

Effect of Quarantine on the Reproductive Number of COVID-19

Caitlin Seibel, Mentor: Dr. Aditi Ghosh
University of Wisconsin – Whitewater, Department of Mathematics

Introduction

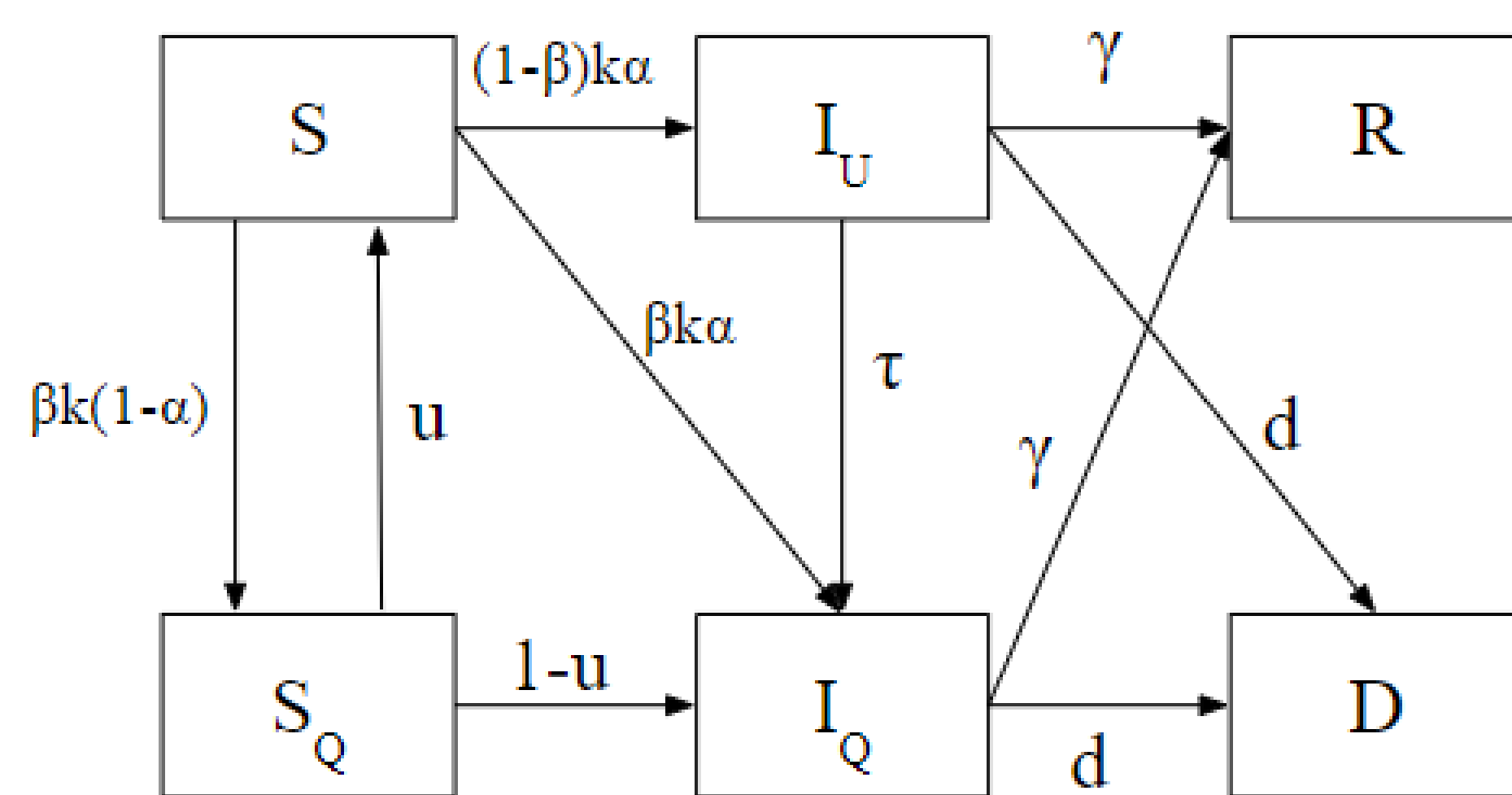
The worldwide outbreak of COVID-19 starting in late 2019 has had a major impact on our everyday lives. Questions have been raised about the most effective methods to control this disease outbreak before vaccines are made available. Many non-pharmaceutical interventions, such as social distancing and mask-wearing, have been proposed to limit person-to-person spread of COVID-19. **In this study, we use a mathematical model to analyze the effect of quarantine in 7 countries in Europe and Asia.**

SIR Mathematical Model

We use the following compartments in our model to define the flow of infection:

- S = Susceptible
- S_Q = Susceptible Quarantine
- I_U = Infectious Undetected
- I_Q = Infectious Quarantine
- R = Recovered
- D = Deceased

Schematic Diagram:

