COVID 19 SIRQ Model and its implications

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Agenda

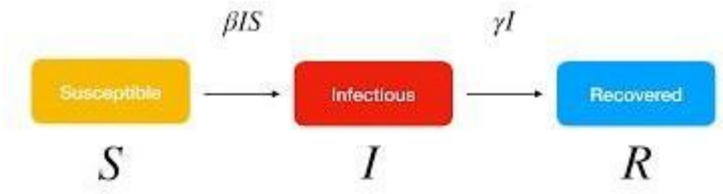
- SIR and SIRQ Model Basics
- SIRQ Model Results
- Confirmed Cases - Numbers

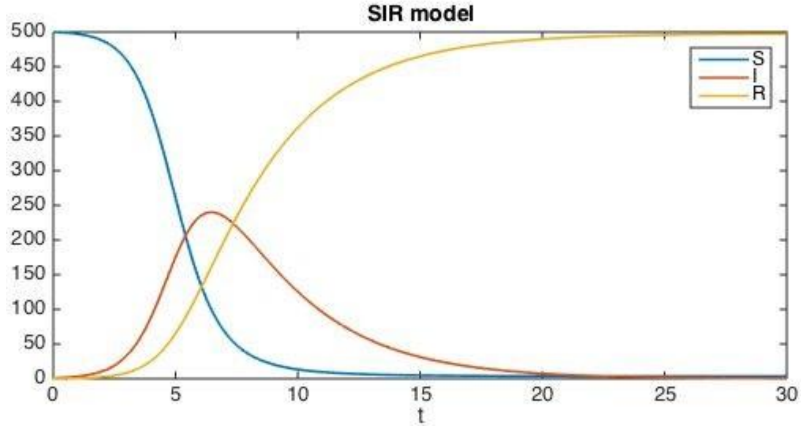
  vs Reality

- Simulations and the Future

Section I -

SIR and SIRQ Models





The SIR Model

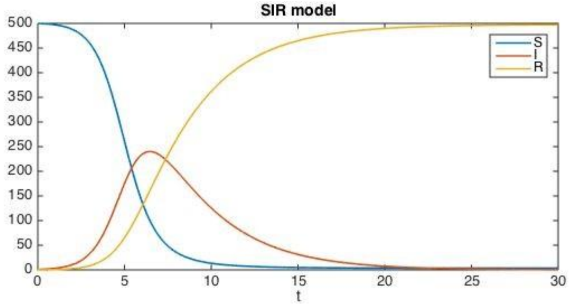
Defining Variables:

- Susceptible (S) - Number of people able to get disease
- Infected (I) - Number of people with disease who are able to spread it
- Recovered (R) - Number of people who are no longer contagious and are now immune to disease
- Beta (***β***) - Rate disease spreads among infected, depends on many factors
- Gamma (γ) - Rate infected people recover, relatively static

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$



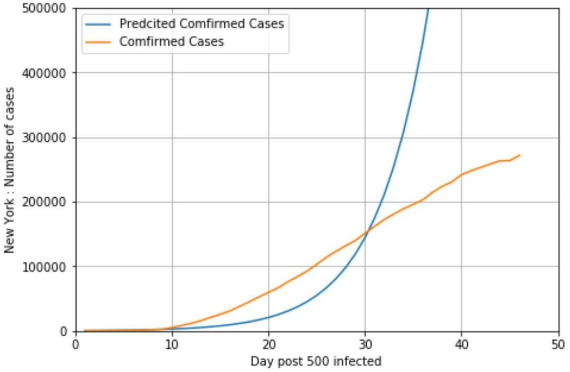
SIR Model Drawbacks - New York Covid

Low $\boldsymbol{\beta}$ and γ

$\boldsymbol{\beta} = 0.2$

$\gamma = 0.005$

Starts too slow, still takes off

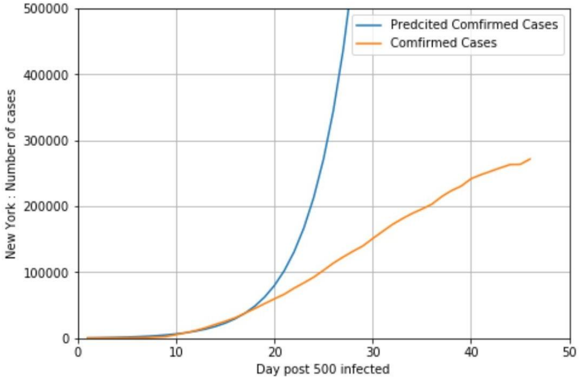


Medium $\boldsymbol{\beta}$ and γ

$\boldsymbol{\beta} = 0.35$

$\gamma = 0.1$

Starts correct, takes off quickly

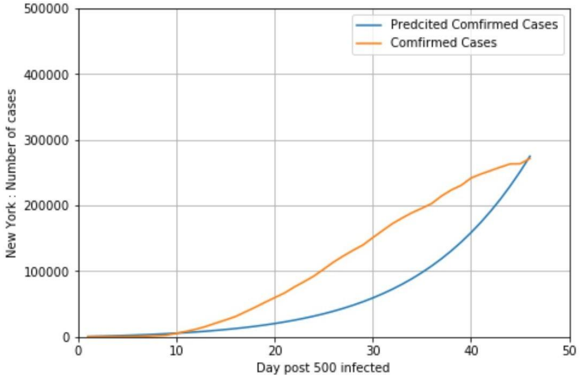


Large $\boldsymbol{\beta}$ and γ

$\boldsymbol{\beta} = 0.7$

$\gamma = 0.6$

Starts low, stays low



The SIRQ Model

Same variables as the SIR model, plus two new ones

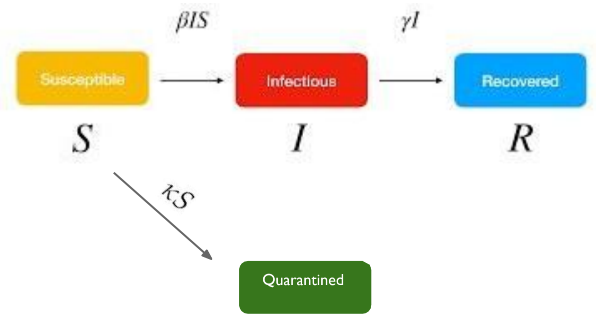
- Quarantine (Q) - Number of people who have not been infected or recovered, but are still unable to get the disease due to quarantining/social distancing
- Kappa (κ) - Rate at which people quarantine

$$\frac{dS}{dt} = -\beta SI - \kappa S$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

