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THE STUDY OF COVID-19 WITHIN THE STATE OF NORTH CAROLINA IN THE UNITED STATES

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Abstract

Research on COVID-19 was done for North Carolina to assess local governmental policies, to measure COVID-19 growth rate, and to discover what predictors impact COVID-19 spread. Using a Time-Delayed SIR model, removal rates were calculated to compare how seven major metros from N.C. handled the pandemic. COVID-19 Data was collected from the Center for Systems Science and Engineering (CSSE) at Johns Hopkins, and the U.S. census was used for N.C. demographic data. MATLAB was used to perform multiple linear regression and solve the time-delayed Susceptible, Infected and Removed (SIR) model to evaluate local governmental policy by measuring four removal rates of each studied metro throughout the government control policies. Through the removal rate calculation, we found that upon lockdown restrictions being eased, locations near the coast suffered, despite doing well in removing infected COVID-19 persons. In the populous Charlotte-

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Concord-Gastonia metro, COVID-19 growth rates were higher than other metros. Nevertheless, it had the highest removal rates meaning this metro did well in handling the pandemic. Next, using multiple linear regression, the most substantial correlating factor for COVID-19 transmission was a young age. The White and Black race populations were correlating factors with COVID-19 spread. Leading the age correlating predictor for the death rate in the largest metros was the 85-100 age group. In this same analysis, the 51-84 age group was found to be inversely correlated. Lastly, our education study indicates less education correlates with COVID-19 cases.

Keywords: COVID-19, time-delayed SIR model, compartmental model, multiple linear regression, government policy, removal rates

The Study of COVID-19 Within the State of North Carolina

On March 3, 2020, North Carolina reported its first confirmed case of COVID-19 in Wake County, North Carolina, US (*Dong et al., 2020*). Due to how COVID-19 has a high transmission rate and spreads through respiratory droplets, health care providers began recommending common measures taken to fight against the flu such as washing one's hands, avoiding touching one's face, and covering coughs and sneezes. Furthermore, Governor Roy Cooper proactively created a Task Force for COVID-19 whose actions (*North Carolina Identifies First Case of COVID-19*, n.d.) are meant to reduce the spread of COVID-19.

COVID-19 has proven to spread quickly and therefore, lockdowns were put in place; however, there are several issues with a global lockdown, such as the increase in depression, the loss of jobs, and the global COVID-19 recession (Fava, 2020). This study will explore the impact of government mandates and regulations affected by each major metro within North Carolina and various correlations of COVID-19 transmission such as race, age, and gender.

Materials & Methods

Data for SIR model and growth rate. In our compartmental (time-delayed SIR) model the seven metros studied were Charlotte-Concord-Gastonia, Raleigh-Durham-Chapel Hill, Greensboro-High Point, Asheville, Hickory-Lenoir-Morganton, Wilmington, and Jacksonville. Data on confirmed COVID-19 cases and deaths were collected from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

Growth Rate Estimate. Upon the onset of the COVID-19 pandemic outbreak, the number of total confirmed cases is growing exponentially. Due to the limitation of the testing, we can assume that.

$$N(t) = F(t)e^{kt}N(0) \quad (1)$$

Where $N(t)$ denotes the number of total confirmed cases at time t, $0< F(t)\leq 1$ represents the capability of testing, k denotes the exponential growth rate, and $N(0)$ indicates the initial value.

Using the data in the format of $log(N(t))$, we can see that the capability of testing $F(t)$ and growth rate k become independent, i.e., the lack of testing does not affect the fitting of growth rate. The reason is explained by equation 2. Suppose that:

$$\log(N(t)) = \log(F(t)) + k(t) * t \quad (2)$$

Consequently, since $log(F(t))$ in equation two will always be relatively small, even on very conservative and extreme estimates for the capability of testing, it will not affect the slope of fitting, which is the growth rate $k(t)$. In addition, the growth rate $k(t)$ can be used to the assessment of reproducing number $R_0 \sim e^{k(t)t}$, the containment of this pandemic needs the growth rate $k(t)$ as small as possible. To understand the situations in North Carolina, we focus on seven major metro regions, they are Charlotte-Concord-Gastonia area, the Research Triangle, Asheville, Greensboro-Highpoint, Wilmington, Jacksonville, and Hickory. It was found that the number of new cases was on a natural decline, but government mandates further decreased the growth rates of cases.

Growth Rate Study. For each metro, we split their cases into four events and considered the incubation period of the virus. The average incubation period of COVID-19 is about seven days (*Qin et al., 2020*), so we used this number for incubation globally through our study when needed. We assume that Event 1 began on the date of the first case and ended seven days after March 17. If no cases were reported by March 17, 2020, then we used that as the starting date by filling the blanks as if having only one reported case until real cases began being reported. This could be done to so we could continue to take logarithm of the confirmed case as $log(1) = 0$. It is important to note that March 17 was chosen as event one because on that date Governor Roy Cooper announces Executive Order NO. 118, a stay-at-home order to go into effect March 27. During this period, schools closed in-person classes and restaurants were closed for dine-in. Event two encapsulates what happened after this initial stay-at-home order was eased. Event three represents the time period of Executive order NO. 131. Event four corresponds to Phase 1 of the N.C. state reopening plan, where businesses could open with restrictions.

