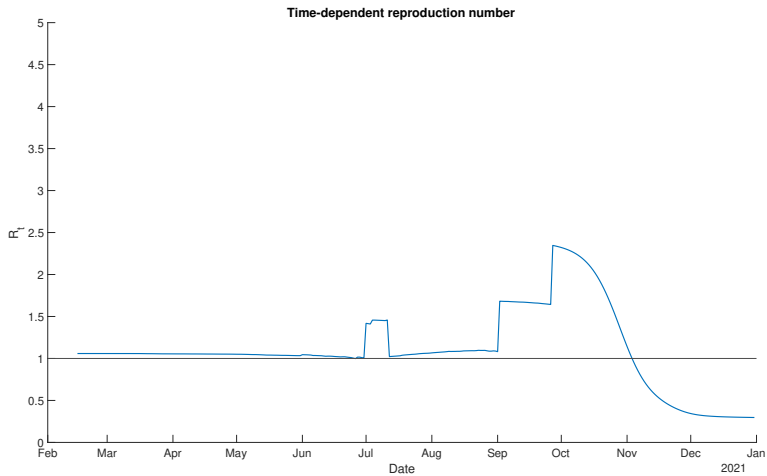


Figure 24: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 9

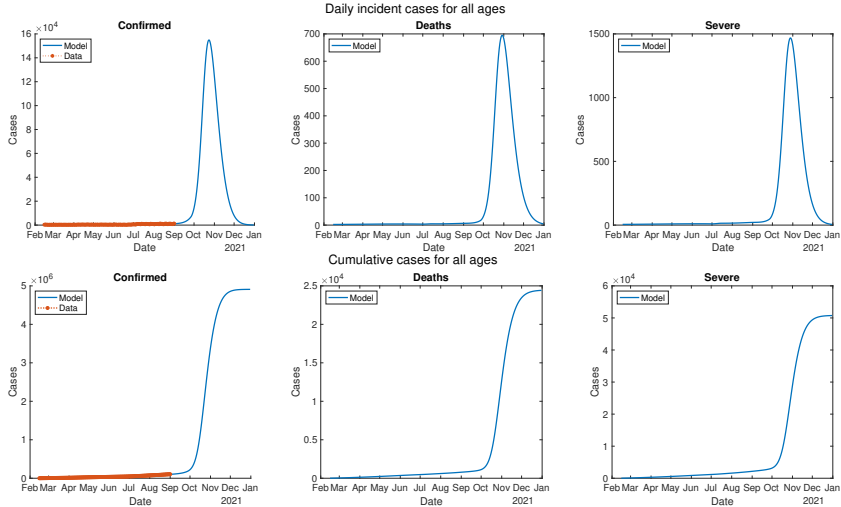


Figure 25: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 9

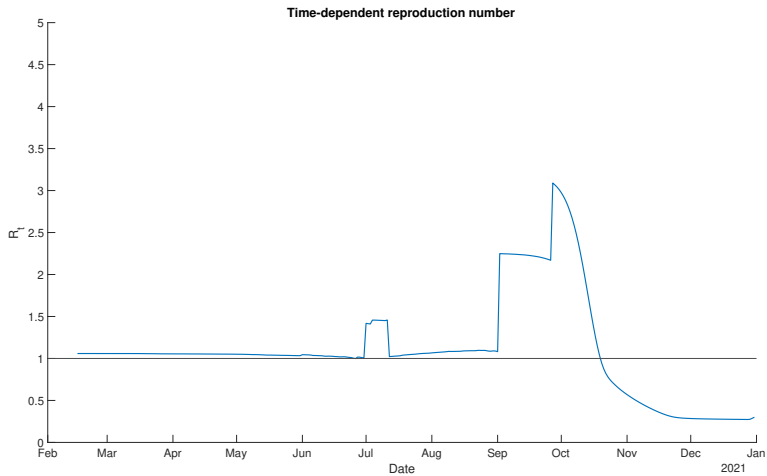


Figure 26: The estimated reproduction number from 2021/02/15 to 2021/09/01.

Experiment 10

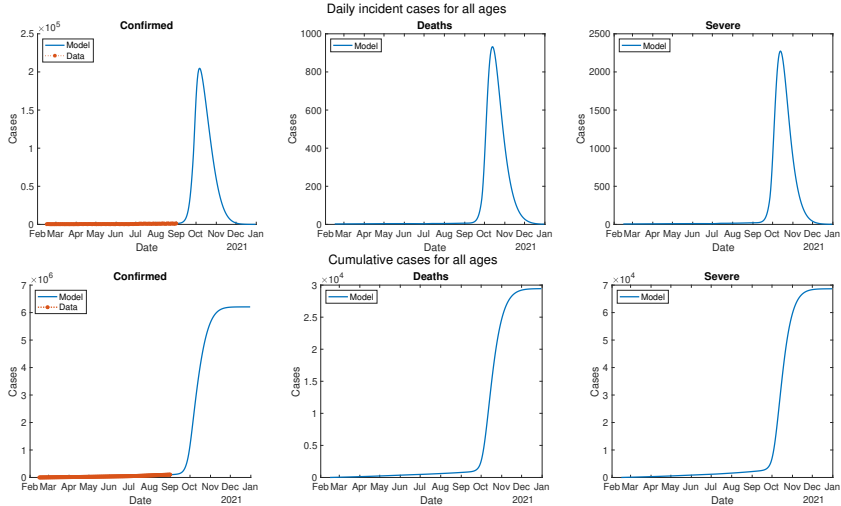


Figure 27: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 10

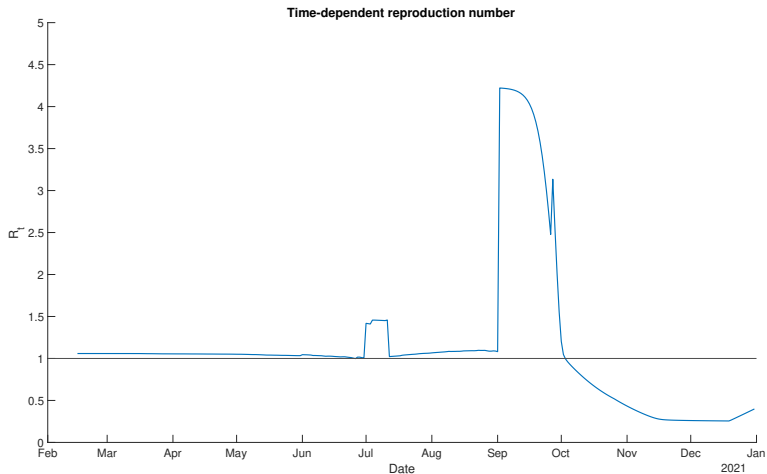


Figure 28: The estimated reproduction number from 2021/02/15 to 2021/09/01.