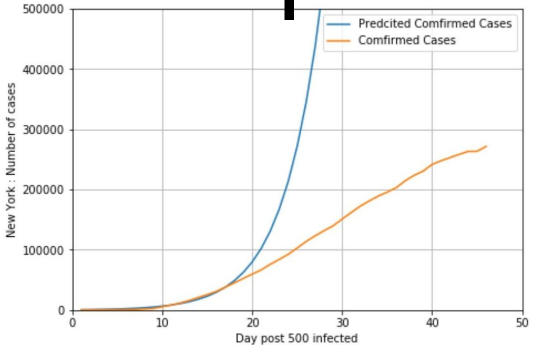
$$\frac{dQ}{dt} = \kappa S$$



SIRQ Model Benefits with COVID 19

- Addresses issue with quarantining
- Give much more effective models for data
- Still allows for very high infectious rate, without constant exponential growth
- Could be used to simulate re-introduction of population from quarantine

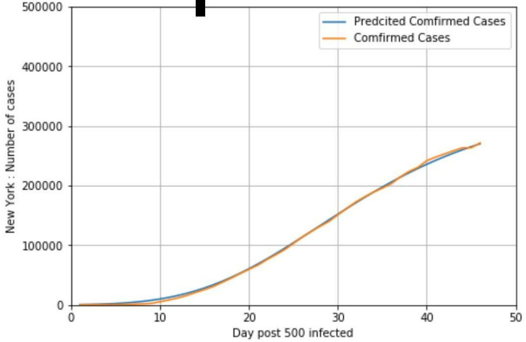
SIR Model



$\boldsymbol{\beta} = 0.35$

$\gamma = 0.1$

SIRQ Model



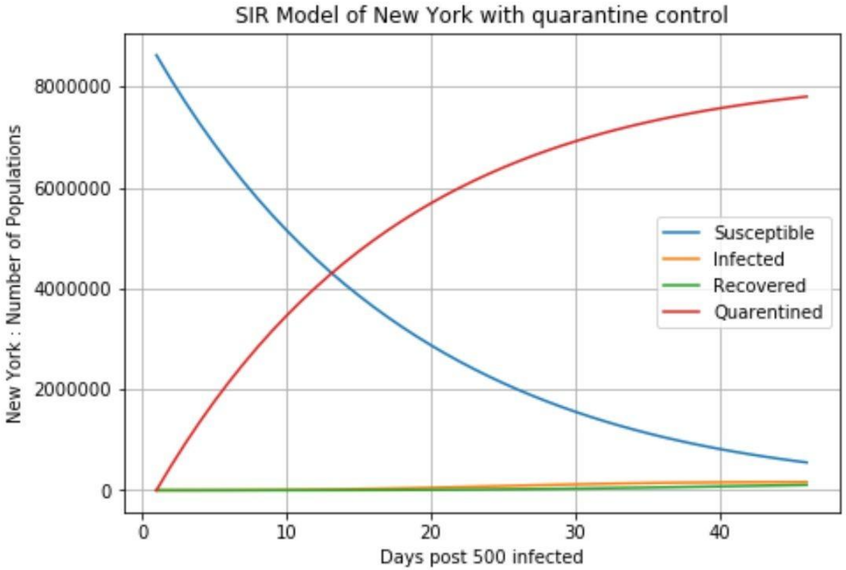
$\boldsymbol{\beta} = 0.45$

$\gamma = 0.03$

$\kappa = 0.057$

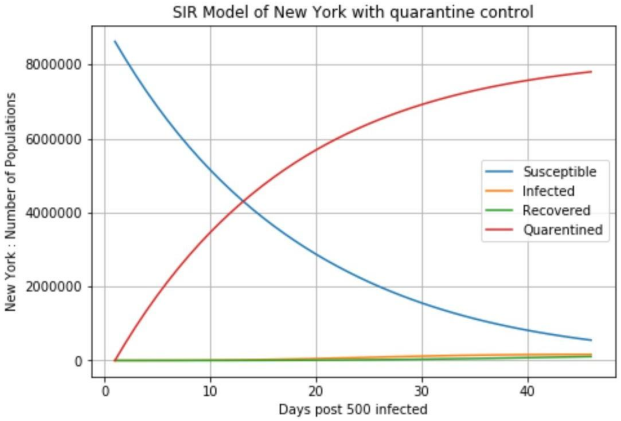
Section II -

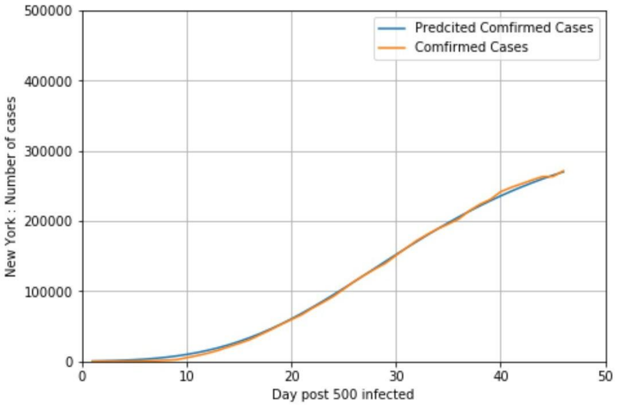
SIRQ Model Results



SIRQ Model Real World Example - New York

- Many infections and therefore a smooth curve with few spikes
- Strong Quarantine Actions taken
- Model predicts majority of population in Quarantine





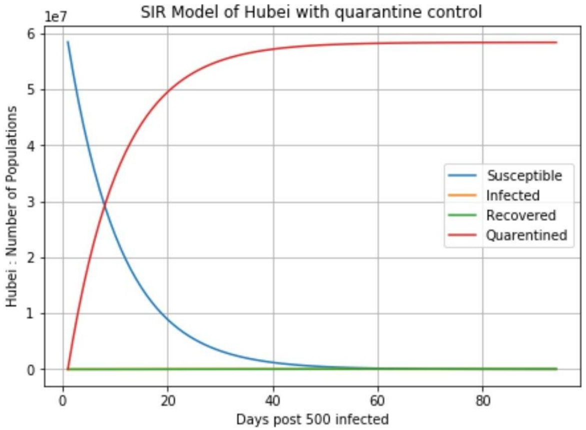
$\boldsymbol{\beta} = 0.45$

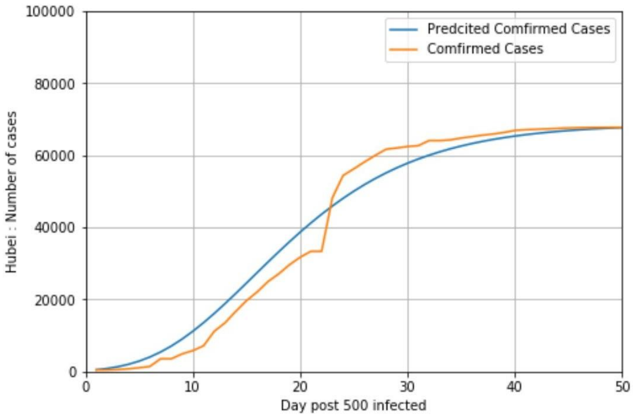
$\gamma = 0.03$

$\kappa = 0.057$

SIRQ Model Real World Example - Hubei

- Due to redefinition of "infected", data has some spikes
- Infection spread even faster than New York ($\boldsymbol{\beta}$ = 0.55 vs. $\boldsymbol{\beta}$ = 0.45)
- Very Strong Quarantine Actions taken (κ = 0.099 much higher than in New York (κ = 0.057)
- Similar Recovery Rate - expected since this is mostly a function of virus
- Model predicts majority of population in Quarantine





