Modelling the impact of vaccination, mask policies and mobility on the COVID-19 pandemic in Singapore

CSE 8803 Project Presentation

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CONTENT

Part 01
Introduction

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Vaccination, mask policies and mobility

- The outbreak of a new crown outbreak depends on many factors, among which human influences include population mobility pat- terns, mask prevalence, and vaccination rates.

Part 01
Introduction

Singapore outbreaks

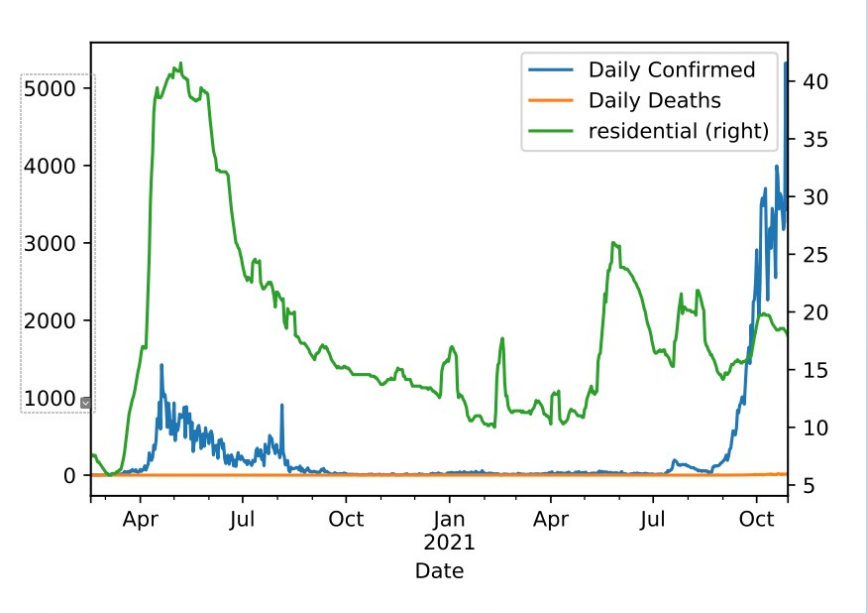
- First outbreak
  - No available vaccines
  - Very strict policies
- Second outbreak
  - 90% fully vaccinated
  - Relatively loose policies

- More effective prevention strategies to achieve successful protests
- Verify whether our research model is reasonable through data to achieve the purpose of accurately predicting the future trend of the epidemic.

