COVID-19 Model in Nebraska Using a Compartmental Model with Focus on the Effect of Social Distancing, the "Beta Factor"

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Introduction

- Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), COVID-19 first reported death in the United States in late February 2020 [1].
- First identified in Wuhan, China, in December 2019 [2].
- The impact including economic shutdowns, mounting death counts, introduction of new terms such as "social distancing".
- Several models have been introduced to help policy makers. The Centers for Disease Control and Prevention (CDC) has utilized 37 different models as of January 27th 2021 [3].
- Two model types, statistical models and compartmental models.
- Statistical models: sum of Gaussian curves or Gaussian error functions in the models used by the CDC
- Compartmental models: differential equations capture the behavior of the epidemic.
- Here, a basic Susceptible, Infected, and Removed (SIR) model was used and data from the Nebraska Department of Health and Human Services (DHHS) applied to find the effect social distancing has made on disease trajectory in Nebraska.

SIR Model

$$S' = \frac{-\beta IS}{N}$$

$$I' = \frac{\beta IS}{N} - \alpha I$$

$$R' = \alpha I$$

Threshold for Epidemic

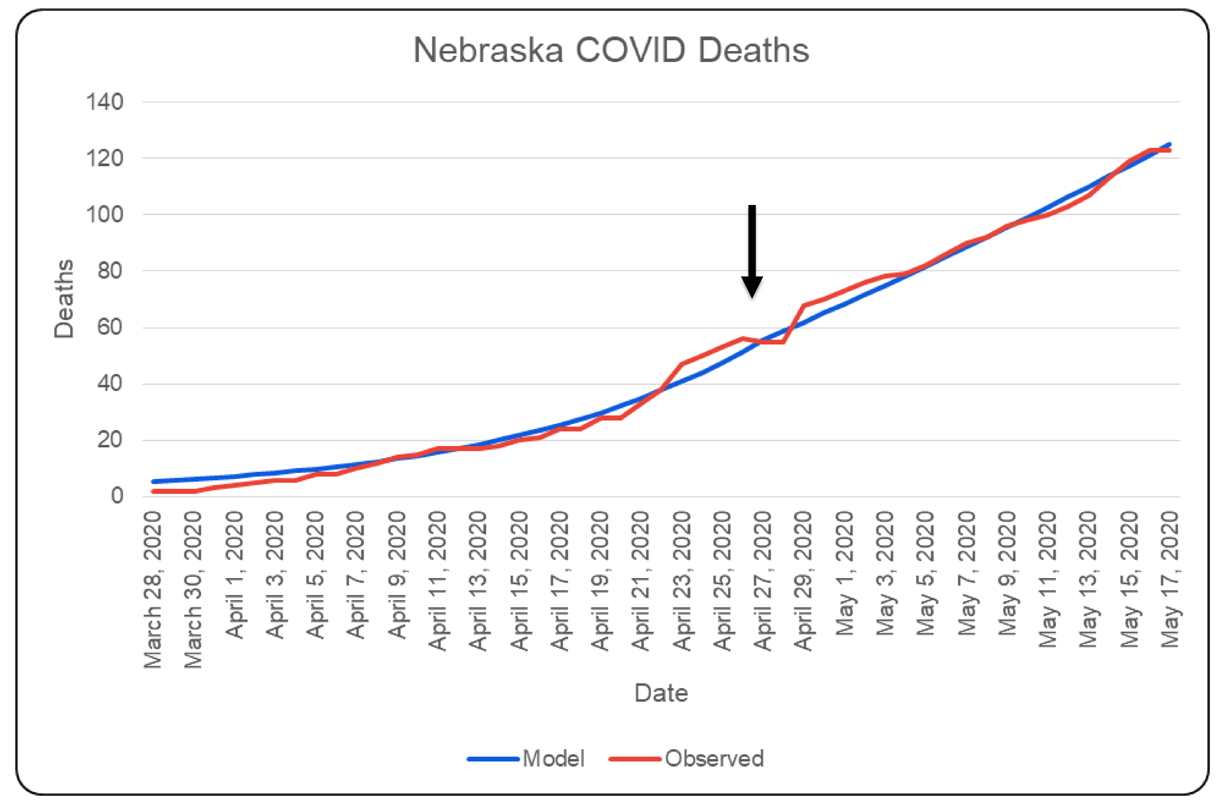
$$S > \frac{\alpha N}{\beta}$$

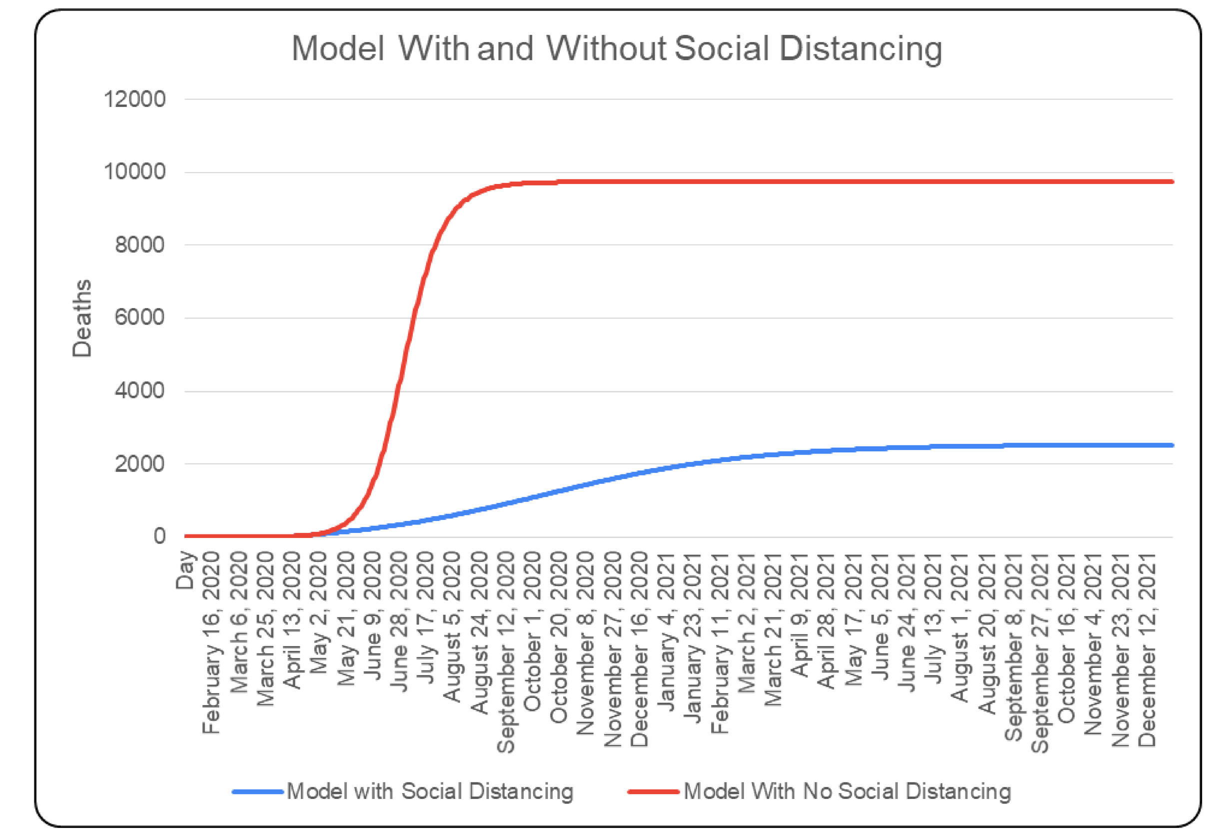
Ways to change threshold

1) Decrease β with social distancing
2) Decrease S with Vaccines
3) Increase α with treatments.

N is total population. *S* total susceptible, *I* is infected, and *R* is total removed. *β* is the "beta factor" and is related to the probability of susceptible person getting infected. *α* is the fraction of infected removed, the inverse of the average time that a person is infectious. Each are functions of time. The prime (') indicates derivative with respect to time.