Event 1: Date of the first COVID-19 case reported + incubation period (seven days) - March 17 + incubation period

Event 2: March 18 + incubation period - April 8 + incubation period

Event 3: April 9 + incubation period - May 7 + incubation period

Event 4: May 8 - July 29

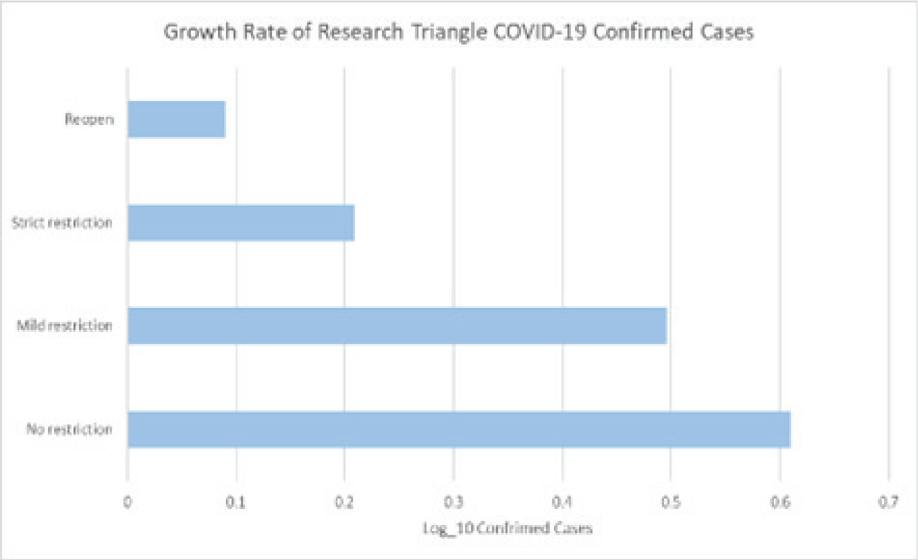
We then took the log of the cases for each event. These are presented below in Figure 1. We can see that right on the event shifts, we are having effects on growth rate. In combination with the SIR model, this part of the study allows seeing the complete picture of how successful government mandates are by analyzing both growth rate and removal rate together. Furthermore, all growth rates were weighted by renormalizing the population of each metro by dividing by the total population in said metro seen in equation 3.

$$\frac{Actual\ Growth\ Rate * Population\ of\ County}{Total\ Population\ of\ Metro} \tag{3}$$

Figure 1

COVID-19 Growth rates of a.) The Research Triangle, b.) Charlotte-Concord-Gastonia, and c.) Asheville

a.) Research Triangle COVID-19 Growth rate



Note. The growth rate, k(t), of COVID-19 in the Research Triangle from equation 2.

Removal Rates Using the SIR Model. In this section, we consider a time-delayed SIR model for the spread of disease. Let *t* be the number of passing days since the disease occurs, and let

- *S(t)* denote the number of susceptible individuals,
- *I(t)* be the number of infected individuals and
- *R(t)* be the number of removed individuals.

The system of time-delayed SIR model reads:

$$\frac{dS}{dt} = -rIS(t - T_1) \quad (4)$$

$$\frac{dI}{dt} = rIS(t - T_1) - aI(t - T_2) \quad (5)$$

$$\frac{dR}{dt} = \gamma I(t - T_2) \quad (6)$$

Where τ_1 is the average days of the incubation period, and τ_2 represents the average days of removal (either starting self-isolation or being hospitalized). We assume that $\tau_{1 \geq} \tau_2$ as when symptoms are nearly on set, that individual usually will be self-isolated. The parameter β is the average infection rate and γ is the average removal rate or removal rate. The removal rate is what we will figure out for each region and then test against our model. When we have a good removal rate to fit our model, we can then compare various metros to figure out what the government control methods were. The removal results are seen in Table 1, and their accuracy can be seen by looking at Figure 2 and seeing how well the pink line matches with the confirmed cases. Table 1 and Figure 2 are explained more in the following pages and the appendix.

The initial conditions are given as $S(0) = S_0$, $I(0) = I_0$ and $R(0) = 0$. The SIR model assumes that the total number of populations remains constant, so we have:

$$S(t) + I(t) + R(t) \equiv S(0) + I(0)$$

To implement the numerical simulation, we employ the MATLAB internal discrete differential equation solver **dde23** and fit the parameters based on real data. Our focus is to estimate the removal rate γ within each metro region, because we think γ is a better quantity than the case growth rate when assessing the local government policies.