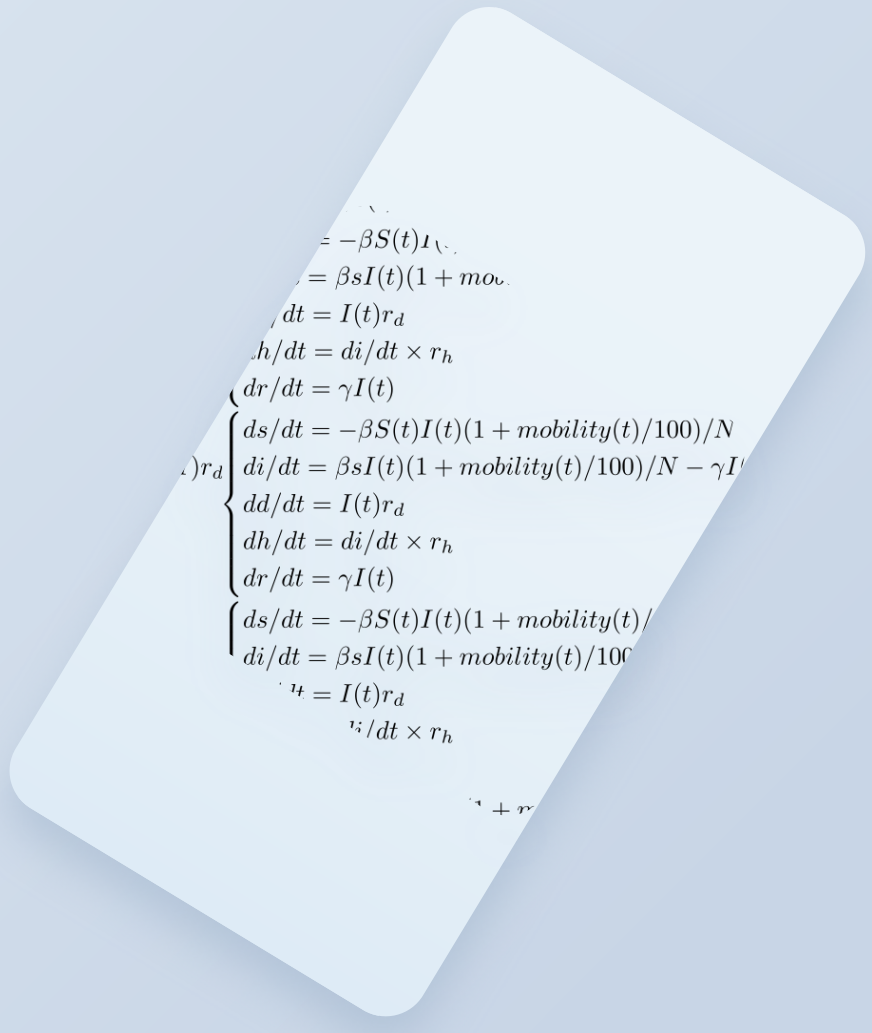
Part 01
Introduction

Data source

- COVID-19 cases/deaths/vaccines: comes from data.world
- Epidemiology & Demographics: built in covasim
- Mobility: We use Google Community Mobility Reports as the indicator of mobility.
- Policy: We use mask policy indicator, which is categorized into five categories



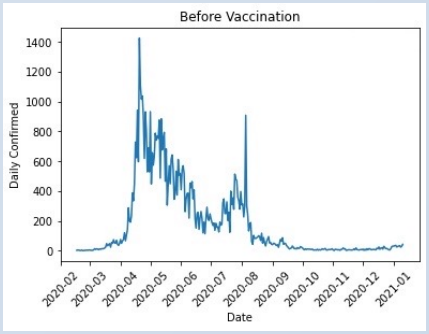
Part 02
ODE Model

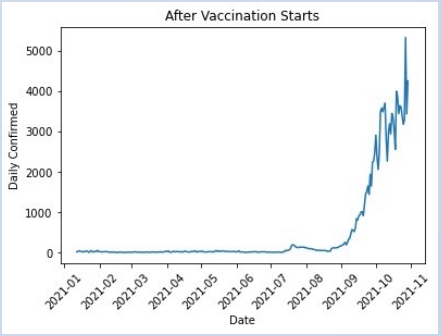


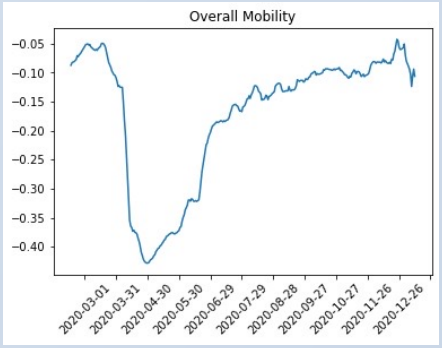
Part 02
ODE Model

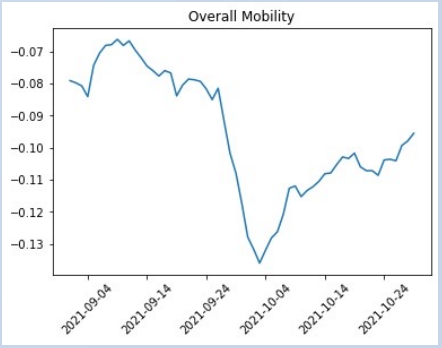
Background & Domain Research

- Two outbreaks
  - Before vaccination: May 2020
  - After vaccination: September 2021
- Need to integrate the influence of policy into ODE model.









