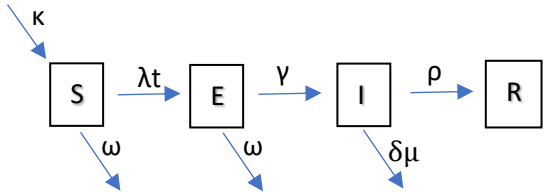
The estimated outcomes of COVID-19 epidemics with different effects of asymptomatic infectiousness in Wuhan, China

Background

In December, 2019, the SARS-Cov-2 virus emerged in Wuhan, China, and quickly swept across other provinces in China and other countries. The force of infectiousness from asymptomatic COVID-19-infected patients is still unknown. This study tried to project different COVID-19 epidemics under different scenarios of asymptomatic infectiousness with other parameters reflecting reality situation of pandemics in Wuhan, and try to estimate the true effect of asymptomatic infectiousness with the reference of reported case data in Wuhan.



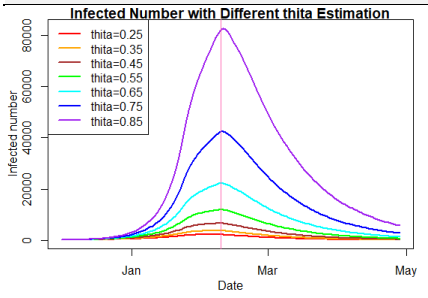
$$dS/dt = -\beta\big(I(t) + \theta E(t)\big)S(t) - \omega S(t) + \kappa S(t)$$
$$dE/dt = \beta\big(I(t) + \theta E(t)\big)S(t) - \gamma E(t) - \omega E(t)$$
$$dI/dt = \gamma E(t) - \rho I(t) - \delta\mu I(t)$$
$$dR/dt = \rho I(t)$$

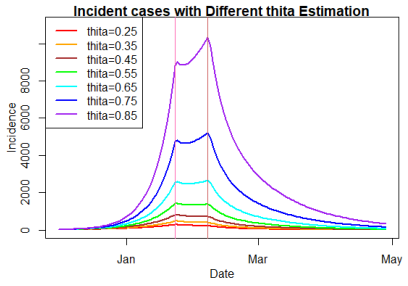
Method

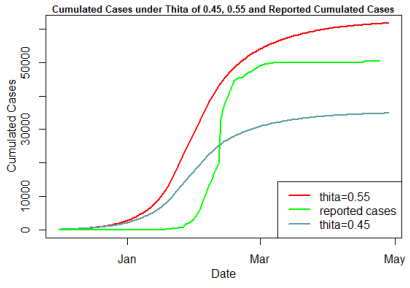
I constructed a deterministic susceptible-exposed-infected-recovered (SEIR) model, fitting the latest estimates of epidemic parameters from other literatures. Considering the comprehensive quarantine measures conducted in Wuhan, the basic reproductive number R_0 is respectively dropped at the time points of city shutdown and 2 weeks after. The total force of infection is dependent on both exposed(asymptomatic) and infected(symptomatic) population while the infectiousness from exposed is less than and fractional to infected (denoted as θ, estimated from 0.25 to 0.85). The model was run in 150 days, from December 1, 2019 to April 28, 2019.

Table: **Parameters of the susceptible-exposed-infected-recovered model**

Basic reproductive number, R_0	2.2 (2019-12-01 to 2020-01-23), 1.05 (2020-01-04 to 2020-02-07), 0.41 (after 2020-02-08)
Fraction of infectiousness acquired from asymptomatic compared with symptomatic, θ	0.25, 0.35, 0.45, 0.55, 0.65, 0.75, 0.85
Rate of infectious (reciprocal of incubation), γ	1/6.4 day^{-1}
Rate of recovery, ρ	1/12 day^{-1}
COVID19-spercific death rate, μ	1/16.1 day^{-1}
Proportion of severe patients, δ	0.35 (2019-12-01 to 2020-02-14), 0.2 (after 2020-02-15)
Daily proportion of population exported from Wuhan, ω	0.014(2019-12-01 to 2020-01-23), 0 (after 2020-01-24)
Daily proportion of population imported to Wuhan, κ	0.0086(2019-12-01 to 2020-01-23), 0 (after 2020-01-24)







Results

The outcomes of the COVID-19 epidemics in Wuhan would vary dramatically under different scenarios of asymptomatic infectiousness as shown on the figures of infected numbers and incident cases. However, the peaks of infected and incidence appear to be around the same dates under different scenarios. The peak of infected number is appeared on February 9, 2020. The peaks of incidence cases are appeared on January 23 and February 7, 2020, which both are the time point of R_0 changing. After fitting the report data of cumulated cases in Wuhan, the fraction of asymptomatic infectiousness compared to symptomatic infectiousness is estimated from 0.45 to 0.55.