Our study of seven metros generally followed the same pattern and flattened over time as government mandates were put in place to control the growth of COVID-19. The use of this model was to evaluate the performance of government policy within each metro by estimating the piece-wise removal rates of each event period defined in the growth rate study.

Methods for Multiple Linear Regression. The areas chosen allowed an analysis of how differences such as age density, geographical properties, and total population played into the study. For the regression study, age and population data were gathered from the North Carolina Office of State Budget and Management (OSBM) and renormalized so we could adequately compare metros with different population sizes. All data was processed through vim script and then extracted and used in MATLAB. The **fitlm** function was used to perform the multiple linear regression. All COVID-19 data is retrieved from the date of each county's first COVID-19 case until July 6, 2020. In our education study, data was gathered from the U.S. census.

We used the following equation with b_1 through b_n representing the weights of the factors and x_1 and x_n represents a potential factor such as age. MATLAB will solve for our b's or weights and the various results are given in the appendix.

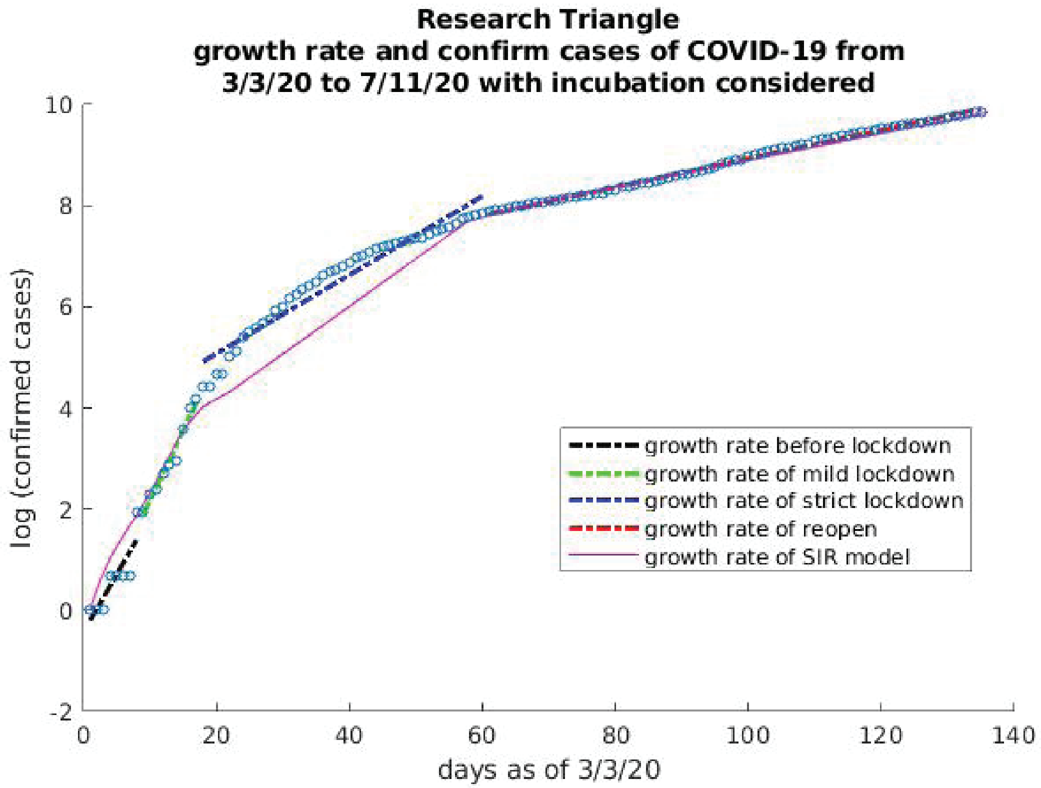
$$y = b_0 + b_1 * x_1 + b_2 * x_2 + \cdots + b_n * x_n \tag{7}$$

Results

Time-Delayed SIR Model & removal rates. By studying the removal rates calculated through our Time-Delayed SIR model, we can compare how government mandates affected each metro. The removal rate, γ in equation 6, is defined as the part of the infected population and cannot infect others. This can be reached by quarantine, dying, and even proper hygiene such as mask-wearing and hand washing. If government policy were effective, we would expect removal rates to increase upon the lockdown phase and decrease at the other phases. Also, by comparing the different stages of reopening, removal rates can again be analyzed to note what is working and what is not. Without government intervention, one would expect the curve to become flatter when everyone eventually becomes infected. Still, there would be huge spikes near the first case, which would cause over-hospitalization. This is mainly because of the higher removal rate being close to 0 without intervention. The time-delayed SIR model is represented by the pink line, such as in Figure 2 and subsequent figures. Please see the appendix for all seven models.

Figure 2:

The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for the Research Triangle Metro



Note. The SIR is modeled as the pink line here from solving the system of equations shown in equations 4,5, and 6. The actual number of cases every day are the dots. The dotted lines represent k(t) calculated in equation 2.

