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Math 301-02

Report 3

Flattening the Curve of COVID-19 cases in Virginia

**Intro:**

In this report we will determine if Virginia has flattened its total number of COVID-19 cases by day logistic curve. We will be using 3 exponential models as an approximation of the logistic curve for the total number of COVID-19 cases by day to estimate the exponential growth rate of the logistic curve. From our analysis and interpretation of the models, we determined that the growth rate had slowed significantly between the models and there is a potential flattening of the logistic curve.

**Data Collection and description:**

Our data was obtained from an observational study done by the New York Times data repository on 4/8/2020 and gives the total number of reported COVID-19 cases and deaths by date for all states in the United States of America through 4/6/2020. Our variables are the total number of COVID-19 cases for Virginia and the days the COVID-19 cases occurred. The total number of COVID-19 cases is quantitative and it is a response variable. The days the COVID-19 cases occurred is categorical and it is an explanatory variable.

The three models we are analyzing are Model 1:  Estimating the exponential growth rate using all data (from days 1 to 27 (3/11/2020 to 4/6/2020)),  Model 2: Estimating the exponential growth rate from days 7 to 16 (3/17/2020 to 3/26/2020), and Model 3:  Estimating the exponential growth rate from days 17 to 26 (3/27/2020 to 4/5/2020).

**Analysis of Models:**

**Model 1:** Fitting an exponential curve to the data from Day 1 to Day 27. The equation of our line is *ln(number of cases)=2.695193+0.208854(Day)*. Given *ln(number of  cases)= 2.695193 + 0.208854(Day)* we now get *e2.695193=14.80837* or *Cases=14.80837e0.208854(Day)*. The growth rate *(r) =0.208854.* To determine if this model gives a significant linear relationship between Ln(Total Number of Cases) verses from Day 1 to Day 27 we look at Test statistic (F(1,25)=1771.4 and p-value=2.2*e-16*. Since the p-value is less than 0.05 we can determine there is a significant linear relationship between ln(number of cases) and Day from Day 1 to Day 27.

*ln(total number of cases)*

R2 = 0.9861. 98.6% of the variation in *ln(cases)* is explained by the linear model using Day. Using our residual plots for Model 1: Residual error shows one sign of non-normality from the histogram (skewed left). Residual error shows one sign of non-normality from the boxplot (outlier). Residual error is independent and not consistent across fit (scatterplot).

**Model 2:** Fitting an exponential curve to the data from Day 7 to Day 16. The equation of our line is *ln(number of cases)=2.434714+0.239086(Day)*. Given *ln(number of  cases)= 2.434714 + 0.239086(Day)* we now get *e2.434714=11.41255426* or *Cases=11.41255426e0.239086(Day)*. The growth rate *(r) =0.239086.* To determine if this model gives a significant linear relationship between Ln(Total Number of Cases) verses from Day 7 to Day 16 we look at Test statistic (F(1,8)=602.74 and p-value=8.092*e-09*. Since the p-value is less than 0.05 we can determine there is a significant linear relationship between ln(number of cases) and Day from Day 7 to Day 16

*ln(total number of cases)*

R2 = 0.9869. 98.7% of the variation in *ln(cases)* is explained by the linear model using Day. Using our residual plots for Model 2: Residual error shows no sign of non-normality (histogram). Residual error shows no sign of non-normality (boxplot). Residual error is not independent and consistent across fit (scatterplot). We are 95% confident the number of days it takes for the number of cases to double is between 2.65 and 3.20.

**Model 3:**  Fitting an exponential curve to the data from Day 17 to Day 26. The equation of our line is *ln(number of cases)=3.632547+0.165449(Day)*. Given *ln(number of  cases)= 3.632547 + 0.165449(Day)* we now get *e3.632547=37.80899* or *Cases=37.80899e0.165449(Day)*. The growth rate *(r) =0.165449.* To determine if this model gives a significant linear relationship between Ln(Total Number of Cases) verses from Day 1 to Day 27 we look at Test statistic (F(1,8)=2169.8 and p-value=4.986*e-11*. Since the p-value is less than 0.05 we can determine there is a significant linear relationship between ln(number of cases) and Day from Day 17 to Day 26.

*ln(total number of cases)*

R2 = 0.9963. 99.6% of the variation in *ln(cases)* is explained by the linear model using Day. Using our residual plots for Model 3: Residual error shows no sign of non-normality (histogram). Residual error shows no sign of non-normality (boxplot). Residual error is not independent and consistent across fit (scatterplot).

We are 95% confident the number of days it takes for the number of cases to double is between 3.99 and 4.41.

**Interpretation of Models:**

Models 2 and 3 indicate a potential flattening of the logistic curve that models the total number of COVID-19 cases for Virginia. In model 2 we have a growth rate of *(r) =0.239086.* In model 3 we have a growth rate of *(r) =0.165449.* From this information, we can determine that the growth rate had slowed significantly between the models and there is a potential flattening of the logistic curve.

These models would not be suitable for extrapolation because it is only the data for 27 days which is not reliable for predicting the damage of a pandemic. The Fitted Curve graphs show that the fitted portion does not line up with the portion beyond the fit days.

These models coincide with Virginia residents’ efforts to flatten the curve. On March 12, 2020, Governor Northam declared a State of Emergency in Virginia. We see in the fitted curve models that was when the growth rate started to increase. As days went on, schools were suspended and Governor Northam issued an order allowing law enforcement to enforce a ban on gatherings of more than 10 people in public spaces. We see in the fitted curve for model 2 that the growth rate began to decrease and beyond the fitted curve. On March 30, 2020,  Governor Northam issued a stay-at-home order, to be effective until June 10 unless amended or rescinded by a further executive order. We can see in the fitted curve for model 3 that the growth rate was not decreasing at the same rate as earlier in the month, so the Governor needed to issue the next order in order to keep flattening the curve.

**Appendix:**

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