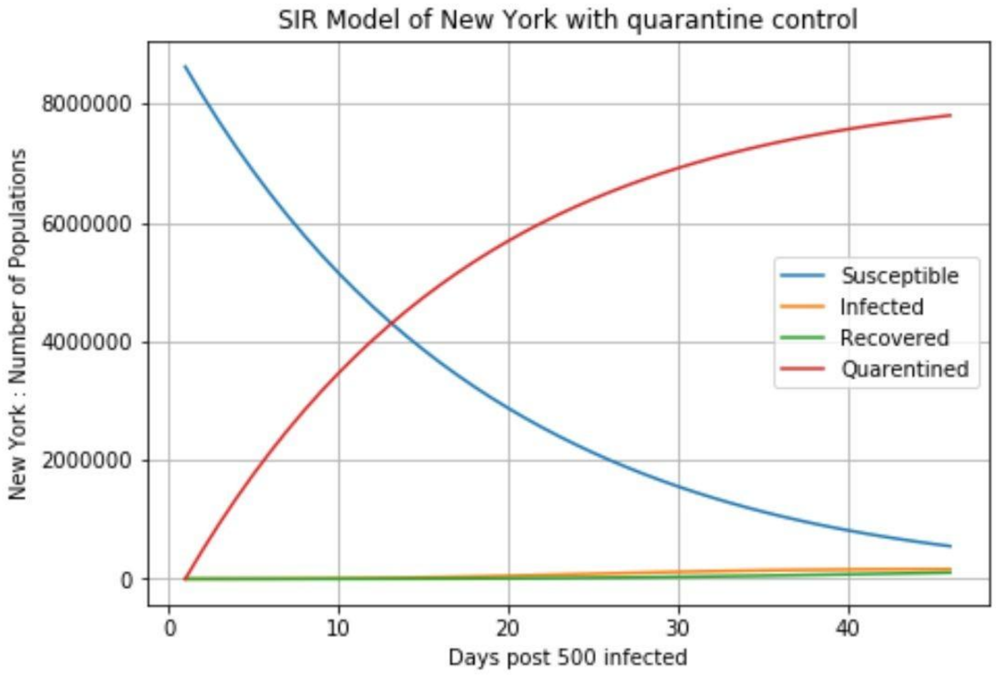
$\boldsymbol{\beta}$ = 0.55

γ = 0.03

κ = 0.099

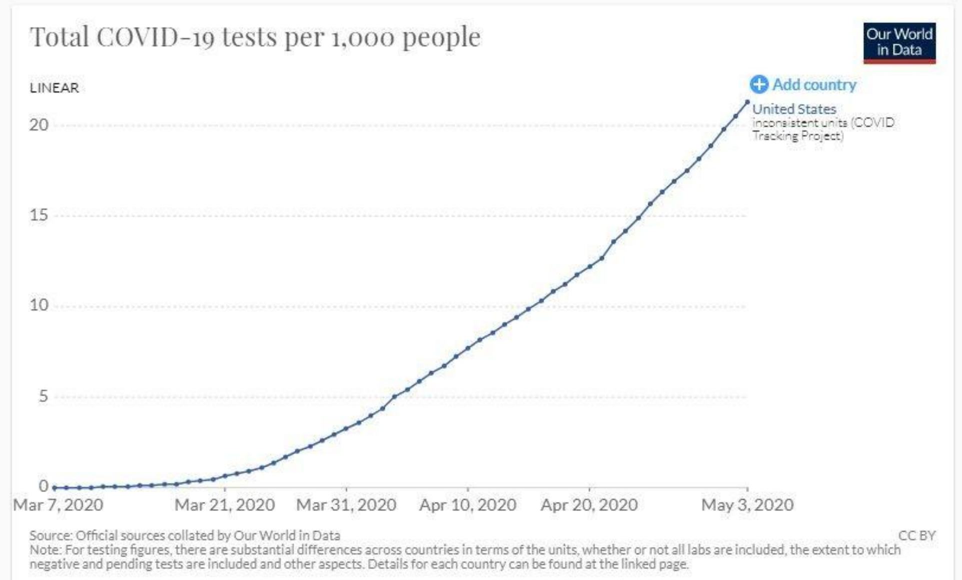
SIRQ Implications - What is Q?

- Looking back at New York, model predicts most of population “In Quarantine”
- If those people were let out, another large spike is likely...or is it?
- The model is trained on “Confirmed Cases” and evaluated on same
- What about unconfirmed cases?



Section III -

Confirmed Cases - Numbers vs Reality



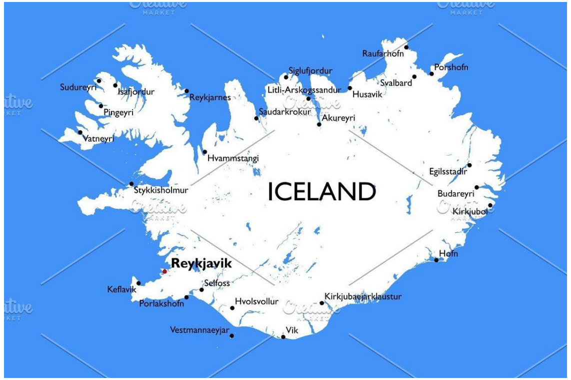
Confirmed Cases vs. Total Cases - The Gap

- Testing is both expensive and rare
- Test rates increase over time
- Testing is done primarily on individuals with obvious symptoms
- COVID 19 has numerous reports of people with no symptoms testing positive
- Locations with high test rates report significant number of asymptomatic cases
- US test rate is ~0.2% of population as comparison