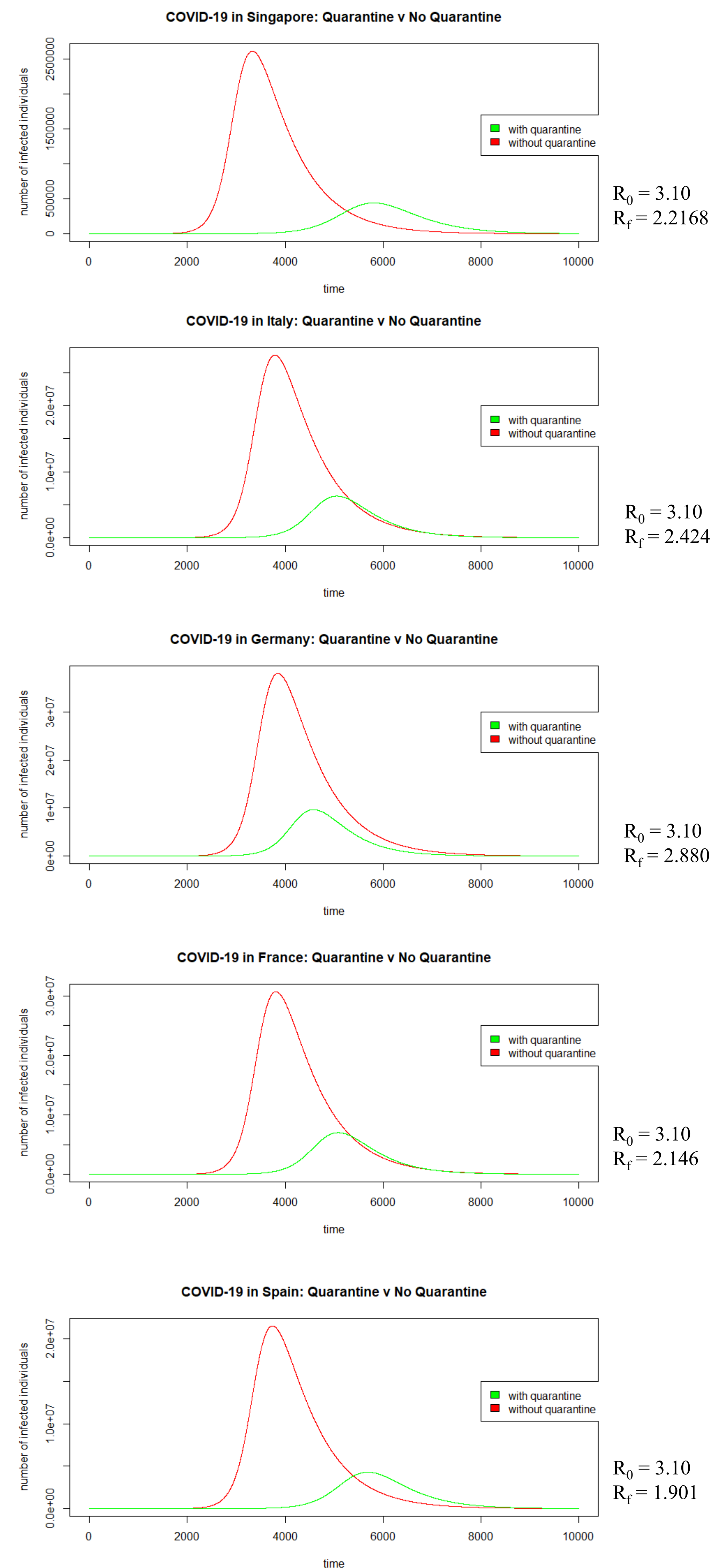


Model:

$$\begin{aligned} \frac{dS}{dt} &= uS_Q - \frac{\beta k(1-\alpha)}{N_0} I_U S - \frac{\beta k \alpha}{N_0} I_U S - \frac{(1-\beta)k\alpha}{N_0} I_U S \\ \frac{dS_Q}{dt} &= \frac{\beta k(1-\alpha)}{N_0} I_U S - uS_Q - (1-u)S_Q \\ \frac{dI_U}{dt} &= \frac{(1-\beta)k\alpha}{N_0} I_U S - (d + \gamma + \tau)I_U \\ \frac{dI_Q}{dt} &= \frac{\beta k \alpha}{N_0} I_U S + \tau I_U + (1-u)S_Q - (d + \gamma)I_Q \\ \frac{dR}{dt} &= \gamma(I_U + I_Q) \\ \frac{dD}{dt} &= d(I_U + I_Q) \end{aligned}$$

Results

In order to analyze how different levels of quarantine effect the spread of COVID-19, we use our model to simulate the effect of quarantine on the number of infected individuals. We assume that with quarantine, individuals who are exposed to or infected with COVID-19 quarantine for approximately 14 days.



Results, cont.

We then use the parameters utilized in the simulation to calculate the basic and effective reproductive number for each country over the months of February to May 2020. The reproductive number is the average number of secondary infections caused by one infectious individual. For the basic reproductive number, we calculate the reproductive number with the parameters for no quarantine measures. The effective reproductive number takes the quarantine measures into account and is impacted by the proportion of individuals who are still susceptible.

We found that the basic reproductive number for COVID-19 was approximately 3.10 for the countries we researched. With quarantine measures, the effective reproductive number ranged from 1.51 to 3.10 depending on the average days spent in quarantine and the average number of person-to-person contacts per day in the different countries. For example, the table of values for Singapore is shown below. The quarantine measures for the country started early (around February 7, 2020) and continued to be moderately strict through the end of the time period we observed.

Reproductive Number of COVID-19 in Singapore

	Feb	Mar	Apr	May
R_0	3.10	3.10	3.10	3.10
R_f	2.880	2.2168	1.5507	1.545

Conclusion

During the COVID-19 pandemic, we have observed that non-pharmaceutical interventions have been heavily utilized to combat the spread of disease before a vaccine becomes available. Through our research, we have seen through our model that quarantine measures that limit person-to-person contacts have reduced the effective reproductive number of COVID-19 in all the countries we incorporated. In addition, countries with stricter regulations, such as Singapore, showed lower reproductive numbers than those with less strict regulations, such as Germany. Our recommendation would be to continue using quarantine as a method to control the spread of COVID-19.

Acknowledgements

We would like to thank the UW-Whitewater Summer Undergraduate Research Fellowship for this amazing research opportunity.