As seen in Table 1 below, Charlotte-Concord-Gastonia had the highest removal rate despite its large population size and most prominent confirmed cases. We know that Charlotte has a large working-class of white-collar workers (*Kotkin*, 2018), and it is suggested that this metro adapted quickly to the pandemic. Logically, working from home was very feasible for many of these city jobs. Furthermore, most metros had high removal rates upon the initial lockdown compared to the pre-lockdown period, meaning that the initial lockdown, among other actions by the state, effectively reduced the growth rate of COVID-19. Additionally, the Research Triangle was less successful than Charlotte-Concord-Gastonia at removing infected people from the susceptible group. This is seen in Table 1 below, a higher removal rate means more COVID-19 infected persons were separated from the non-infected population

Table 1

Removal Rates of Seven NC Metros

Location	Pre-lockdown Removal Rate	Lockdown Removal Rate	Phase 1 Removal Rate	Reopen Removal Rate
Asheville	.0065	.008	.007	.012
Research Triangle	.0065	.001	.01	.013
Charlotte-Concord-Gastonia	.01	.005	.0135	.014
Wilmington	.0065	.001	.0145	.0015
Greensboro-High Point	.0065	.00095	.01	.015
Hickory	.01	.006	.004	.008
Jacksonville	.035	.01	.008	.012

Note. These values here is the piecewise calculated from the system of equations in 4,5, and 6.

In the future, by studying removal rates, one can provide data on how mask-wearing has affected COVID-19 transmission. For example, on June 26, 2020, face masks became required in public spaces statewide. By adding another event into this study, we can look at how this control measure affected the COVID-19 growth rate. Furthermore, it is difficult to measure how the lock-down affects people, so we do not suggest a severe lockdown is necessary. The metros not near the beach experience slower growth rates upon lockdown restrictions being eased. Also, besides the economic recession brought on by the pandemic, preliminary research shows that the pandemic increases depression and anxiety among people (*Twenge,* 2020).

Multiple Linear Regression. It was hypothesized that the younger population, those under 65 years of age, were the primary spreaders of the disease. Multiple Linear regression was used to test this. The data used came from a CSV data set provided by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University(*Dong et al.,* 2020 that tracked the confirmed cases by county in the USA in real-time. The **fitlm** function was used in MATLAB and our two variables for predicting cases were the age group of people under 65 and second, the group of people over 65. The results show that the age groups under 65 positively correlated with confirmed cases in Table 2 below. The resulting small p-value of .0002 indicates that we can reject the Null Hypothesis that age is not a correlating contributor to COVID-19 cases and we can say that a younger population correlates with more cases.

This does not mean that older people take better care of themselves but that the younger population has more contacts with infected people. A possible justification for this is that they often work or go to school. It is known that 65 is a typical retiring age (*Lumsdain, Robin, et al., 1995*). Also, we can see that by looking at our T-statistics in general, younger age groups were correlated to the growing number of COVID-19 cases and older people reduced the number of cases. This is confirmed by our test statistic because we produce an extremely high value for b1 and a negative value for b2. It is important to note that both Charlotte-Concord-Gastonia and the combinations of all studied locations respectfully produced p-values of .046 and .0002. These low values show how little evidence there is against the claim that younger people correlate with more COVID-19 cases and that the older population correlates with fewer cases. Due to the number of counties, Jacksonville and Wilmington did not produce quantifiable results. When separating the data into male and female, our study concludes that just age is the correlating factor for COVID-19 transmission and not gender in any way. The separate gender results are seen in Table 3 and Table 4 in the appendix.

Table 2

Age Correlation Data for All Genders

Location	Number of Observations (Counties)	Error degrees of freedom	b1: 0-65 age range	b2: 65-100 age range	Test Statistic 1	Test Statistic 2	Coefficient of b1 is greater than Coefficient of b2
Asheville	5	3	.0024	.0058	.30	.20	False
Research Triangle	9	7	.01	.0096	2.11	.26	True
Charlotte-Concord-Gastonia	7	5	.019	-.04	2.64	-1.17	True
Greensboro-High Point	3	1	.02	-.05	.88	- .70	True
Hickory	4	2	-.002	.05	-.06	.3	False
Combined Areas	31	29	.01	-.01	4.27	-.94	True

Note. The results of Multiple Linear Regression when studying the correlation between gender and COVID-19 cases.

Similarly, the correlation between age and dying of COVID-19 was investigated in Table 5 below. For the Charlotte-Concord-Gastonia area, p-values for b3(51-84 age group) and b4(85-100) were .03. Also, although the 0-23 age group did not have a p-value of under 0.05; however, the table shows that this group contributed to the number of diseased cases. Therefore, we can conclude that the 51-84 age group are not at high risk of dying in this region. This study does not, however, consider the health of those in this age group. If someone has underlying health issues at this age, they would be put into a high-risk group based on other studies (*Cases, Data, and Surveillance, 2020)*. Furthermore, the age group 85-100 were at a high risk of dying. For the combined regions and the Research Triangle, it was found that no age group was at particular risk.

