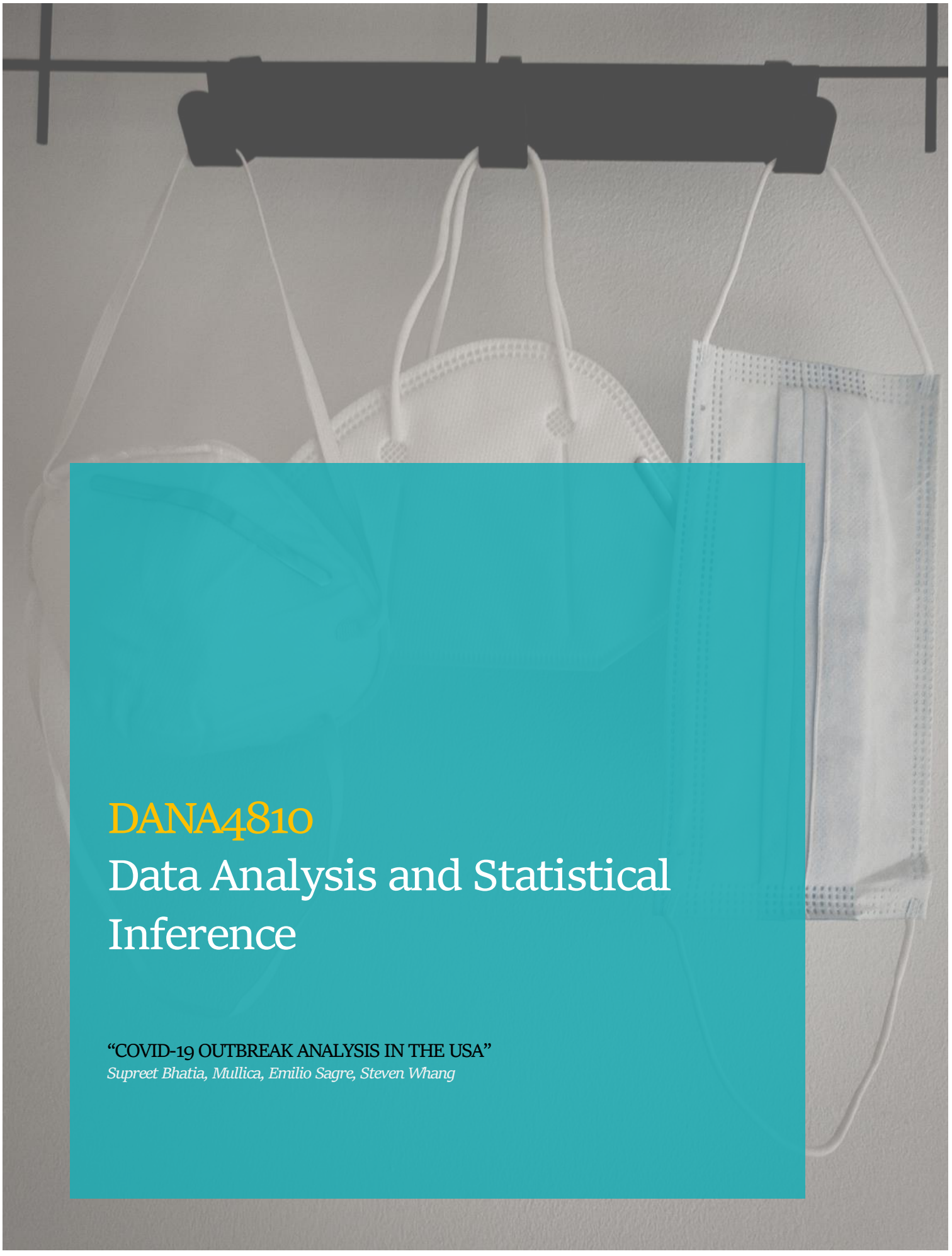

DANA4810
Data Analysis and Statistical Inference

"COVID-19 OUTBREAK ANALYSIS IN THE USA"

Supreet Bhatia, Mullica, Emilio Sagre, Steven Whang

Contents

Overview

Purpose

The purpose of this study is to investigate the COVID-19 outbreak in the United States. This paper will use different statistical techniques in analysis. The details of various features are described in the article written by Haratian et al. (2021).

