Project 1: Infectious Disease Modeling

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Modeling and Simulation Fall 2020

QUESTION: What public health interventions are most likely to be effective? (Consider whether they're aimed at changing the infection rate, the recovery rate, or the rate at which people become able to be re-infected.)

It is interesting because it affected a lot of people and looking at any disease outbreak now can give us insight on our current situation. If there are limited resources available for stopping an outbreak, it is important to know where they should be directed to have the maximum impact.

Public health officials and the general public would be interested in answering this question.

METHODOLOGY/MODEL:

S_t = Count of Susceptible persons at time t
I_t = Count of Infectious persons at time t
R_t = Count of Recovered persons at time t

ΔI_t = Number of Infections at time t
ΔR_t = Number of Recoveries at time t

ΔS_t = Number of reinfections at time t

$S = \Delta R_t$ = (recovered people loop back to being susceptible?)

S_t --> I_t --> R_t

$\Delta I_t = S_t * \beta$

$\Delta R_t = I_t * \gamma$

$\Delta S_t = R_t * \xi$

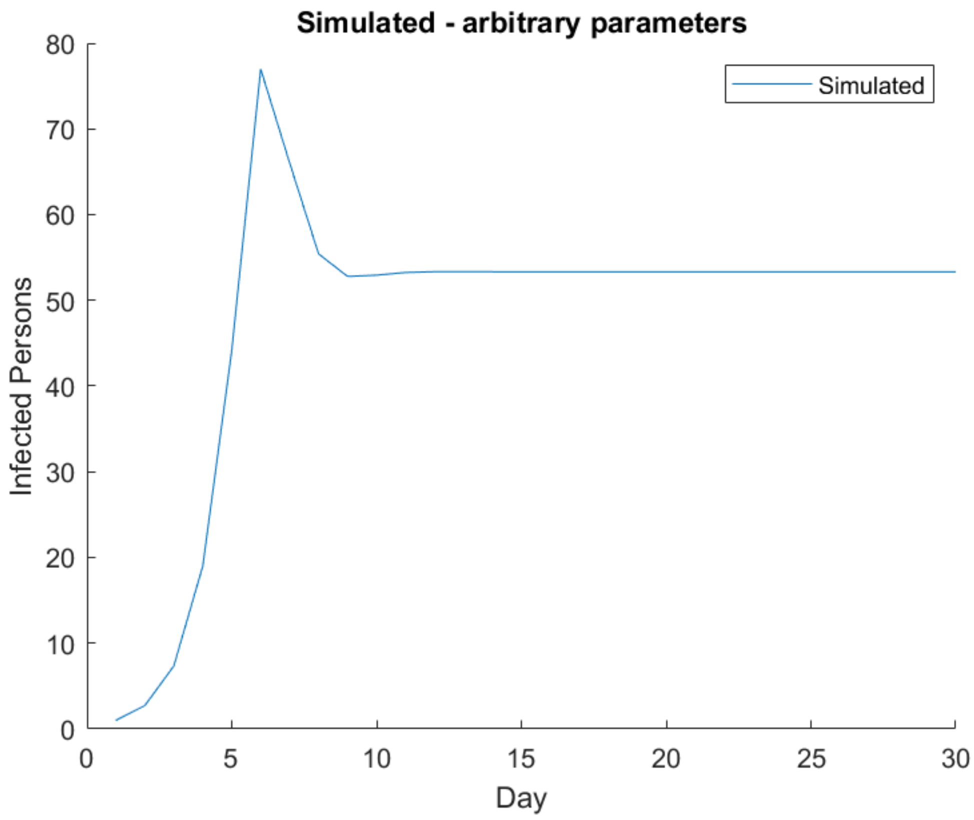
We added an additional flow for reinfections, from recovered to susceptible

```
% FIRST CUT MODEL (with Zach's parameters)
% Define initial state
% A population of 100 persons, 99 susceptible and 1 infectious
s_0 = 99;
```

```
i_0 = 1;
r_0 = 0;
```

```
% Let's interpret t to be Days; thus
% Infection rate: Each infected person has a chance to infect 1 susceptible person out of 50
% Recovery rate: The infection lasts 4 days before recovery
% Resusceptibility rate: Immunity lasts 2.5 days before becoming susceptible
beta = 1 / 50;    % steepness of increase (most prominent on first increase) (larger = more ste
gamma = 1 / 4;    % magnitude of subsequent infections (how SQUIGGLY) (larger = more squiggly)
xi = 1 / 2.5;     % larger number = more squiggly, number of infections higher even as plateaui
```