Table 5

Age-Diseased Correlation Study

Location	b1:0-23 age group	b2:24-50 age group	b3:51-84 age group	b4: 85 – 100 age group	Test Statistic 1	Test Statistic 2	Test Statistic 3	Test Statistic 4
Combined Metro Areas	-0.0002	0.0006	-0.0001	0.004	-0.37	0.72	0.17	0.76
Charlotte-Concord-Gastonia	0.002	-0.001	-0.001	0.35	2.7	-1.7	-3.67	3.88
Research Triangle	-0.00008	-0.0006	0.001	0.002	-0.023	-0.19	0.74	0.17

Note. The results and parameters of the Multiple Linear Regression when looking at the correlation between the COVID-19 deceased population and age.

When considering race, we began by comparing how two separate races fared on the transmission of COVID-19 in Table 6. The two races were: Black and White. Other races were not included due to how small their percentage is in the North Carolinian population. We see that both the combined Metro areas and Charlotte-Concord-Gastonia suggest a correlation among COVID-19 cases for both black and white people. We also see that our p-value for this conclusion, in these two areas, is .03, meaning both races have a correlation with COVID-19 cases. Therefore, we can reject the null hypothesis that race does not affect COVID-19 transmission. However, since both races did have positive correlation, we can justify that race is not an important factor for predicting COVID-19. There is, however, an issue. The whole picture of race and its correlation with COVID-19 cases is not complete until socioeconomic and education levels are considered. It should also be noted that there could be a connection from our earlier conclusion that masks helped control the spread of COVID-19.

Table 6

Data for Race Study

Location	b1: Black Population	b2: White Population	Test Statistic 1	Test Statistic 2	P value 1	P value 2
Combined Metro Areas	.02	.01	3.5	4.8	.001	6.4e-5
Charlotte-Concord-Gastonia	.05	.005	5.2	5.4	.04	.03
Research Triangle	.01	.01	1.3	2.6	.25	.06
Greensboro-High Point	.01	.01	1.3	2.6	.25	.06

Note. The results and parameters of the Multiple Linear Regression when looking at the correlation between Race and COVID-19 cases.

By comparing the Charlotte-Concord-Gastonia area against the Research Triangle area in

Table 6 above, we can see that there is statistically significant evidence to support the claim that in Charlotte-Concord-Gastonia, both Black and White people correlate with confirmed cases. Socioeconomic status was not considered, so the complete picture is not yet fully understood. When studying race and its play in the transmission of COVID-19 it was essential to consider education as an alternative for socioeconomic status.

The correlation program considered three predictor variables: Percentage of Population without High School Graduation, Percent of Population with a High School Diploma, and Percentage of Population with a bachelor's degree or higher. In Table 7, Our highest T-statistic was produced from the percentage of population without a High School diploma, and the lowest T-statistic was produced from the college education proportion of the population.

Table 7

Education Correlation with COVID-19 transmission

Location	b1: % of Population without High School Graduation	b2: % of Population with only High School Diploma	b3: % of Population with a Bachelor's Degree or Higher	Test Statistic 1	Test Statistic 2	Test Statistic 3
Combined Metro Areas	0.032	0.009	0.005	0.99	1.66	0.95

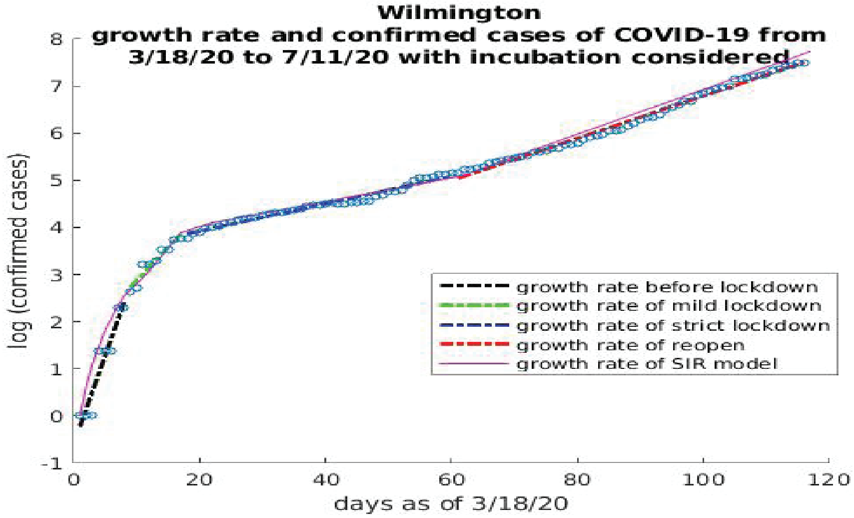
Note. The results and parameters of the Multiple Linear Regression when looking at education and its correlation with COVID-19 cases.