References:
Haratian, A., Fazelinia, H., Maleki, Z., Ramazi, P., Wang, H., Lewis, M.A., Greiner, R., et al. (2021), "Dataset of COVID-19 outbreak and potential predictive features in the USA", Data in Brief, Data Brief, Vol. 38, available at:https://doi.org/10.1016/J.DIB.2021.107360.

Introduction

The COVID 19 pandemic, which started in 2019, has changed the way the world works. Due to global deaths, nations around the world have taken precautions that have affected their respective economies. Because of this, it is important to study what has already transpired in order to brace for what is about to come. From the past couple of years that the pandemic has taken place, there have been heaps of real data that can be studied. This dataset provides these data. Although it only includes data regarding the United States, it can give us a clearer picture of what we are actually dealing with, so we can predict and plan accordingly for the future.

This dataset includes numerous variables that may explain the pandemic's dynamics. Most importantly, it also includes the number of daily confirmed cases and deaths of all 50 states and their respective counties across 9 months in 2021. From this, we can investigate which variables contribute to cases and deaths the most, and properly predict these all-important variables as well. By doing so, we can slow down the deaths globally since we will find out the contributing factors to both cases and deaths.

Note:

Several pre-identified variables were removed from the dataset using Microsoft Excel. See appendix A for details.

Dataset

- Covid Dataset.csv (original dataset)
- Covid_cleanish1.csv (initially cleaned dataset where several columns were dropped using MS Excel based on the note above. We will use this dataset moving forward)

Variables

There are 36 variables. These are listed below. As for the descriptions and type, please refer to Appendix B.

- date
- county_fips
- count_name
- state_fips
- state_name
- covid_19_confirmed_cases
- total_population
- covid_19_deaths
- social_distancing_total_grade
- daily_state_test
- precipitation
- temperature
- virus_pressure
- political_party

- female_percent
- area
- population_density
- hospital_beds_ratio
- ventilator_capacity_ratio
- icu_beds_ratio
- houses_density
- total_college_population
- percent_smokers
- percent_diabetes
- religious_congregration_ratio
- airport_distance
- passenger_load_ratio
- meat_plants
- median_household_income
- percent_insured
- deaths_per_100000
- gdp_per_capita
- Age_0_19
- Age_20_59
- Age_60
- immigrant_student_ratio

Statistical Software

- Data Transformation and Inferential Analysis

  R language using RStudio 2021.09.2+382 "Ghost Orchid" Release (fc9e217980ee9320126e33cdf334d4f4e105dc4f, 2022-01-04) for Windows Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) QtWebEngine/5.12.8 Chrome/69.0.3497.128 Safari/537.36

- Visualization

  Tableau Desktop Professional Edition 2021.4.4 (20214.22.0213.1102) 64-bit

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Cleaning and Data Transformation

The partially cleaned dataset has a total of 562,128 observations with 36 variables. The team tried loading the whole dataset into R Studio but came across an issue when running certain inferential analysis like linear regression. Our current machine can't handle large dataset computation. This leads us into reducing the number of observations with the following steps:

1. We created additional columns based on week count as reference to the date variable.
2. We converted the categorical variable 'social_distancing_total_grade' to numerical variable by converting them to a factor and then assigning them as numeric (A as 1, A- as 2 to F as 12).
3. Dropped the following variables: 'date', 'county_name', 'state_name'.
4. Grouping of the datasets will be based on aggregating the observations by 'week' and 'county_fips' since the data were recorded based on 'date' and 'county_fips'.
5. Created 2 groups of datasets for joining later since a different aggregation process will be applied.
   a. Dataset 1: 'week', 'county_fips', 'covid_19_confirmed_cases', 'covid_19_deaths' will be grouped by getting the sum of 'covid_19_confirmed_cases', 'covid_19_deaths' values.
   b. Dataset 2: all other variables except 'covid_19_confirmed_cases', 'covid_19_deaths' will be grouped by getting the mean values.
6. 2 datasets were merged using row names as reference

The new dataset has a total of 82,320 from 562,128 observations. The new dataset was reduced to 85.36% without affecting the behaviour and nature of the data.