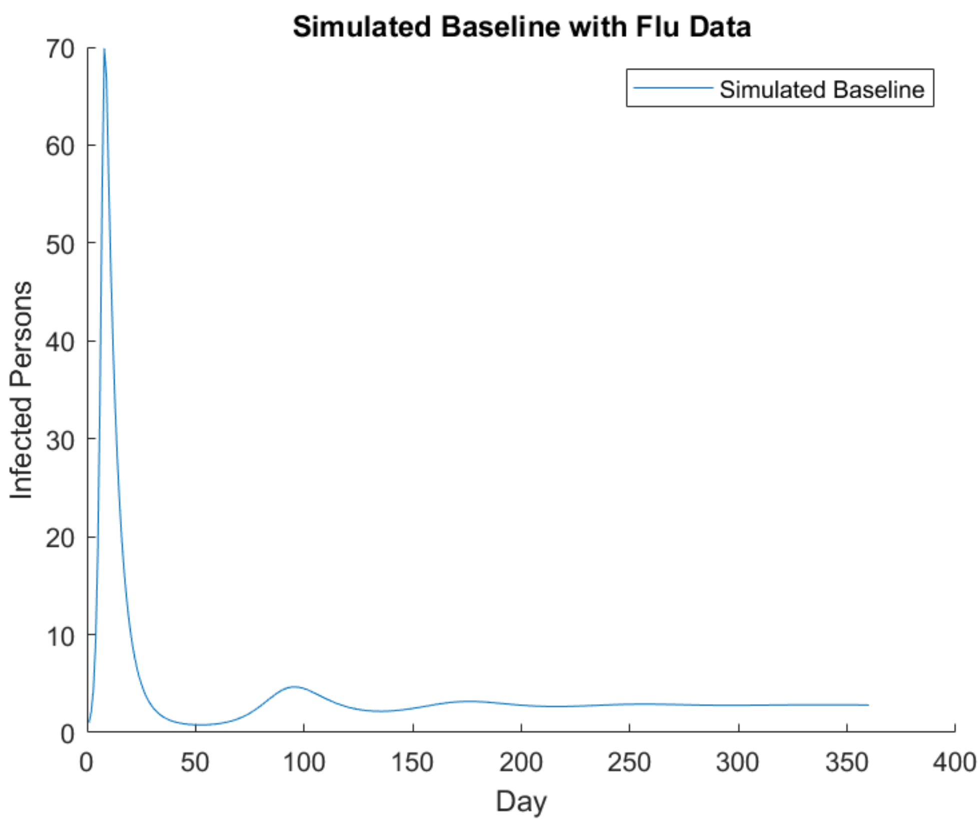
```
% Run simulation
[S_sim, I_sim, R_sim, W_sim] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 30);
% Plot
figure(1); clf; hold on;
plot(W_sim, I_sim); label1 = "Simulated";
xlabel("Day")
ylabel("Infected Persons")
legend({label1})
title("Simulated - arbitrary parameters")
```




```
% UPDATED MODEL (using H1N1 data)
% Let's interpret t to be Days; thus
```