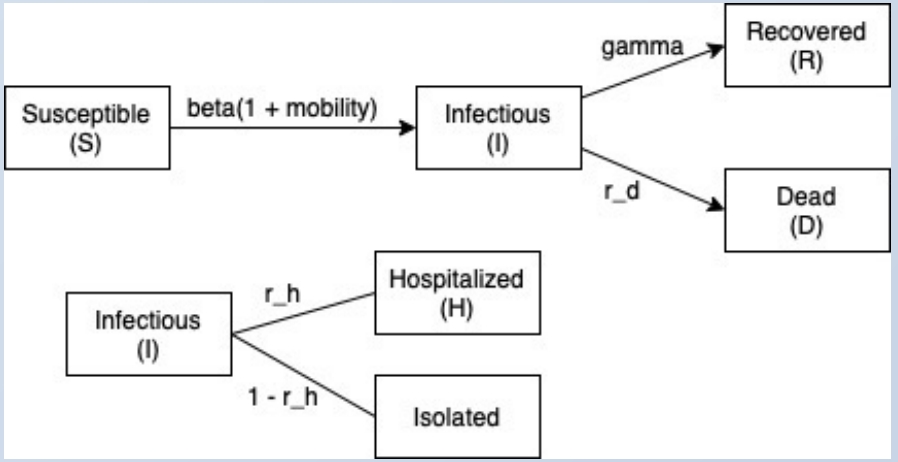
Part 02
ODE Model

Model description

- ODE equations

$$\begin{cases} ds/dt = -\beta S(t)I(t)(1 + mobility(t)/100)/N \\ di/dt = \beta sI(t)(1 + mobility(t)/100)/N - \gamma I(t) - (I)r_d \\ dd/dt = I(t)r_d \\ dh/dt = di/dt \times r_h \\ dr/dt = \gamma I(t) \end{cases}$$

- Flow diagram of this SIR model
- Input Data
  - S = Population - I - R
  - I = Intensive Care Unit (ICU) + General Wards + In Isolation
  - R = Cumulative Confirmed - Cumulative Death - I



Part 02
ODE Model

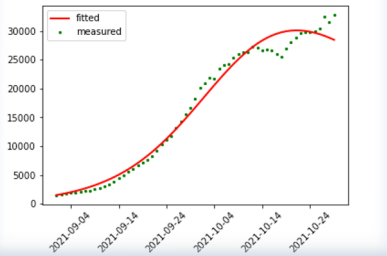
Data fitting

- Initial attempt (X)
  - MaxiR = Cumulative Confirmed - Cumulative Death - I

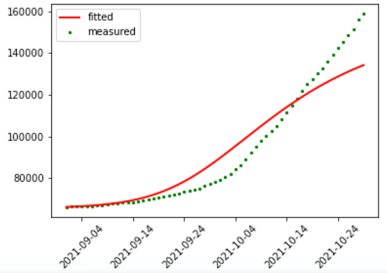
$$error = \sum_{t} \{(St_m - St_f)^2 + (It_m - It_f)^2 + (Rt_m - Rt_f)^2 + (Dt_m - Dt_f)^2\}^{1/2}$$

- Using an iterative way to fitting multiple curves
- Manually set the initial value of S state

```
[[Fit Statistics]]
    # fitting method   = leastsq
    # function evals   = 61
    # data points      = 59
    # variables        = 4
    chi-square         = 1.3549e+08
    reduced chi-square = 2463516.47
    Akaike info crit   = 872.166869
    Bayesian info crit = 880.477019
##  Warning: uncertainties could not be estimated:
    k2:  at initial value
[[Variables]]
    s:   90000 (fixed)
    i:   1523 (fixed)
    d:   55 (fixed)
    h:   499 (fixed)
    r:   66222 (fixed)
    k0:  0.18322830 (init = 0.1460235)
    k1:  0.04446609 (init = 0.1)
    k2:  0.08000000 (init = 0.08)
    k3:  1.0025e-04 (init = 0.00015667)
```



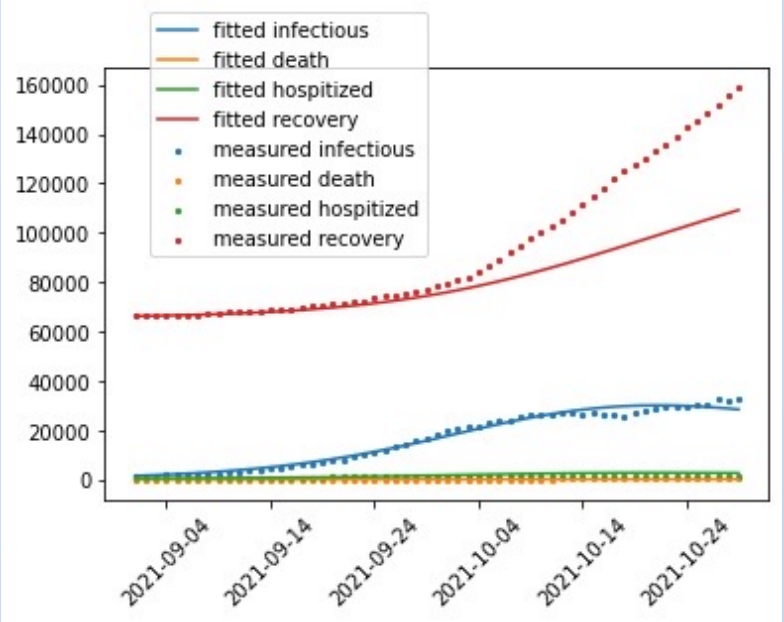

```
    chi-square         = 4.1471e+09
    reduced chi-square = 75401423.0
    Akaike info crit   = 1074.01981
    Bayesian info crit = 1082.32996
##  Warning: uncertainties could not be estimated:
    k2:  at initial value
    k2:  at boundary
    k3:  at boundary
[[Variables]]
    s:   90000 (fixed)
    i:   1523 (fixed)
    d:   55 (fixed)
    h:   499 (fixed)
    r:   66222 (fixed)
    k0:  0.26362917 (init = 0.1860235)
    k1:  0.05932823 (init = 0.1)
    k2:  0.20000000 (init = 0.2)
    k3:  1.0000e-05 (init = 0.00015667)
```