Diamond Princess - 100% Tested

50% of Cases Asymptomatic with 100% Test Rate

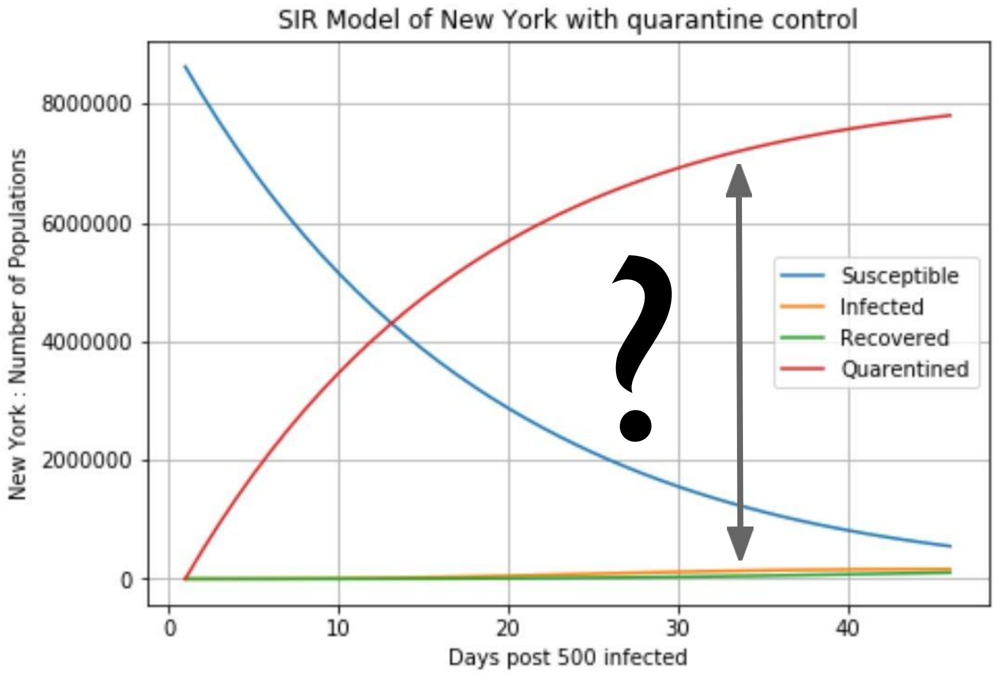
Iceland - 6% Tested



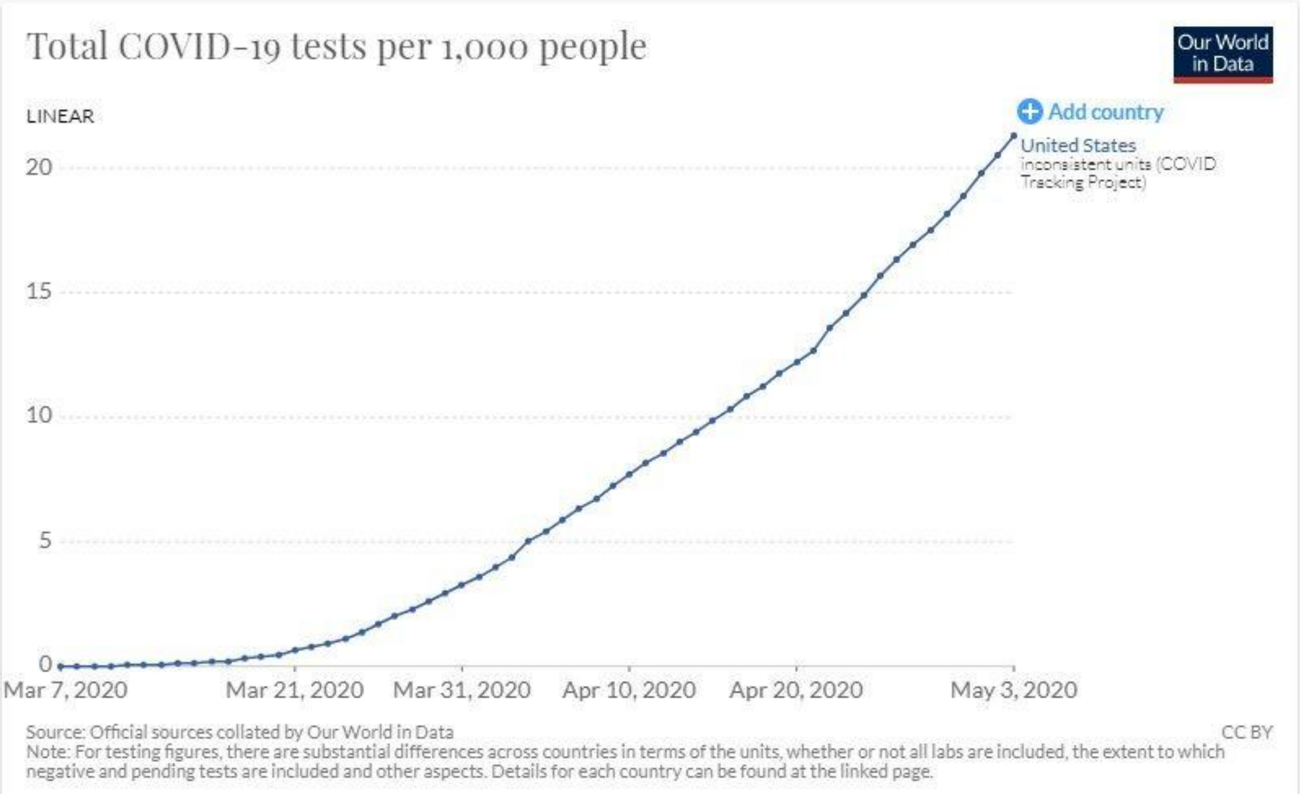
Harvard/MIT collaboration estimates 88-94% of cases were missed by government mandated testing