Based on the data brief, the following age variables should add up to 100%. However, upon checking the data there were several observations with a sum of around 103%. To solve the proportion issue, we applied a simple mathematical formula to resolve the issue. We divided the variable with a certain age bracket with the total age multiplied by 100 to get the new age proportion. See below:

Age_0_19/(Age_0_19 + Age_20_59 + Age_60.)*100

Age_20_59/(Age_0_19 + Age_20_59 + Age_60.)*100

Age_60. /(Age_0_19 + Age_20_59 + Age_60.)*100

Note: For the codes, see Appendix B.

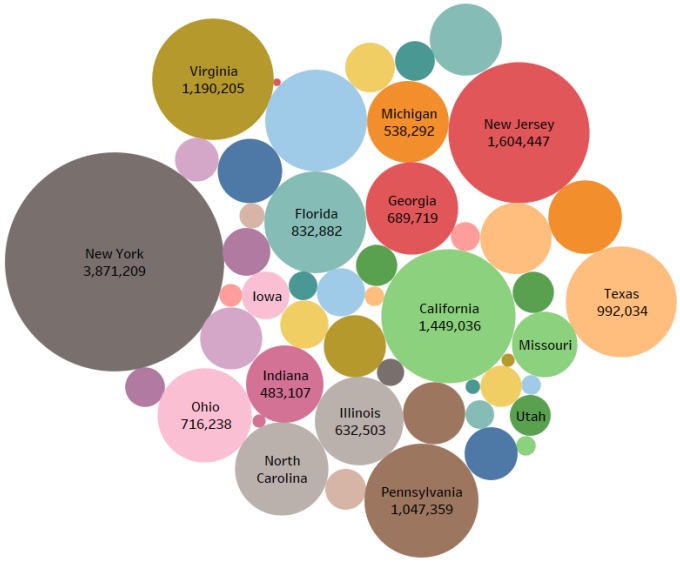
Descriptive Analysis

Overview of Dataset

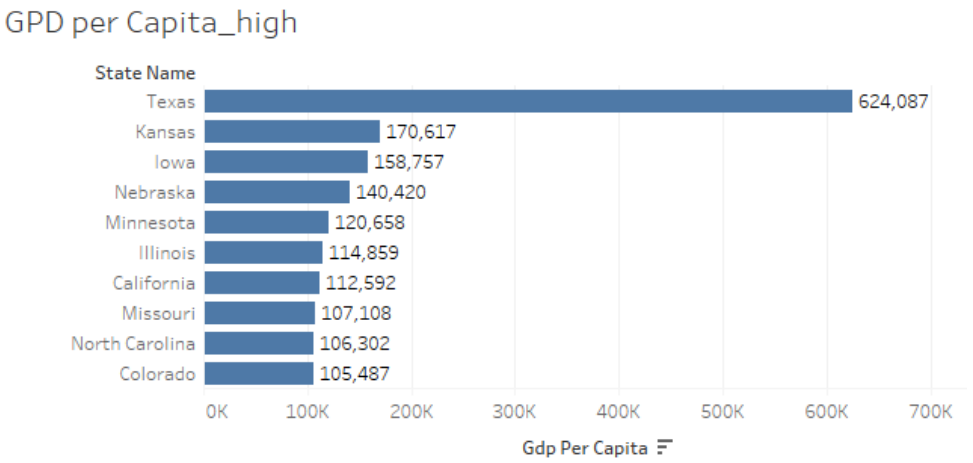
We will look at different obvious factors in our dataset that may impact the spread of COVID-19 and if these factors also impact the number of deaths caused by the virus. We will look at the performance by state and see how each differs from each other.