Part 02
ODE Model

Conclusion

- Beta
  - Before Vaccination: 0.44964359
  - After Vaccination:0.18322830
- Things need to be improved
  - Not fitting every curve as well
  - Value of S can’t reflect the fact



Part 03
Agent-based Model

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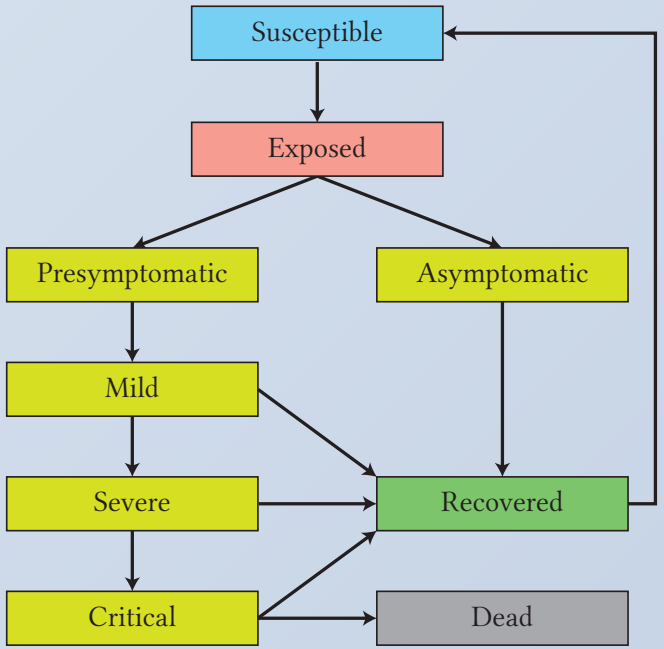
Agent-based Model

Disease progression

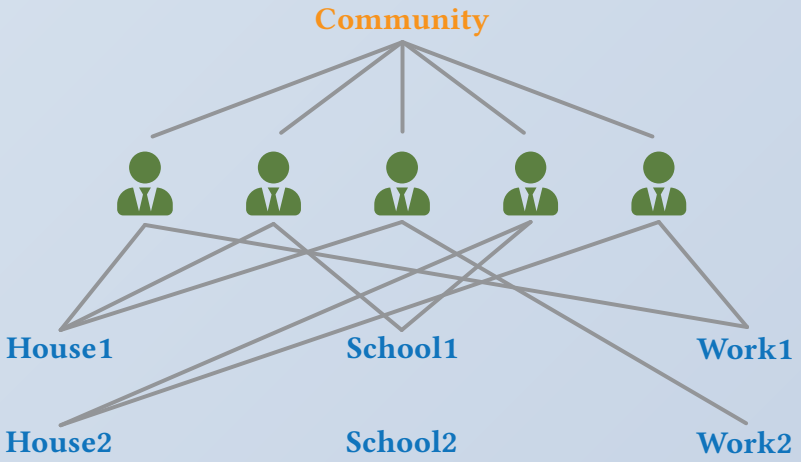
- Generalized SEIR model
- Each transformation is parameterized with a probability p and a duration τ
- Age-linked parameters are built -in in covasim