The “Hidden Recovered” in the SIRQ Model

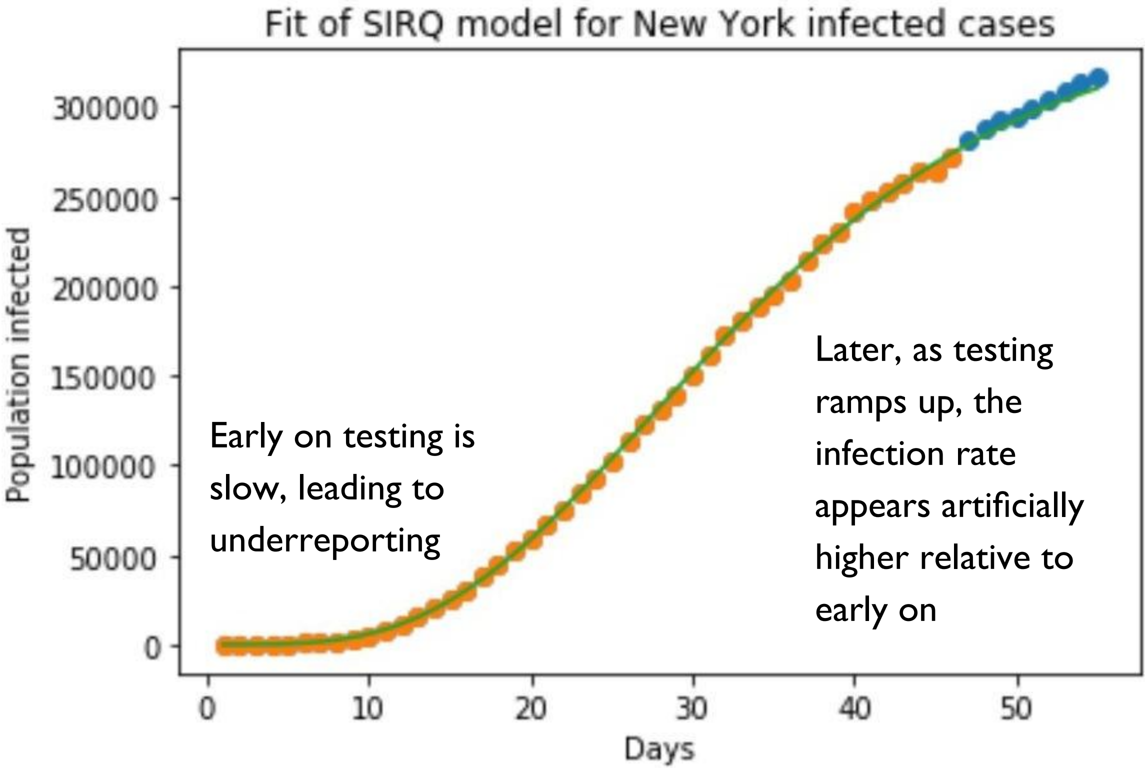
- Current model treats all those in Q as still possibly susceptible when re-opening of society occurs
- We know for certain that there is a section of the population that has been infected and recovered without being tested
- This gap between confirmed cases and actual cases leads to the “Hidden Recovered” (HR)