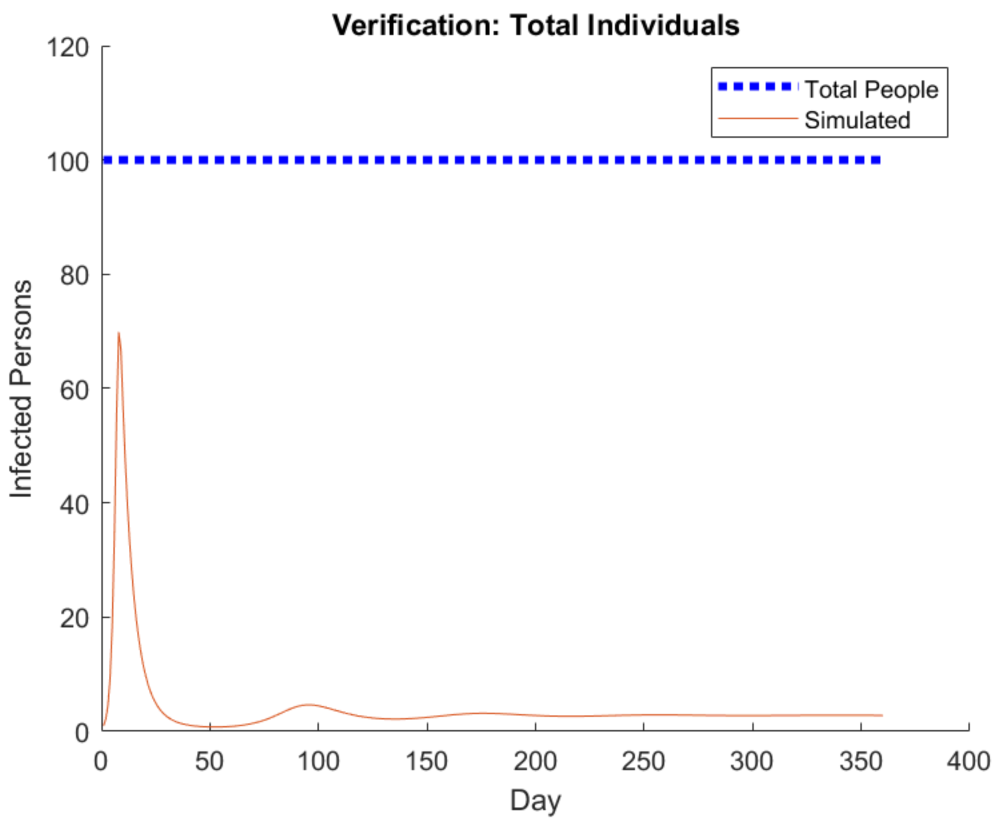
```
% Infection rate: Each infected person has a chance to infect 1.3 susceptible
%                 person out of 100
% Recovery rate: The infection lasts 6 days before recovery
% Resusceptibility rate: Immunity lasts 180 days before becoming susceptible again
beta = 1.3 / 100;
gamma = 1 / 6;
xi = 1 / 180;
```

```
% Run simulation
[S_sim, I_sim, R_sim, W_sim] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360);
% Plot
figure(2); clf; hold on;
plot(W_sim, I_sim); label1 = "Simulated Baseline";
xlabel("Day")
ylabel("Infected Persons")
legend({label1})
title("Simulated Baseline with Flu Data")
```



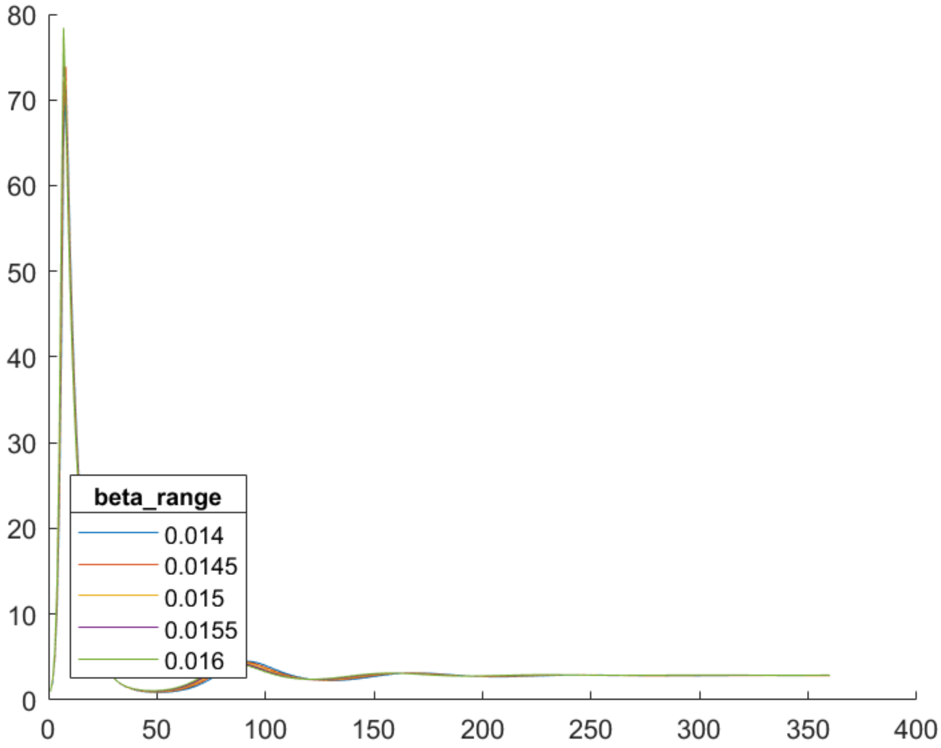

```
% Our verification that the total number of people stays constant
figure(3); clf; hold on;
plot(W_sim, S_sim + I_sim + R_sim, 'b:', 'LineWidth', 3); label1 = "Total People";
plot(W_sim, I_sim); label2 = "Simulated";
xlabel("Day")
ylabel("Infected Persons")
legend({label1, label2})
```

```
title("Verification: Total Individuals")
```