A. Population Density

The USA has several big cities across the country. This massive growth was a result of the industrial revolution which attracted more jobs to different people from the rural areas and immigrants across the world. The top dominating dense states are New York at 3.87 million per square mile followed by New Jersey at 1.6 million per square mile, California at 1.49 million per square mile, Virginia at 1.19 million per square mile, and Pennsylvania at 1.04 per square mile. This massive urbanization can increase the density of the state, hence may impact the spread of COVID-19.

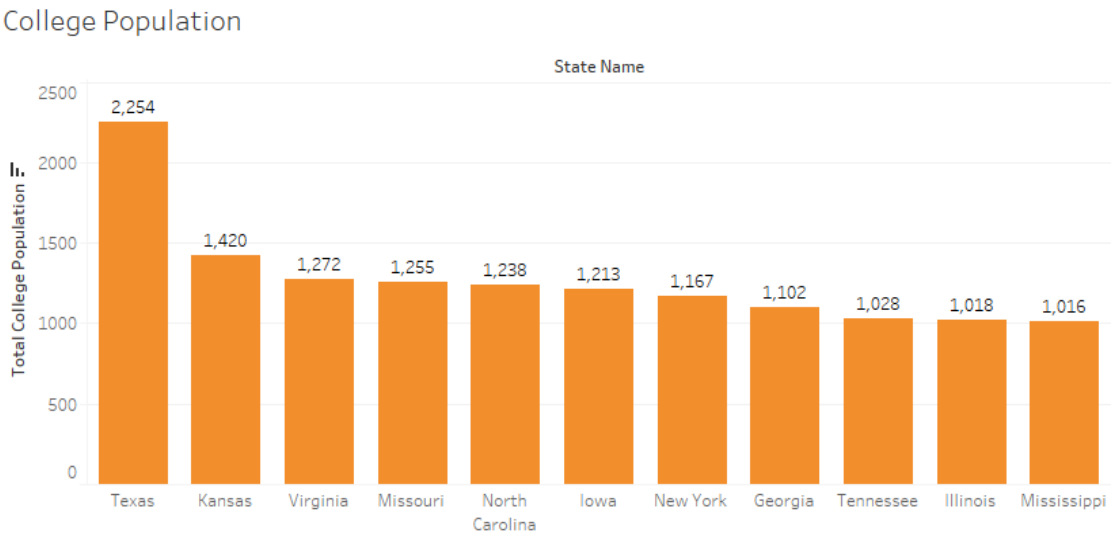


B. Gross Domestic Product (GDP) per capita



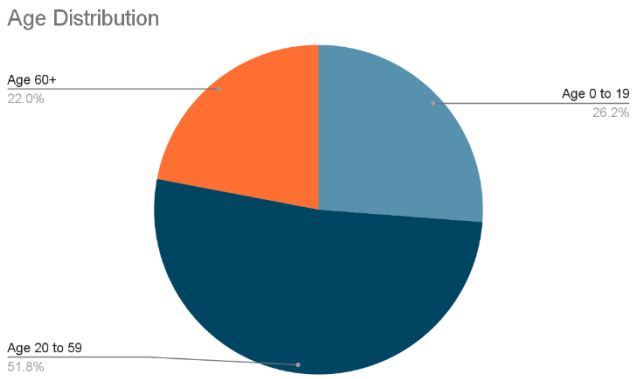
Looking at the GDP per Capita per state, Texas dominated the list at 624,087 followed by Kansas at 170,617, Iowa at 158,757, Nebraska at 140,420 and Minnesota at 120,658. The top 5 most dense state did not make it to the top 10 except for California at rank 7. This showed population density is not a good indicator that the state is performing well in terms of standard of living across different demographics. We will try to see later if having high GDP per capita can help curb the fight against the spread of COVID-19.

C. Total College Population



We are in the age of information. There are several sources we can find and consume our information. The way we consume it is based on how our critical thinking was molded. Education level plays a big role in this thinking process development. The data showed that Texas has the most educated demographics at 2,254 per total population. This is followed by Kansas at 1,420 per total population and Virginia at 1,272 per total population. This tells us that having high standard of living could be attributed to higher education as well. Later, we will see if this has impact on the spread of COVID-19 and deaths as during the peak of the pandemic there were several measures like stay-at-home orders, social distancing and wearing masks were introduced to help curve the spread. The enforcement of this however rely on the individuals who believes the true impact of this virus to the community.