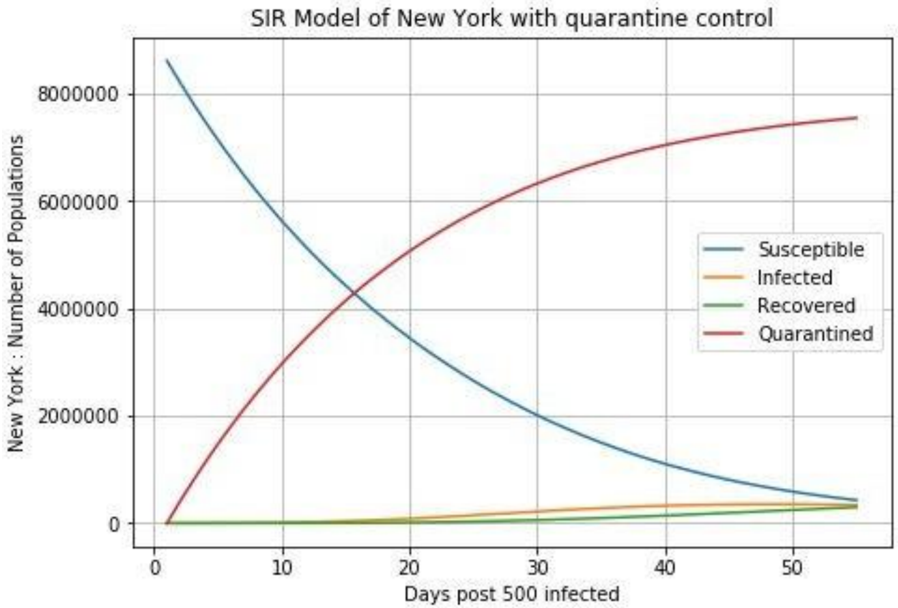
Increasing Testing Rates

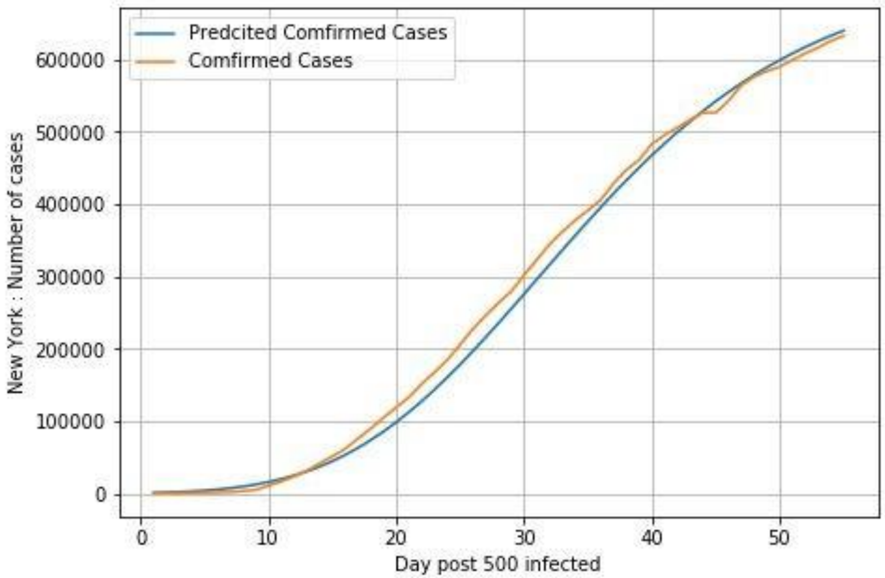


Data Biases and Other Issues

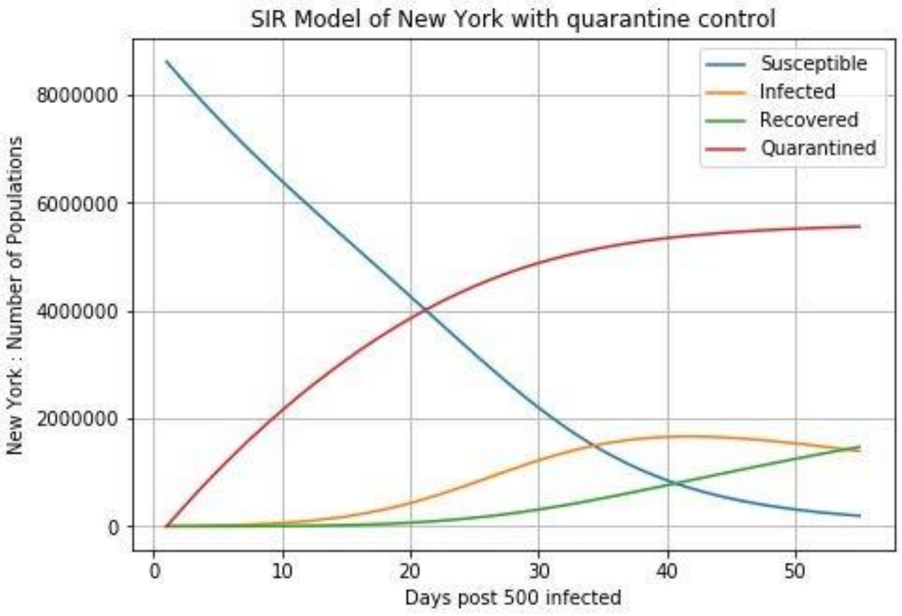


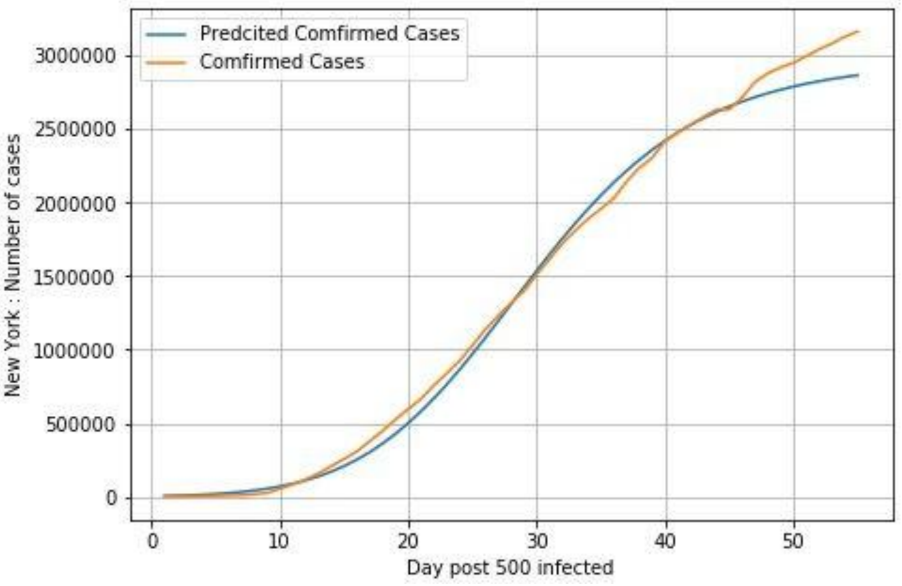
Corrected Data and Re-Modeling - 2x infected



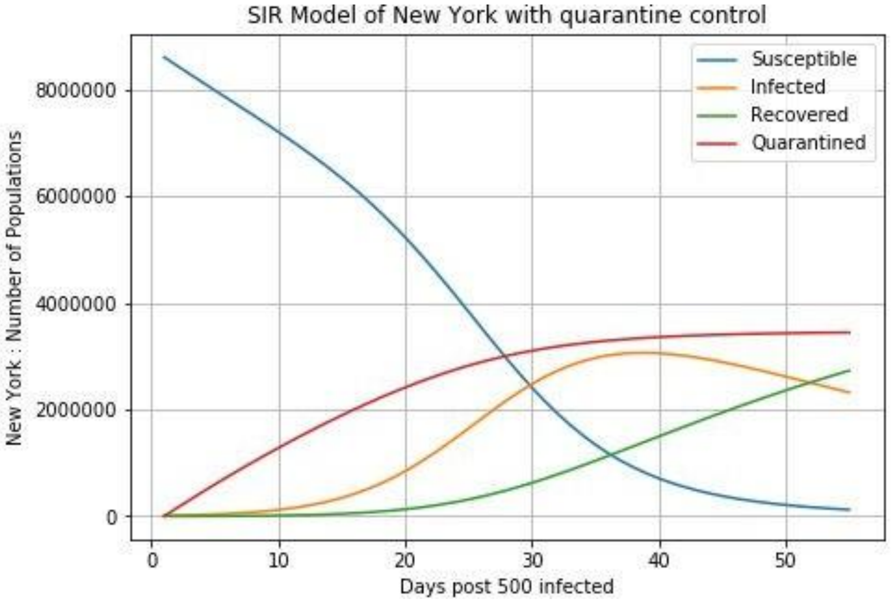


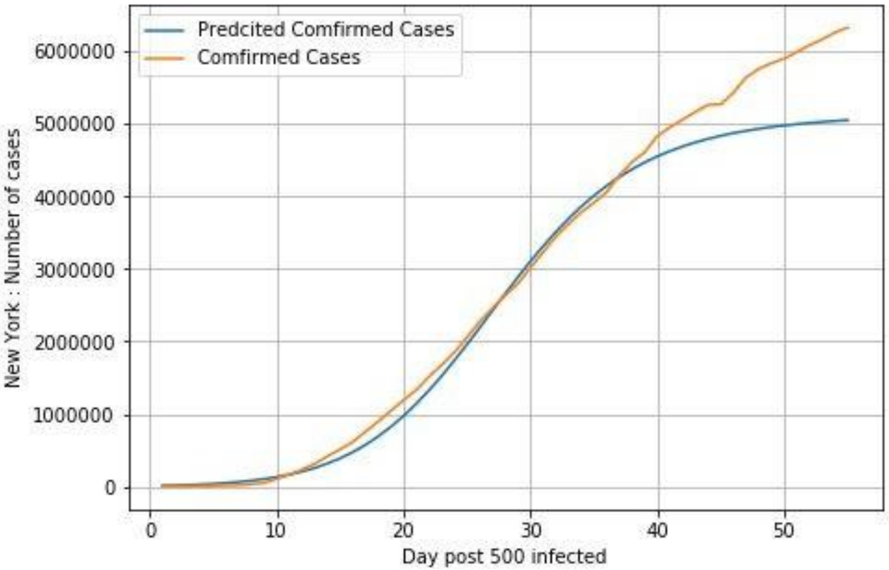
Corrected Data and Re-Modeling - 10x infected