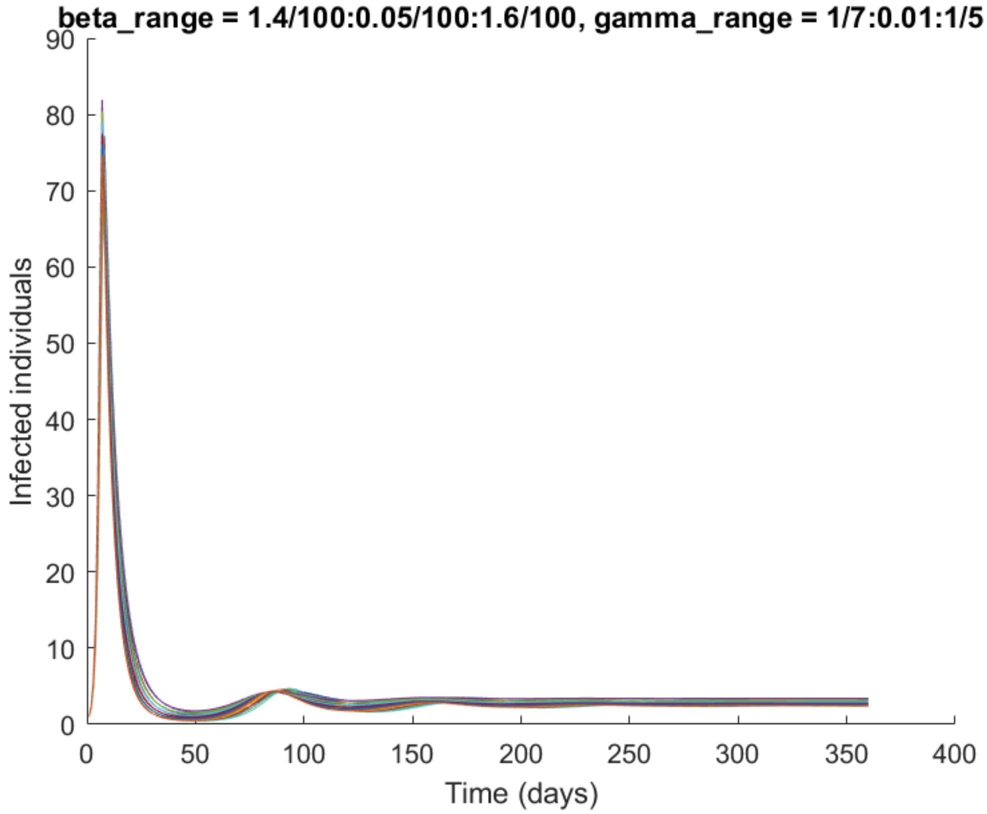


Next steps = parameter sweeping based on our research, creating multiple models based on different interventions

```
figure(5); clf; hold on;
beta_range = 1.4/100:0.05/100:1.6/100;
for beta1 = beta_range
    [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta1, gamma, xi, 360);
    plot(W_sweep, I_sweep)
end
lgd = legend(string(beta_range));
lgd.Title.String = 'beta\_range';
lgd.Location = 'southwest';
```

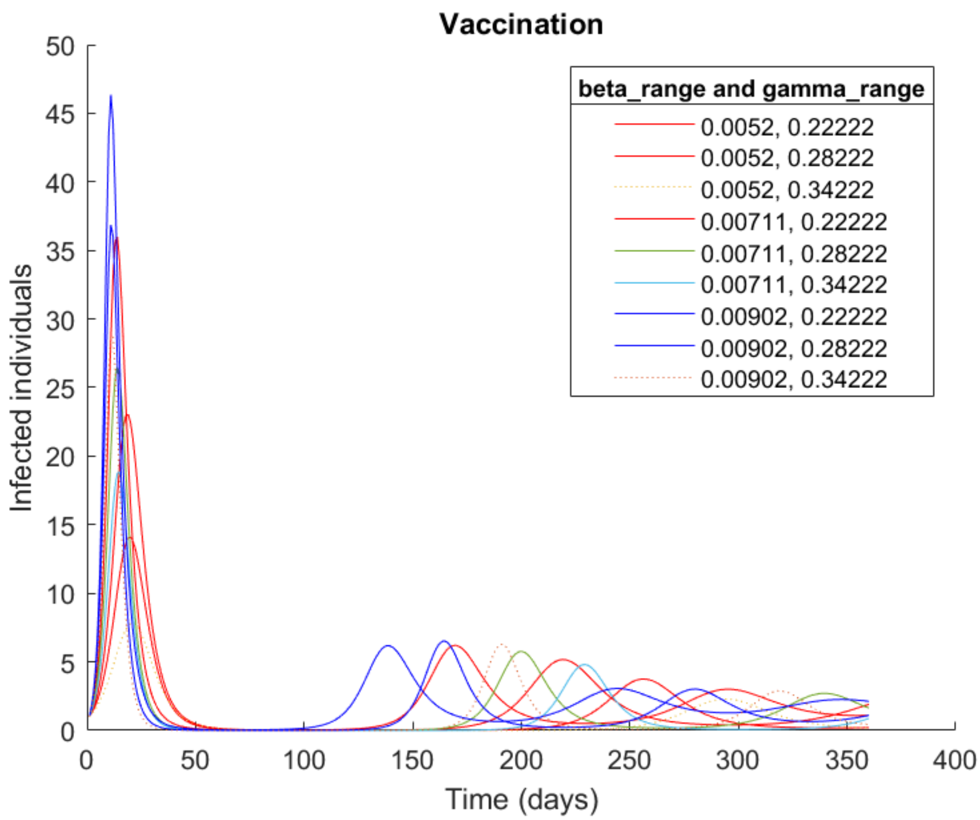



```
% Baseline sweep
figure(4); clf; hold on;
beta_range = 1.4/100:0.05/100:1.6/100;
gamma_range = 1/7:0.01:1/5;
for beta = beta_range
    for gamma = gamma_range
        [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360
        plot(W_sweep, I_sweep)
    end
end
xlabel('Time (days)');
ylabel('Infected individuals');
title(['beta\_range = 1.4/100:0.05/100:1.6/100, gamma\_range = 1/7:0.01:1/5'])
```