Discussion

By studying North Carolina metros, one could decide on government policy by metros instead of for the whole state. For example, the study adds conclusive evidence that something is not working correctly with the government policy in areas with beaches close by, as seen by the low removal rates. It is suggested that these beach areas high in tourism take extra precautions for COVID-19 transmission. Wilmington had the most notable results when studying the removal rates. We see that post-lockdown cases soared. We also see that Wilmington somehow was able to lower its removal rate upon reopening. This might seem contradictory until the geographical properties of the area are considered. Wilmington is near the ocean, and tourism is vital for its economy. The data points to the conclusion that Wilmington did not do well to remove infected people due to the high tourism. The lockdown helped slow the growth rate, but the data suggests that this metro area needs to undergo further control measures such as more increased hygiene and fever tests for tourists. We can also draw a similar conclusion for Jacksonville as they have many beaches close by and equal results.

Figure 3:

The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for the Wilmington Metro



Note. The SIR is modeled as the pink line here. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

Additional events can also be studied. By studying removal rates, one can provide data on how, for example, mask-wearing has affected COVID-19 transmission. For instance, on June 26, 2020, face masks became required in public spaces statewide. By adding another event into this study, we can look at how this control measure affected COVID-19 growth rate. Furthermore, it is difficult to measure how the lockdown affects people, so we do not suggest a severe lockdown is necessary. The metros not near the beach experience slower growth rates upon lockdown restrictions being eased by looking at our growth rates. Also, besides the economic recession brought on by the pandemic, preliminary research shows that the pandemic increases depression and anxiety among people (*Twenge,* 2020).

Lastly, on June 26, masks became mandated when going outside and being near people. The study done here stops checking cases just ten days after this; however, masks were still commonly worn. Furthermore, due to restrictions of the data date ranges, it is not studied here how the mask government regulation affected COVID-19 growth rate and removal rate. Finally, the results of our age study in combination with the education study show that younger people can be used as a predictor for COVID-19 transmission.

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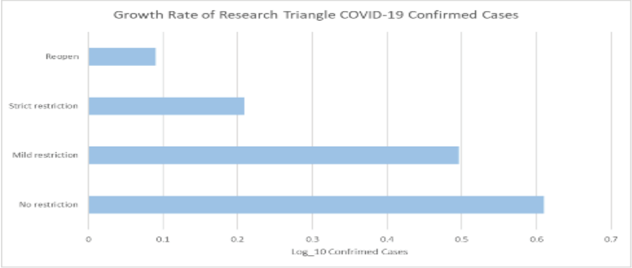
APPENDIX A

The following figure shows the growth rate k(t) of COVID-19 split into four major events.

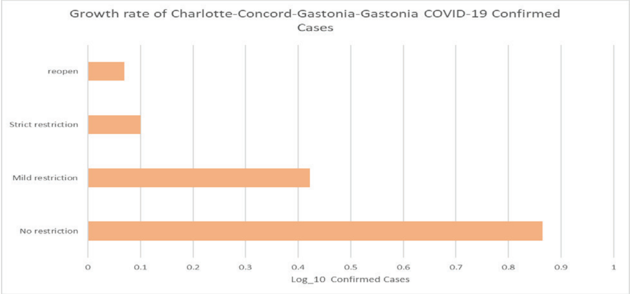
Figure A1

COVID-19 Growth rates of a.) The Research Triangle, b.) Charlotte-Concord-Gastonia, and c.) Asheville

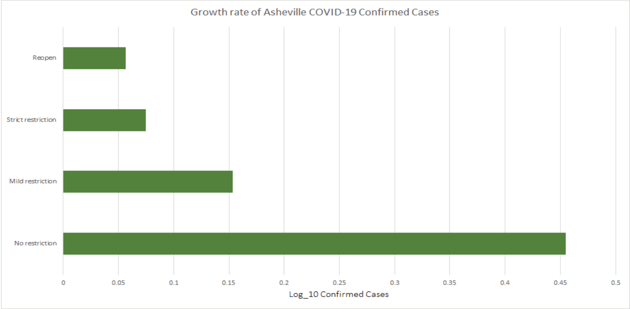
a.*)* Research Triangle COVID-19 Growth rate



b.) Charlotte-Concord-Gastonia COVID-19 Growth rate



c.) Asheville COVID-19 Growth Rate

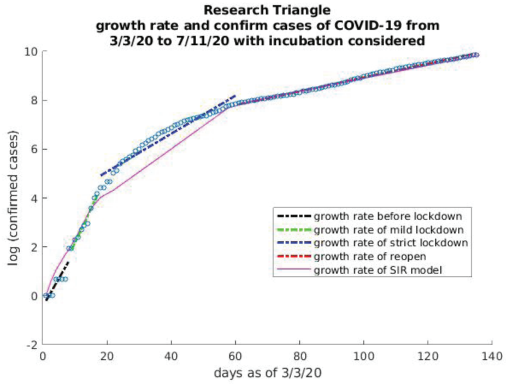


Note. The growth rate k(t), of COVID-19 in three metros calculated in equation 2.

