Parameter estimation 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)

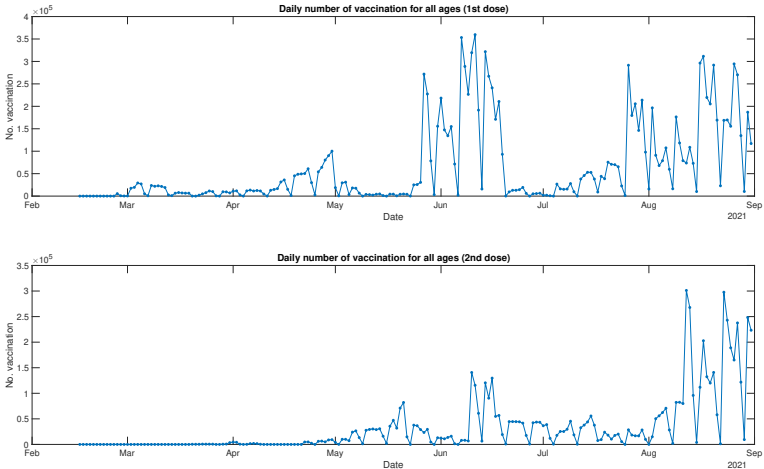


Figure 1: The daily number vaccination for 1st dose and 2nd dose from 2021/02/15 to 2021/08/31

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.

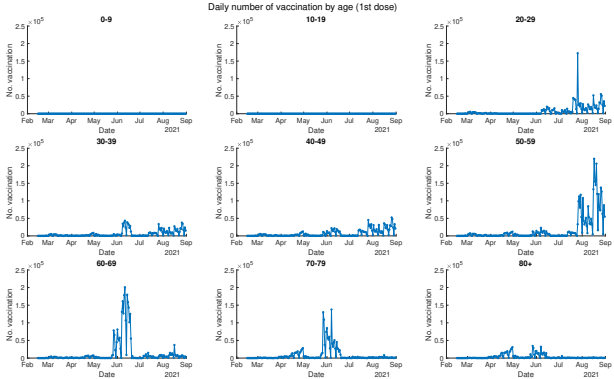


Figure 2: The daily number vaccination for 1st dose by age from 2021/02/15 to 2021/08/31

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.

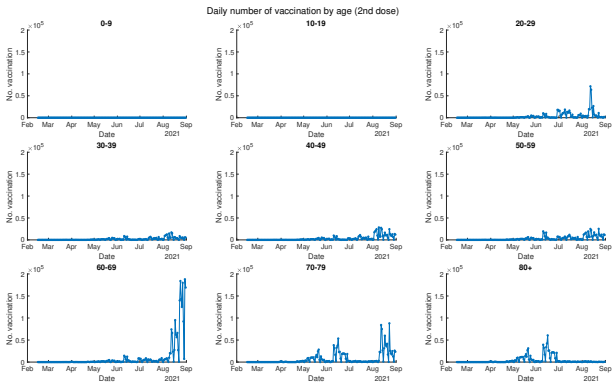


Figure 3: The daily number vaccination for 2nd dose by age from 2021/02/15 to 2021/08/31

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

		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%

[1] Jamie 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

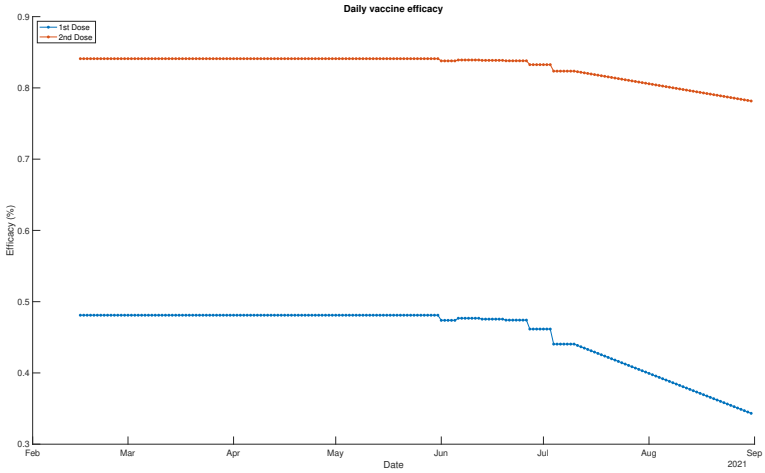
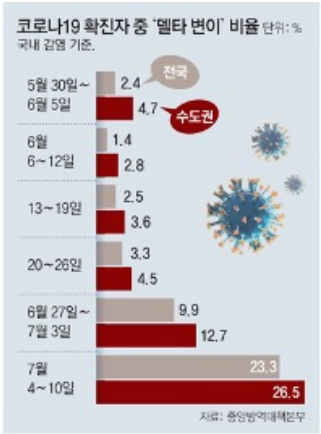


Figure 4: The estimated daily vaccine efficacy for 1st dose and 2nd dose.