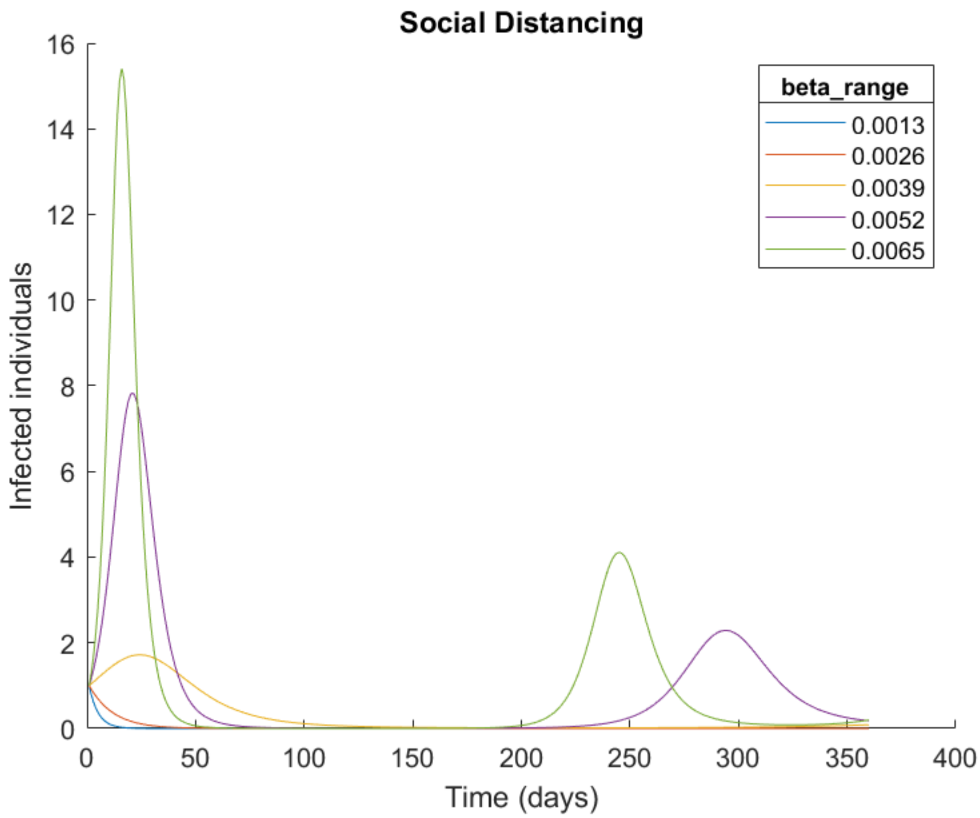



```
% Actual sweeping for vaccines
figure(5); clf; hold on;
beta_range = .52/100:0.191/100:1.092/100;
gamma_range = 1/4.5:0.06:1/2.5;
options = ['r', 'r:', 'r--','b', 'b:', 'b--','g', 'g:', 'g--'];
option=1;
for beta = beta_range
    for gamma = gamma_range
        [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360
%         plot(W_sweep, I_sweep,'r:')
        plot(W_sweep, I_sweep,options(1,option))
        option = option + 1;
    end
end

i=1;
for beta = beta_range
    for gamma = gamma_range
        legendvals(i,1) = beta;
        legendvals(i,2) = gamma;
        i = i + 1;
    end
end

for j=1:length(legendvals)
    lgdsliced(1, j) = string(legendvals(j,1)) + ', ' + string(legendvals(j,2));
end
```