The following graphs show the SIR model with the log of the confirmed cases. The removal rate being chosen correctly allows the pink line to properly simulate the real data. The dot points are a scatter plot of the real data.

Figure A2:

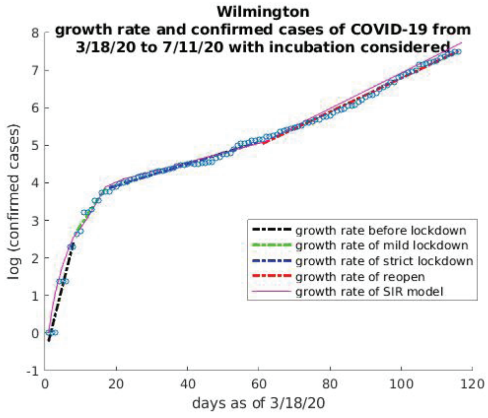
The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for the Research Triangle Metro



Note. The SIR is modeled as the pink line here from solving the system of equations below in equations 4,5 and 6. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

Figure A3:

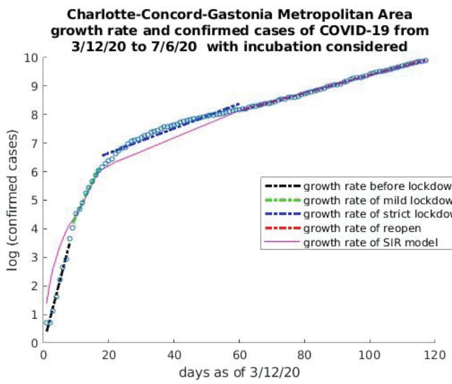
The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for the Wilmington Metro



Note. The SIR is modeled as the pink line here. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

Figure A4:

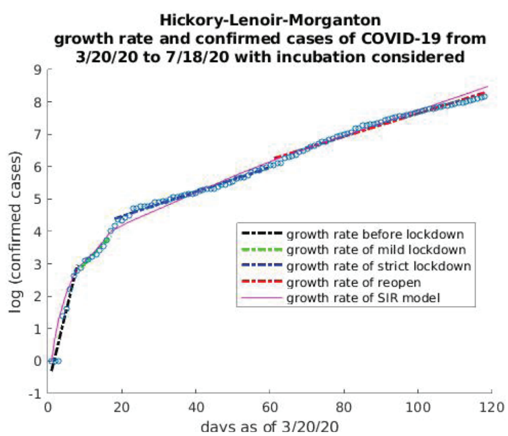
The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for the Charlotte-Concord-Gastonia Metro



Note. The SIR is modeled as the pink line here. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

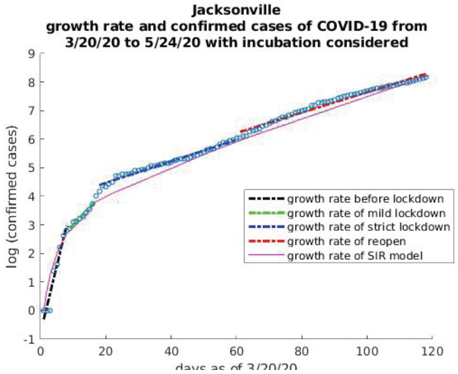
Figure A5:

The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for Hickory-Lenoir-Morganton Metro



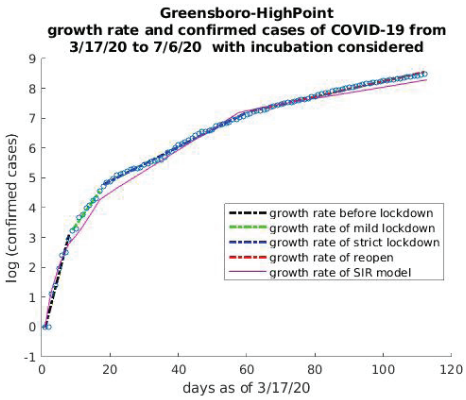
Note. The SIR is modeled as the pink line here. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

Figure A6:
The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for Jacksonville Metro



Note. The SIR is modeled as the pink line here. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

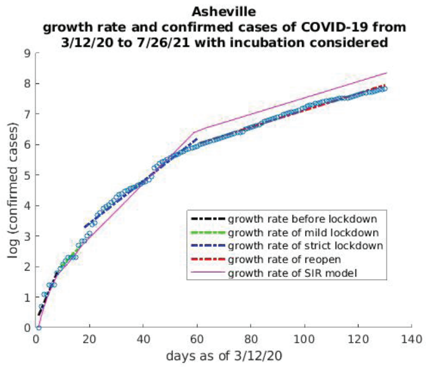
Figure A7:
The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for Greensboro-Highpoint Metro



Note. The SIR is modeled as the pink line here. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

Figure A8:

The Time-Delayed SIR Model Graphed with the Log of the Confirmed Cases for the Asheville Metro



Note. The SIR is modeled as the pink line here. The actual number of cases everyday are the dots. The dotted lines represent k(t) calculated in equation 2.