Corrected Data and Re-Modeling - 20x infected





Antibody Testing

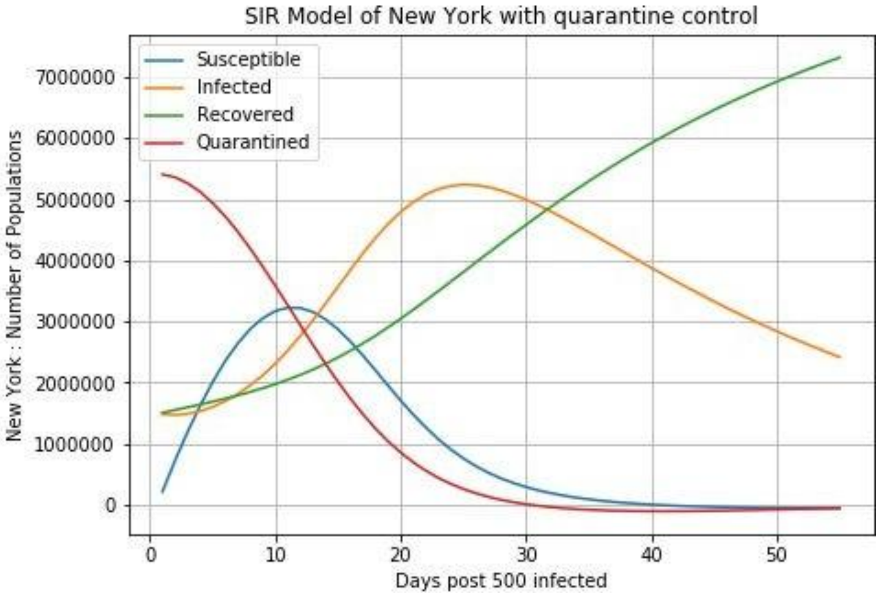
- New York Testing of shoppers estimates ~15% of population has antibodies
- It is unclear if antibody testing is positive for those currently still infectious or not

SIRQ Models - New York

Infected Factor	1	2	10	20
Recovered	1.7%	3%	17%	31%
Recovered + Infected	3.7%	7%	34%	58%
Susceptible+ Quarentined	96.3%	93%	66%	42%

Section IV -

Simulations and the Future



The SIRQ Reverse Model

Same variables as the SIRQ model, with people now leaving quarantine instead of entering

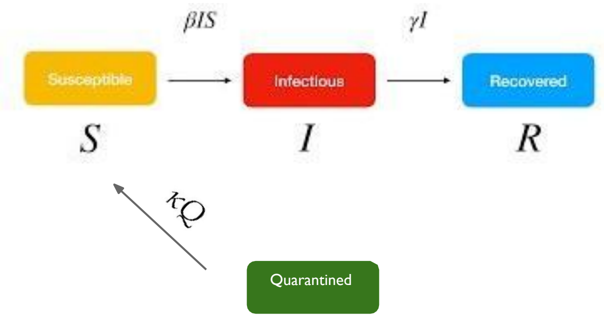
- Quarantine (Q) - Number of people who have not been infected or recovered, but are still unable to get the disease due to quarantining/social distancing
- Kappa (κ) - Rate at which people LEAVE quarantine

$$\frac{dS}{dt} = -\beta SI + \kappa Q$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

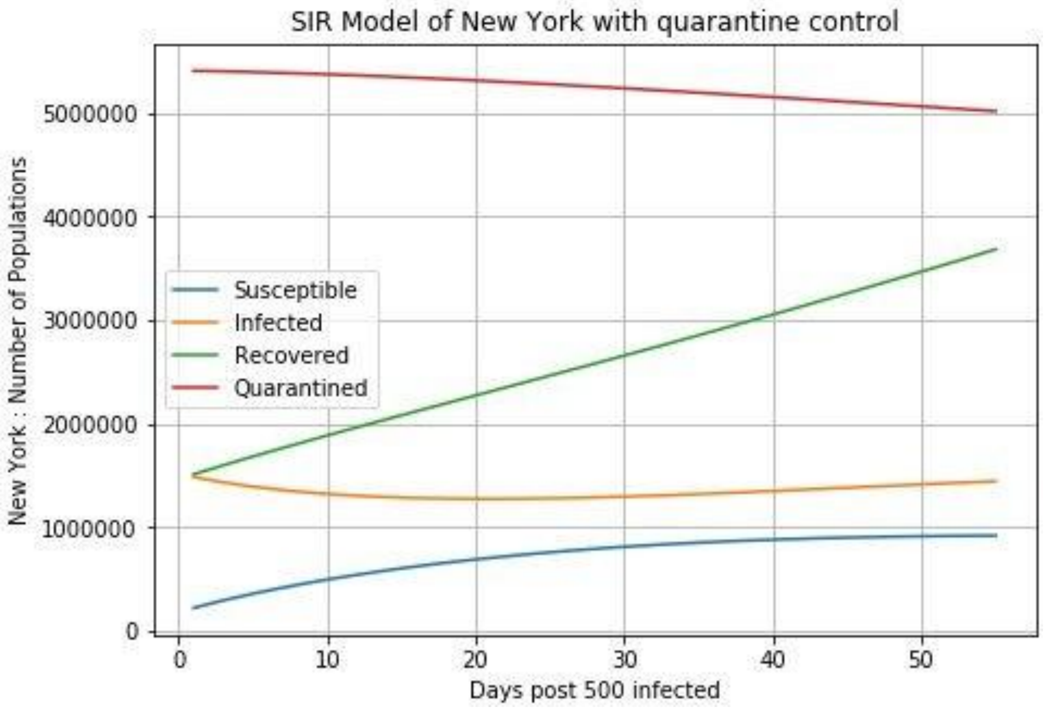
$$\frac{dR}{dt} = \gamma I$$

$$\frac{dQ}{dt} = -\kappa Q$$



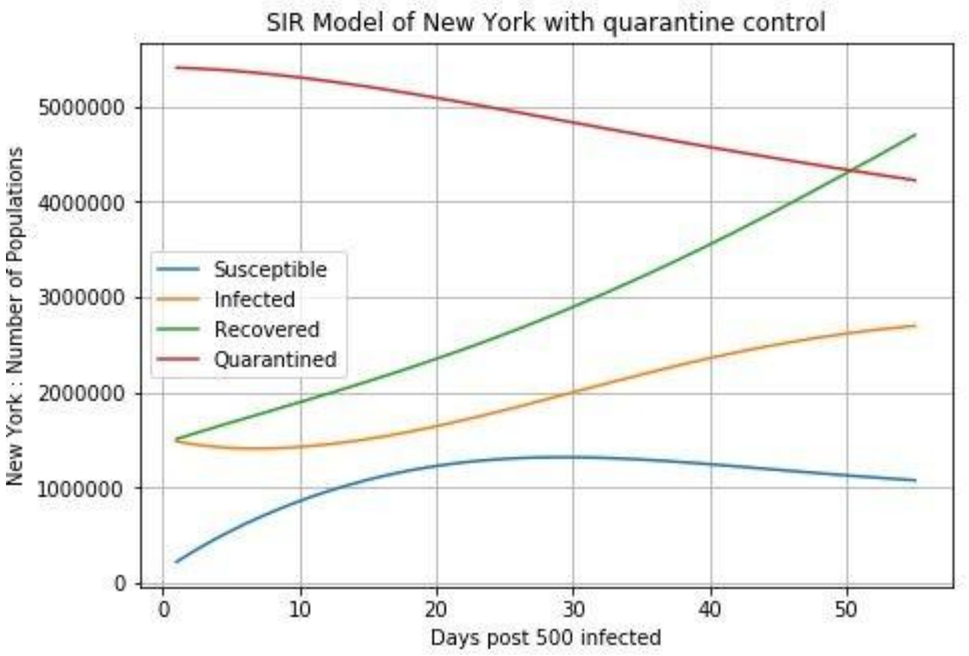
A best case scenario - based off 10x infectfactor