Part 03
Agent-based Model

Contact network

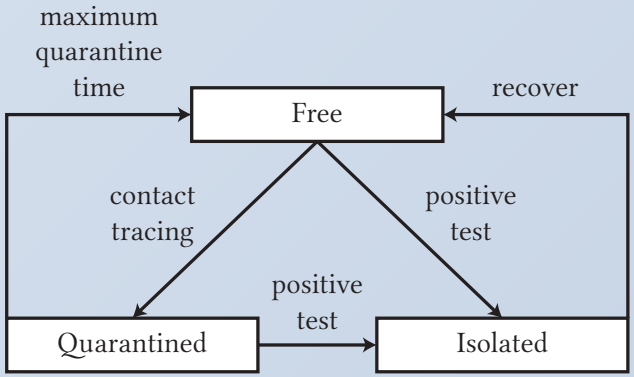
- Four contact networks:
  - Household
  - School
  - Work place
  - Community



Part 03
Agent-based Model

Agent states

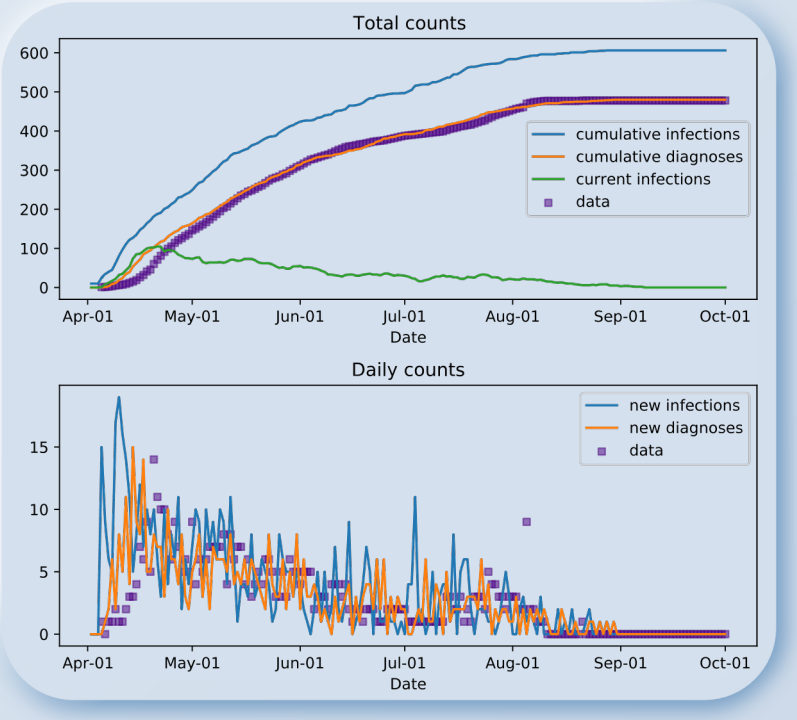
- Agents in different states have different beta values