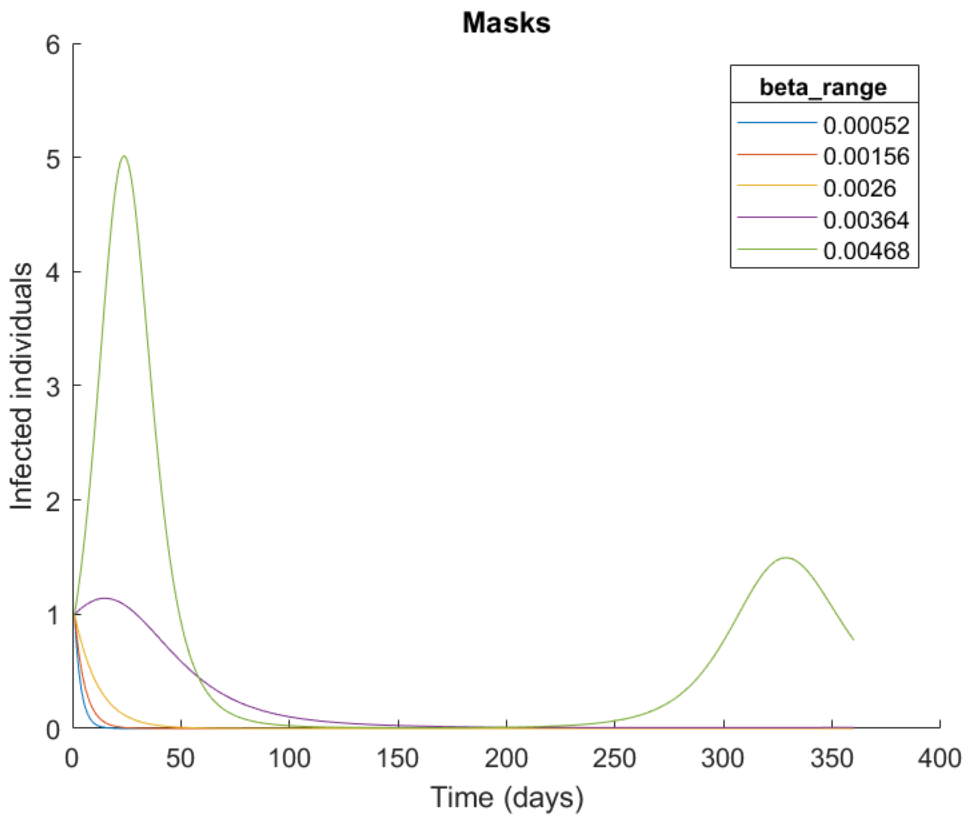
```
title('Vaccination');
xlabel('Time (days)');
ylabel('Infected individuals');
lgd = legend(lgdsliced);
lgd.Title.String = 'beta\_range and gamma\_range';
lgd.Location = 'northeast';
```