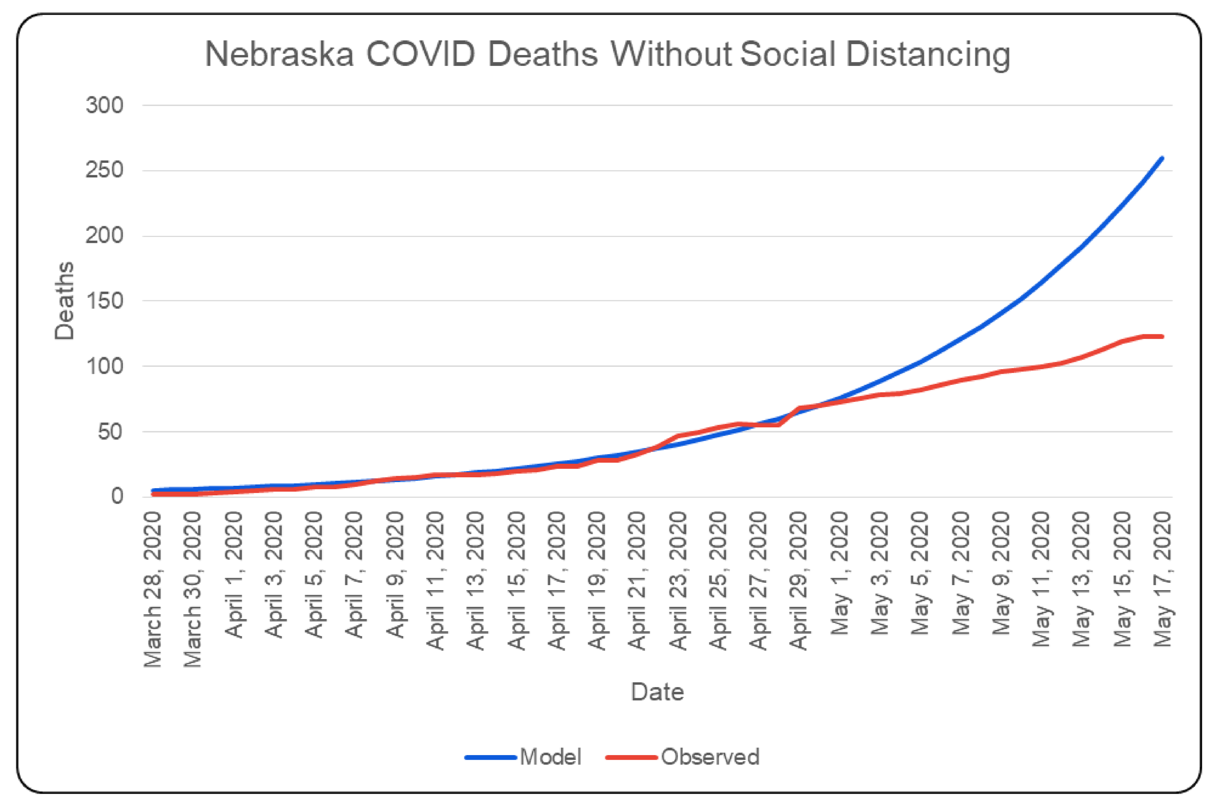
Results

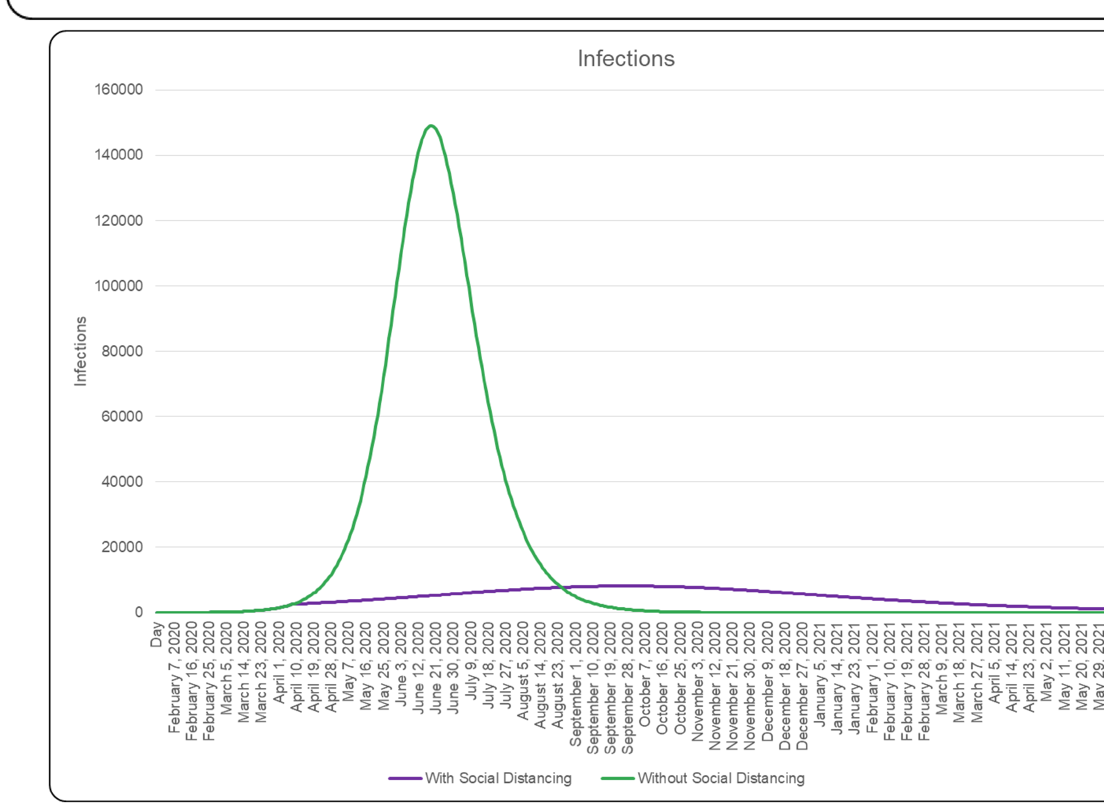




Top Left: Observed (red) and Model (blue) data, arrow indicates Social Distancing shift

Top Right: Trajectory of disease model data with no social distancing (red) and with social distancing (blue)





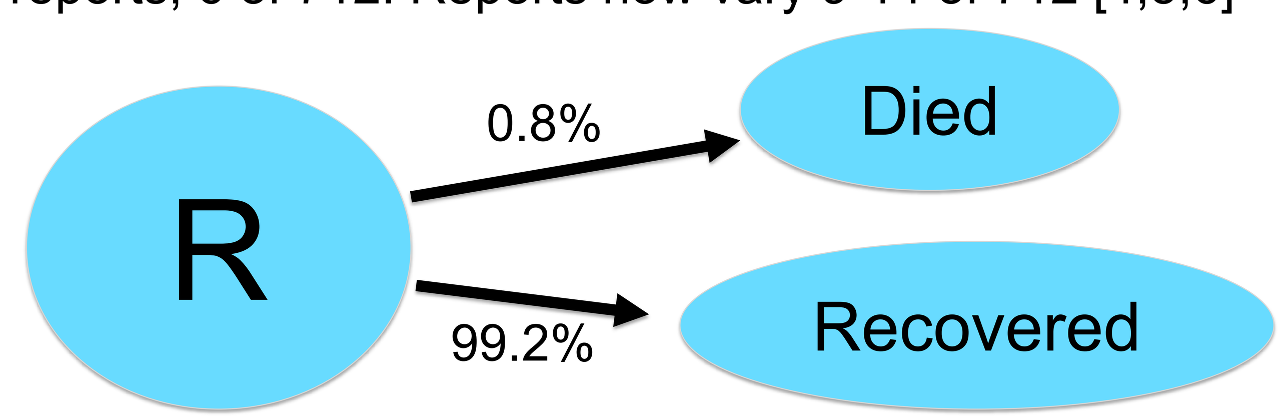
Bottom Left: Model data if no social distancing measures were applied

Bottom Right: Infections with social distancing (purple) and no social distancing (green)

Methods

Data from the Nebraska DHHS website was collected from March 28, 2020 to May 17, 2020. COVID-19 confirmed deaths was the fit statistic used in this study. The following assumptions were applied.

1) 0.8% death rate based on the Diamond Princess initial reports, 6 of 712. Reports now vary 9-14 of 712 [4,5,6]



2) 18 days from disease onset to death on average [7,8].
3) 7 days as average infectivity period [9,10]
4) Social distancing taking effect April 9, 2020 [11]
5) Population of Nebraska of 1,934,000
6) Nebraska being isolated, no one in or out.
7) No chance of re-infection.

Equations solved numerically, time steps of 1 day. Deaths data fit to observed data using a sum of least squares fit for March 28 to April 26 and April 27 to May 17, separately. The change in β was found.

Conclusion and Discussion

Weaknesses: Isolation of Nebraska, no re-infected, accuracy of 0.8% death rate, one COVID virus, β static in nature

Strengths: One variable fit, using deaths for fit statistic.

Of 1,934,000 people in Nebraska 700,582 would need to be removed before the epidemic would subside with pre-COVID social practices. This can be done via infection or vaccination.

β = 0.224 Before

β = 0.155 After

$\frac{\alpha N}{\beta}$ =1,233,418 Before

$\frac{\alpha N}{\beta}$ = 1,782,488 After

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