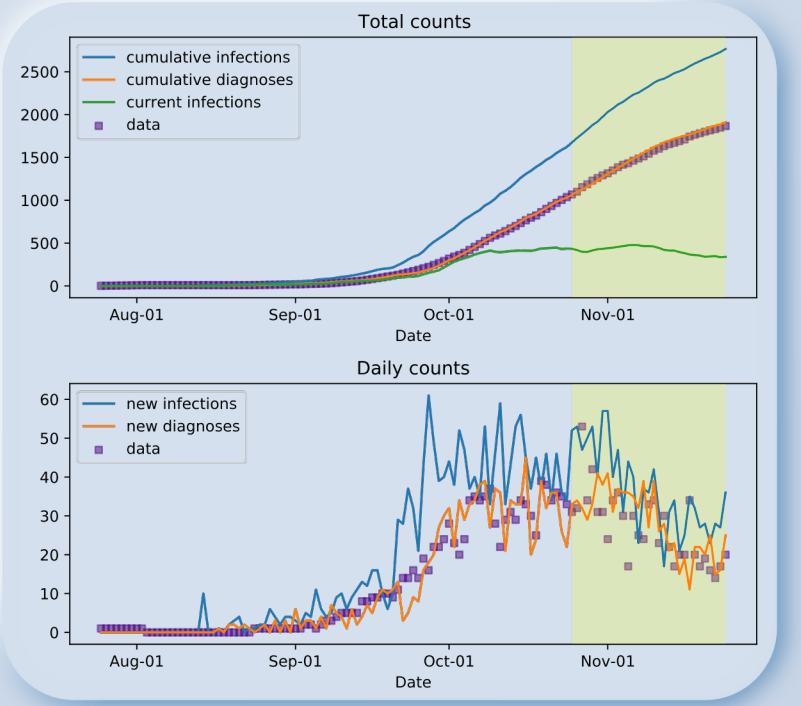
Part 03
Agent-based Model

Calibration results

First outbreak



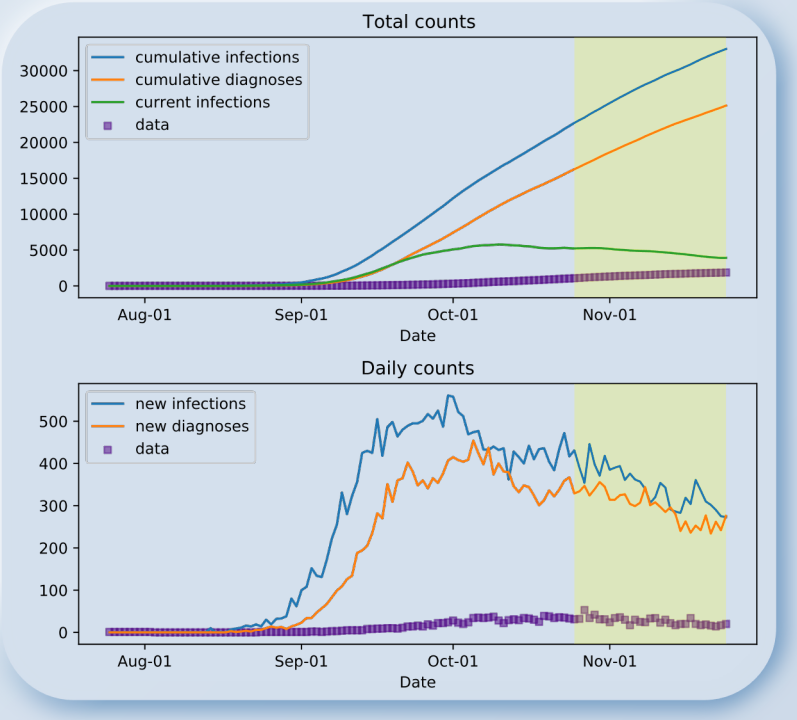
Second outbreak



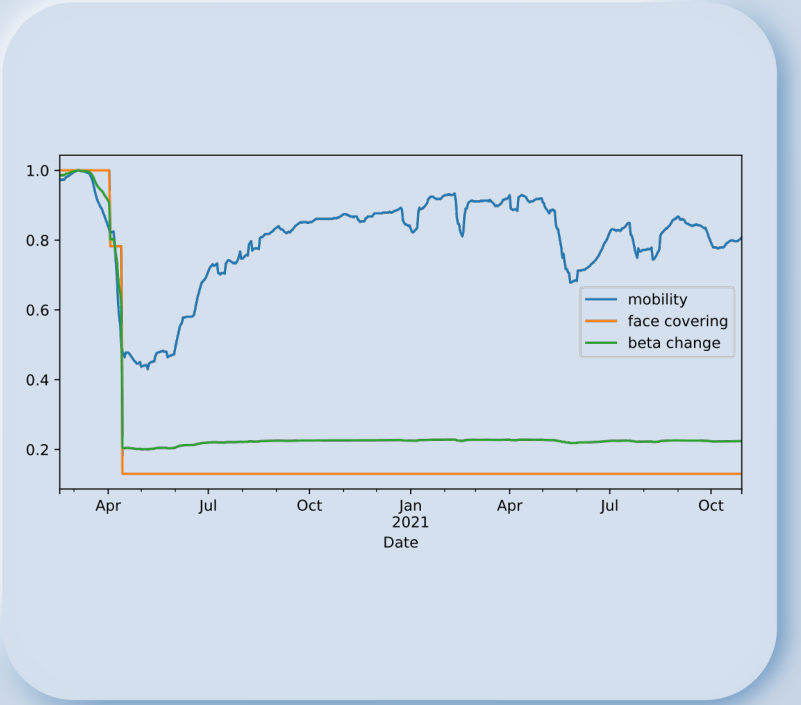
Part 03
Agent-based Model

Calibration results

Second outbreak without vaccination



Impact of mobility and policies



Thanks for Listening

-2021/12/07-

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Reference

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