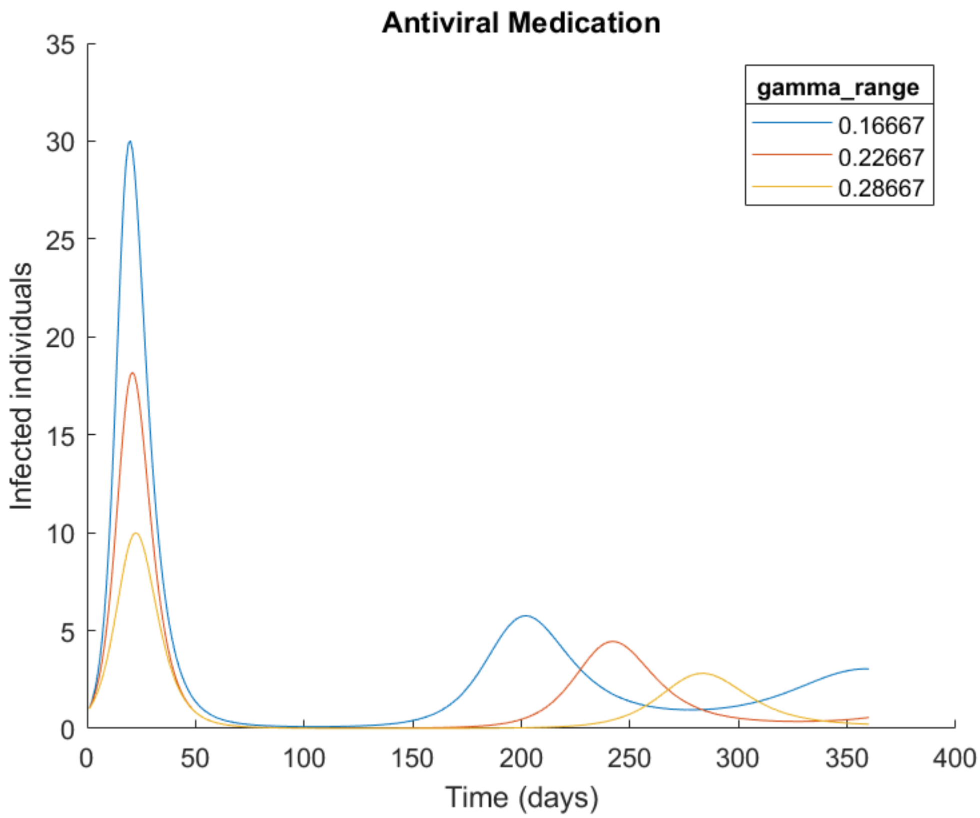

```
% Actual sweeping for social distancing
figure(5); clf; hold on;
beta_range = .13/100:.13/100:.65/100;
for beta = beta_range
    [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360);
    plot(W_sweep, I_sweep)
end

title('Social Distancing');
xlabel('Time (days)');
ylabel('Infected individuals');
lgd = legend(string(beta_range));
lgd.Title.String = 'beta\_range';
lgd.Location = 'northeast';
```



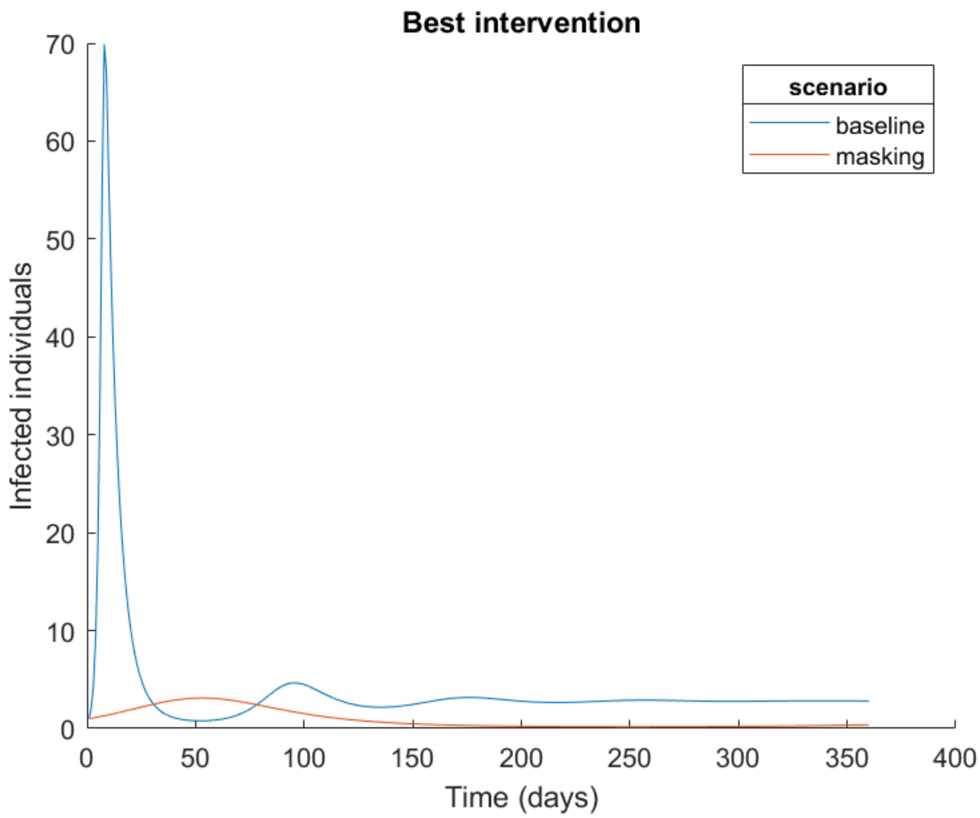

```
% Actual sweeping for Masks
figure(5); clf; hold on;
beta_range = .052/100:.104/100:.468/100;
for beta = beta_range
    [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360);
    plot(W_sweep, I_sweep)
end

title('Masks');
xlabel('Time (days)');
ylabel('Infected individuals');
lgd = legend(string(beta_range));
lgd.Title.String = 'beta\_range';
lgd.Location = 'northeast';
```