4. Proportion of δ variant



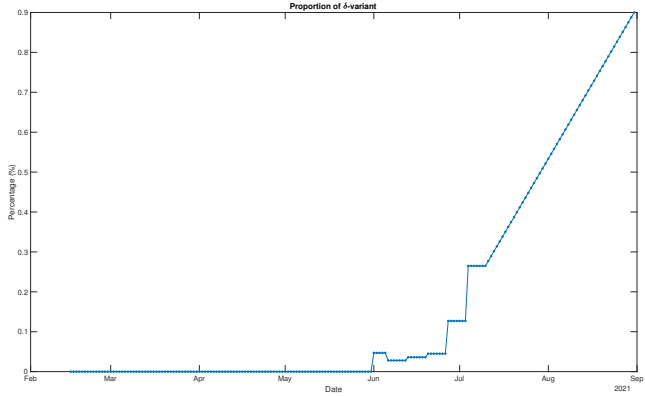


Figure 5: Estimates of proportion of δ variant.

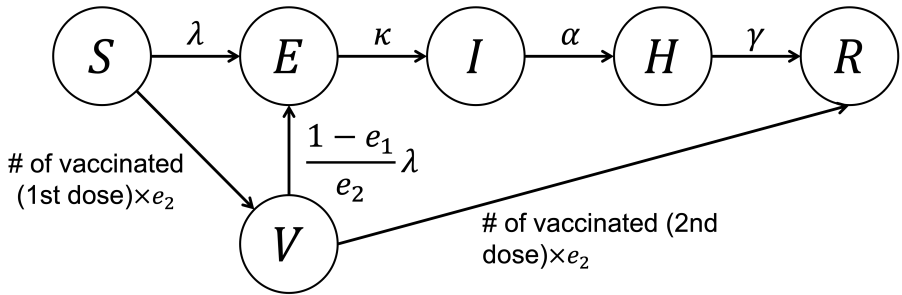


Figure 6: Diagram of age-structured model for SARS-CoV-2.

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 1: Definition of states and parameters.

Social distance level

- 0.5단계 감소: transmission rate 전단계 대비 68.5% 증가
- 0.5단계 증가: transmission rate 전단계 대비 33% 감소
- 1단계 증가: transmission rate 전단계 대비 67% 감소

Date	Social distancing level	Change of transmission rate
2021/02/15-2021/06/30	2	
2021/07/01-2021/07/11	1.5	$\times 1.685$
2021/07/12-2021/08/31	4 (assumed as 3)	$\times 0.67 \times 0.33$

Table 2: The change of transmission rate according to the social distancing level from 2021/02/15 to 2021/08/31.

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 $W(t)$.

Experimental setting

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

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

Experiment 1: Estimates

Parameter estimation

- Method: Maximum likelihood estimation
- Assumption: Poisson distributed data
- $\hat{\beta} = 0.0432$ (similar to 상용 & 지연's estimate: 0.0486)

Parameter	Initial	Estimates
δ	7.0000e+00	7.9462e+00
Cost	8.4372e+04	6.1147e+04
Time	0.0000e+00	2.0194e+01

Table 3: The estimated parameters using maximum likelihood estimation.

Experiment 1: Fitting

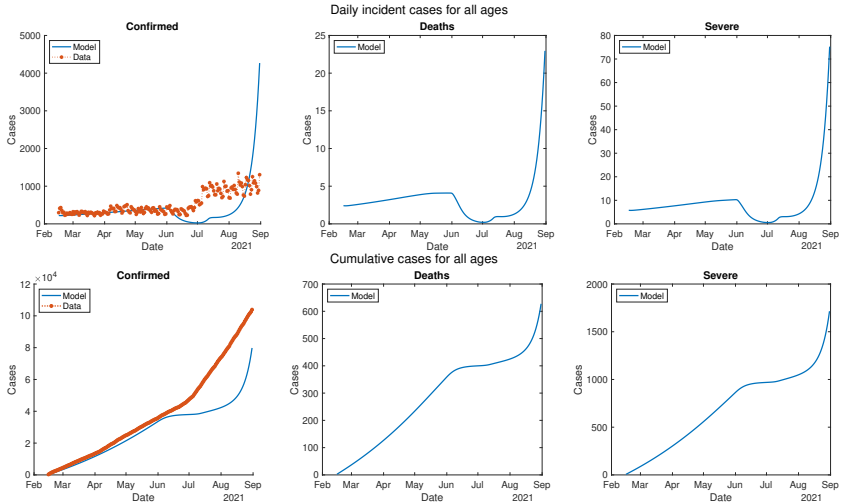


Figure 7: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 1: Reproduction number