APPENDIX B

Table B1

Removal Rates of Seven NC Metros

Location	Pre-lockdown Removal Rate	Lockdown Removal Rate	Phase 1 Removal Rate	Reopen Removal Rate
Asheville	.0065	.008	.007	.012
Research Triangle	.0065	.001	.01	.013
Charlotte-Concord-Gastonia	.01	.005	.0135	.014
Wilmington	.0065	.001	.0145	.0015
Greensboro-High Point	.0065	.00095	.01	.015
Hickory	.01	.006	.004	.008
Jacksonville	.035	.01	.008	.012

Note. These values here is the piecewise calculated from the system of equations in 4,5, and 6.

Table B2

Age Correlation Data for All Genders

Location	Number of Observations (Counties)	Error degrees of freedom	b1: 0-65 age range	b2: 65-100 age range	Test Statistic 1	Test Statistic 2	Coefficient of b1 is greater than Coefficient of b2
Asheville	5	3	.0024	.0058	.30	.20	False
Research Triangle	9	7	.01	.0096	2.11	.26	True
Charlotte-Concord-Gastonia	7	5	.019	-.04	2.64	-1.17	True
Greensboro-High Point	3	1	.02	-.05	.88	- .70	True
Hickory	4	2	-.002	.05	-.06	.3	False
Combined Areas	31	29	.01	-.01	4.27	-.94	True

Note. The results of Multiple Linear Regression when studying the correlation between gender and COVID-19 cases.

Table B3

Age Correlation Data for Males

Location	Number of Observations (Counties)	Error degrees of freedom	b1: 0-65 age range	b2: 65-100 age range	Test Statistic 1	Test Statistic 2	Coeffi-
Asheville	5	3	0.005	0.01	3.02	-1.38	
Research Triangle	9	7	0.02	0.023	1.68	0.46	
Charlotte-Concord-Gastonia	7	5	0.03	-0.07	2.23	-0.88	True
Greensboro-High Point	3	1	-0.016	0.1	-5.77	7.2	
Combined Areas	31	29	0.024	-0.016	4	-0.7	True

Note. The results and parameters of the Multiple Linear Regression for studying the correlation between the male gender and COVID-19 cases.

Table B4

Age Correlation Data for Females

Location	Number of Observations (Counties)	Error degrees of freedom	b1: 0-65 age range	b2: 65-100 age range	Test Statistic 1	Test Statistic 2	Coefficient of b1 is greater than Coefficient of b2
Asheville	5	3	0.0024	0.0058	0.23	0.2	False
Research Triangle	9	7	0.01	0.059	0.34	0.027	True
Charlotte-Concord-Gastonia	7	5	0.034	-0.067	2.23	-0.89	True
Greensboro-High Point	3	1	-.0.18	0.087	-3.5	4.3	False
Hickory	4	2	n/a	n/a	n/a	n/a	n/a
Combined Areas	31	29	0.026	-0.028	4.49	-1.05	True

Note. The results and parameters of the Multiple Linear Regression for studying the correlation between the female gender and COVID-19 cases.

Table B5

Age-Diseased Correlation Study

Location	b1:0-23 age group	b2:24-50 age group	b3:51-84 age group	b4: 85 – 100 age group	Test Statistic 1	Test Statistic 2	Test Statistic 3	Test Statistic 4
Combined Metro Areas	-0.0002	0.0006	-0.0001	0.004	-0.37	0.72	0.17	0.76
Charlotte-Concord-Gastonia	0.002	-0.001	-0.001	0.35	2.7	-1.7	-3.67	3.88
Research Triangle	-0.00008	-0.0006	0.001	0.002	-0.023	-0.19	0.74	0.17

Note. The results and parameters of the Multiple Linear Regression when looking at the correlation between the COVID-19 deceased population and age.

Table B6

Data for Race Study

Location	b1: Black Population	b2: White Population	Test Statistic 1	Test Statistic 2	P value 1	P value 2
Combined Metro Areas	.02	.01	3.5	4.8	.001	6.4e-5
Charlotte-Concord-Gastonia	.05	.005	5.2	5.4	.04	.03
Research Triangle	.01	.01	1.3	2.6	.25	.06
Greensboro-High Point	.01	.01	1.3	2.6	.25	.06

Note. The results and parameters of the Multiple Linear Regression when looking at the correlation between Race and COVID-19 cases.

Table B7

Education Correlation with COVID-19 transmission

Location	b1: % of Population without High School Graduation	b2: % of Population with only High School Diploma	b3: % of Population with a Bachelor's Degree or Higher	Test Statistic 1	Test Statistic 2	Test Statistic 3
Combined Metro Areas	0.032	0.009	0.005	0.99	1.66	0.95

Note. The results and parameters of the Multiple Linear Regression when looking at education and its correlation with COVID-19 cases.

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