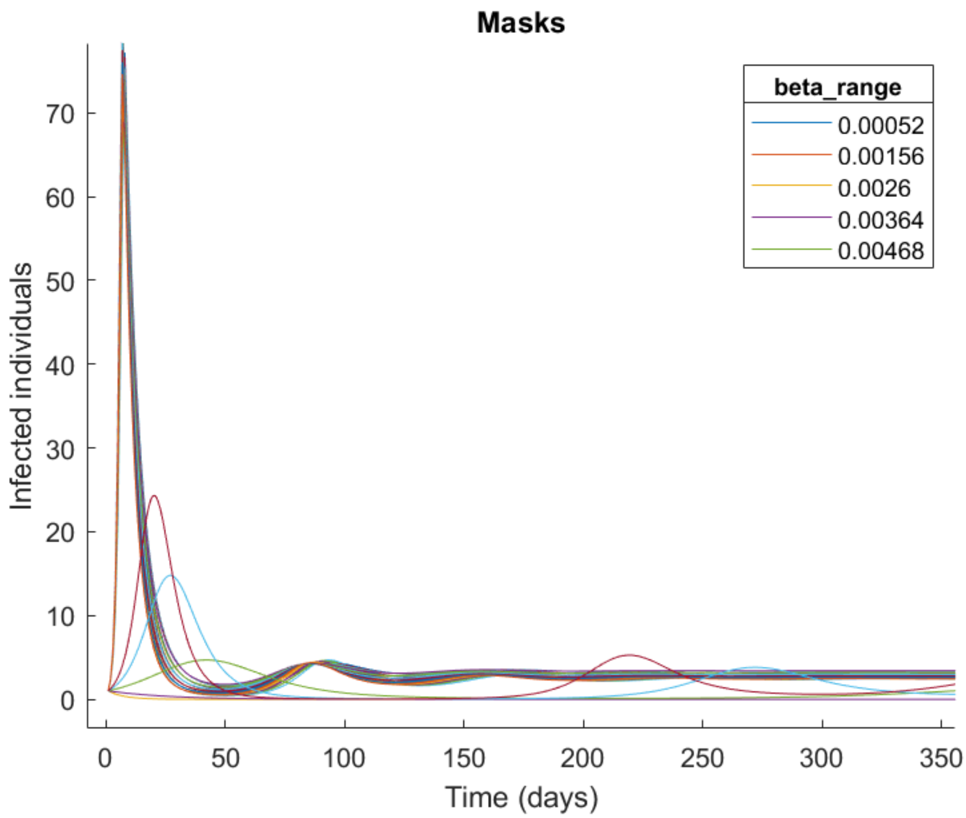

```
% Actual sweeping for Antiviral medication
figure(5); clf; hold on;
gamma_range = 1/6:0.06:1/3;
for gamma = gamma_range
    [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360);
    plot(W_sweep, I_sweep)
end

title('Antiviral Medication');
xlabel('Time (days)');
ylabel('Infected individuals');
lgd = legend(string(gamma_range));
lgd.Title.String = 'gamma\_range';
lgd.Location = 'northeast';
```




```
% best intervention vs. baseline
figure(10); clf; hold on;

% Baseline
beta = 1.3 / 100;
gamma = 1 / 6;
xi = 1 / 180;
[S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360);
plot(W_sweep, I_sweep)

% Masking
beta = .208 / 100;
[S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360);
plot(W_sweep, I_sweep)

title('Best intervention');
xlabel('Time (days)');
ylabel('Infected individuals');
lgd = legend({'baseline', 'masking'});
lgd.Title.String = 'scenario';
lgd.Location = 'northeast';
```




```
figure(100); clf; hold on;
beta_range = 1.4/100:0.05/100:1.6/100;
gamma_range = 1/7:0.01:1/5;
for beta = beta_range
    for gamma = gamma_range
        [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 36
        plot(W_sweep, I_sweep)
    end
end

beta_range = .052/100:.104/100:.468/100;
for beta = beta_range
    [S_sweep, I_sweep, R_sweep, W_sweep] = sir_simulate(s_0, i_0, r_0, beta, gamma, xi, 360);
    plot(W_sweep, I_sweep)
end

title('Masks');
xlabel('Time (days)');
ylabel('Infected individuals');
lgd = legend(string(beta_range));
lgd.Title.String = 'beta\_range';
lgd.Location = 'northeast';
```


Masks
beta_range
0.00052
0.00156
0.0026
0.00364
0.00468
Infected individuals
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
Time (days)