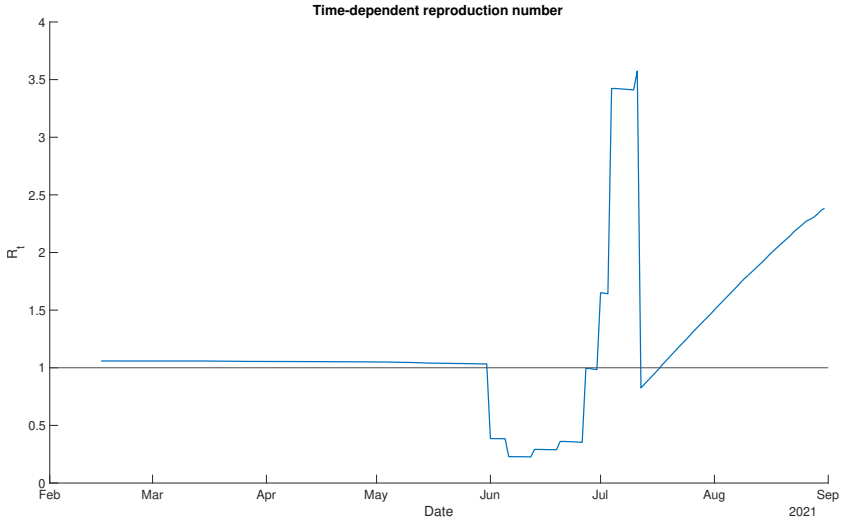


Figure 8: The estimated reproduction number from 2021/02/15 to 2021/08/31

Experiment 2: Estimates

Parameter estimation

- Method: Maximum likelihood estimation
- Assumption: Poisson distributed data
- $\hat{\beta} = 0.0432$ (similar to 상용 & 지연's estimate: 0.0486)

Parameter	Initial	Estimates
δ	7.0000e+00	2.9559e+00
Cost	3.3889e+05	2.2129e+04
Time	0.0000e+00	2.2411e+01

Table 4: The estimated parameters using maximum likelihood estimation.

Experiment 2: Fitting

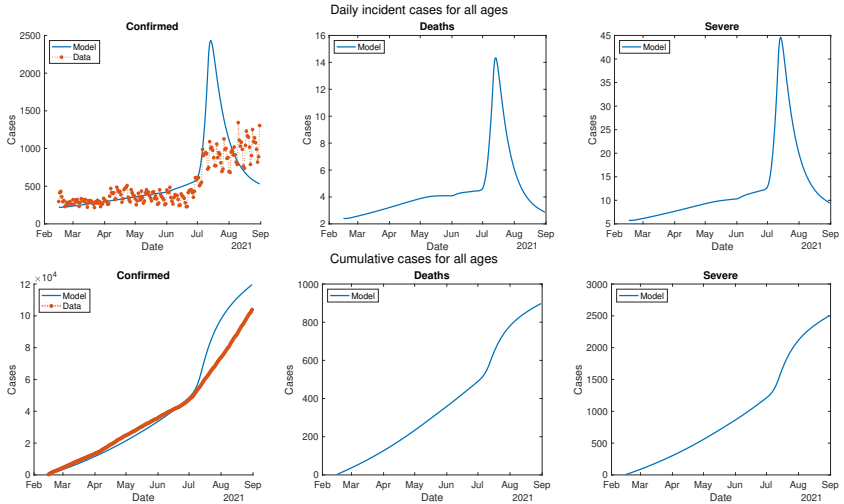


Figure 9: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 2: Reproduction number