- People exit quarantine slowly and the infection rate remains steady
- This assumes hospitals can handle the current infection rate for an extended period of time



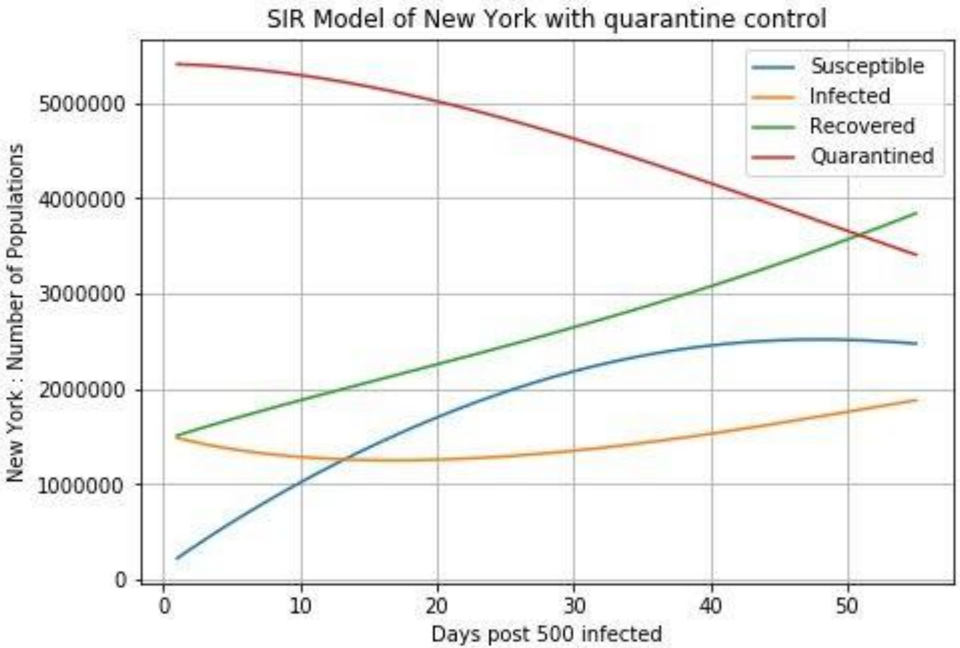
A "best guess" estimate

- People exit quarantine reasonably and the infection rate goes up some but doesn't spike
- Hospitals will need some increased capacity, but not an exponential amount



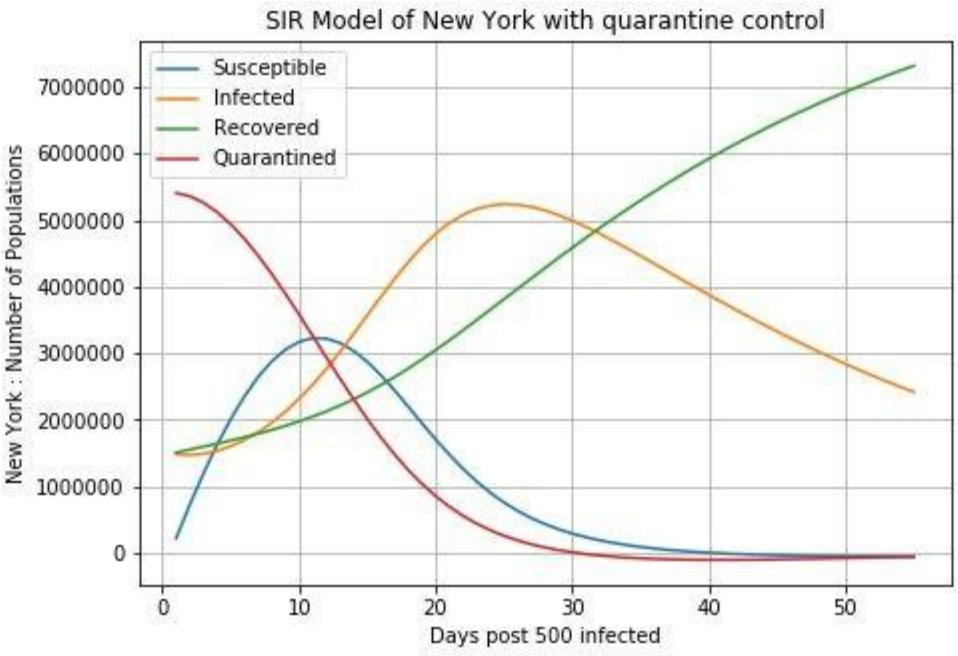
A “best guess” estimate - reduced infection rate

- People exit quarantine reasonably and the infection rate initially decreases and then balances out
- The new “culture” of social distancing halves the infectivity rate of Coronavirus
- Hospitals will need only to hold current capacity



A bad case scenario

- People exit quarantine very quickly and a huge spike in cases happens
- Hospitals will be overwhelmed



Using new data to inform policy

- As quarantine is released, the shape of the infection curve is likely to match one of the simulations, make sure it matches the one we want.
- Quarantine release should pay close attention to hospital resources.
- As testing improves, re-factor models to include more accurate data.

Sources, Thanks, and Questions?

Estimates of the Undetected Rate among the SARS-CoV-2 Infected using Testing Data from Iceland

James H. Stock[a], Karl M. Aspelund[b], Michael Droste[a], Christopher D. Walker[a]

April 6, 2020

T.W. Russell et al. Estimating the infection and case fatality ratio for COVID-19 using age-adjusted data from the outbreak on the *Diamond Princess* cruise ship. medRxiv.org. March 9, 2020. doi: 10.1101/2020.03.05.20031773

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