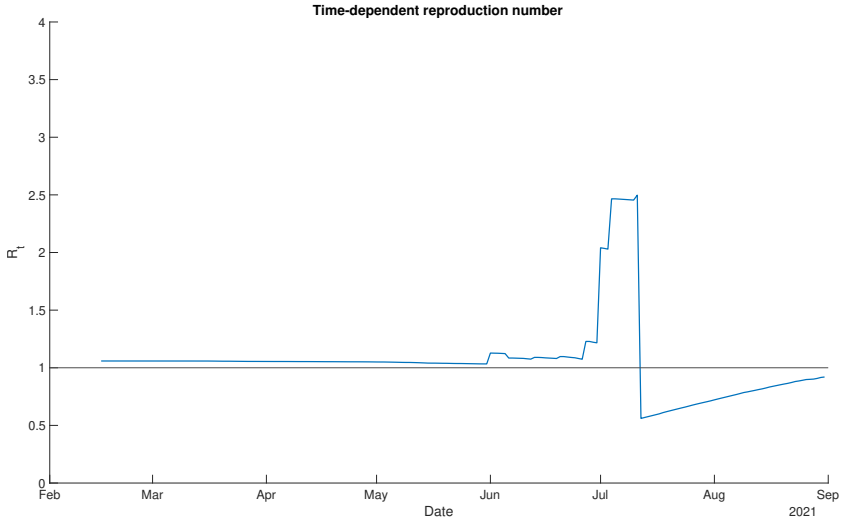


Figure 10: The estimated reproduction number from 2021/02/15 to 2021/08/31

Experiment 3: Estimates

Parameter estimation

- Method: Maximum likelihood estimation
- Assumption: Poisson distributed data
- $\hat{\beta} = 0.0432$ (similar to 상용 & 지연's estimate: 0.0486)

Parameter	Initial	Estimates
δ	7.0000e+00	1.4531e+00
Cost	3.1808e+05	1.5308e+04
Time	0.0000e+00	1.9765e+01

Table 5: The estimated parameters using maximum likelihood estimation.

Experiment 3: Fitting

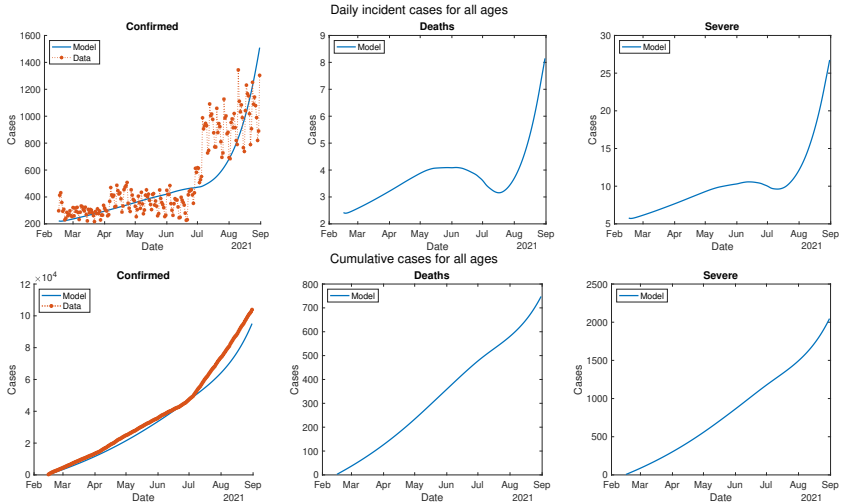


Figure 11: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

Experiment 3: Reproduction number

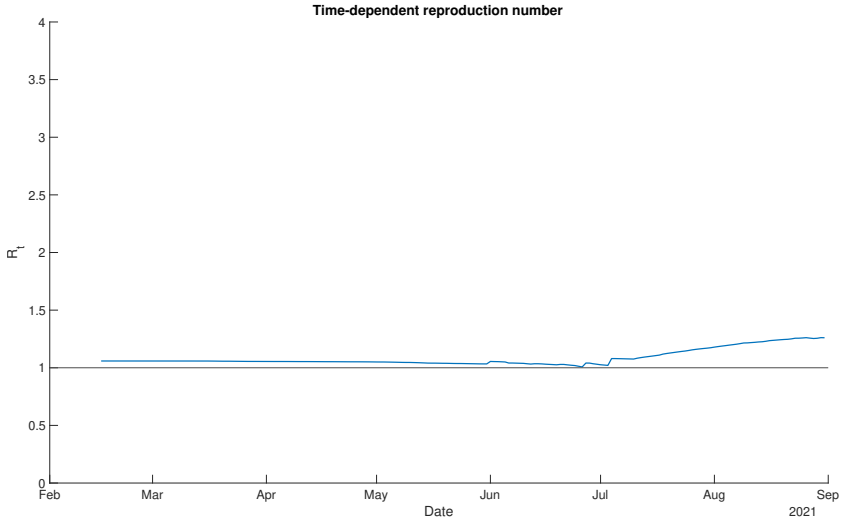


Figure 12: The estimated reproduction number from 2021/02/15 to 2021/08/31

Conclusions

- In Experiment 1, the model prediction for daily confirmed cases grows exponentially.
- In Experiment 2, the model prediction for daily confirmed cases increases drastically in July because of the increased δ effect and weak social distance stage (stage 1.5).
- In Experiment 2, the model prediction for daily confirmed cases decrease drastically in mid-July because of the strong social distance stage (stage 4).
- In Experiment 3, the social distancing effect is removed and it shows the best fits compared to the previous experiments.