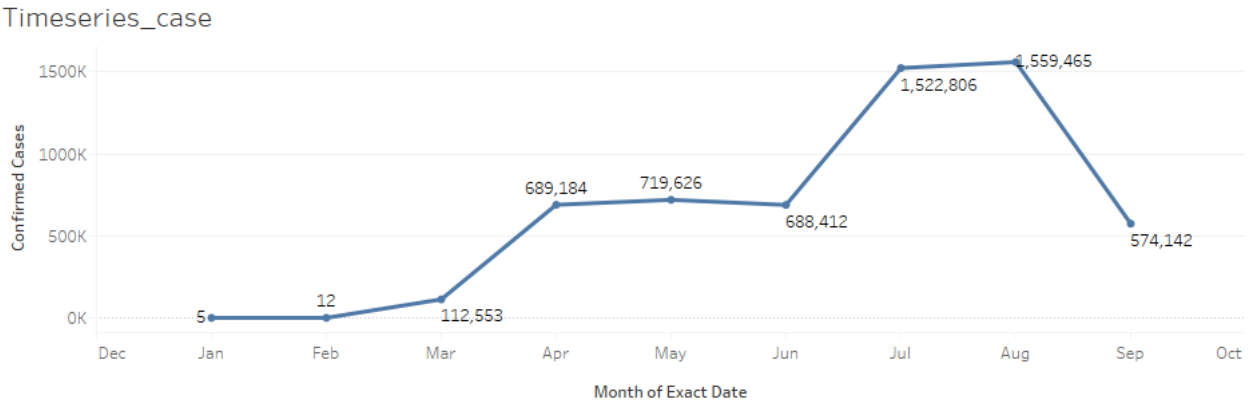
D. Age Distribution

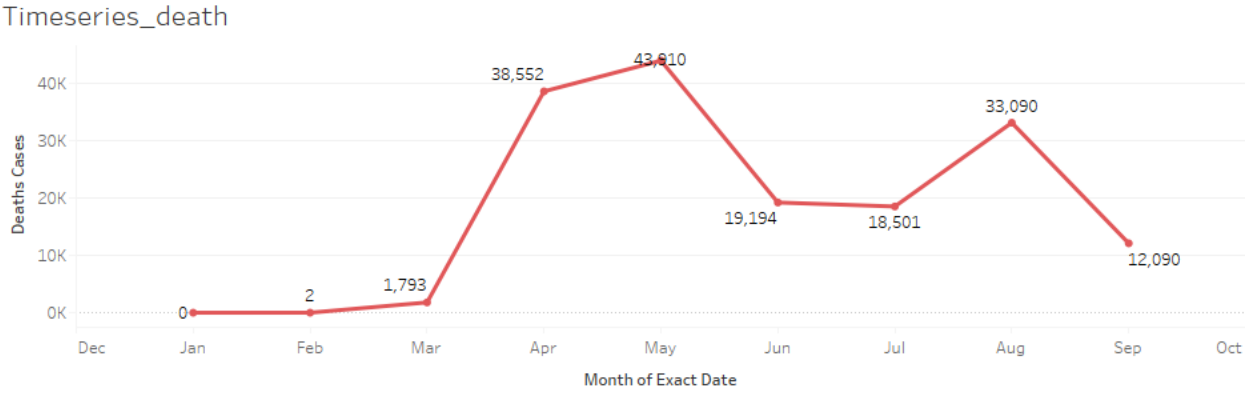


The last factor we are looking at that can impact the spread of COVID-19 and deaths is age. 51% of the Americans are of ages 20 to 59. This is followed by 26 at ages 0 to 19 and age 60 plus at 22%. We know that COVID-19 virus is more lethal to ages 60 plus and above and this has no to little impact to ages 19 and below. However, since 73% of the population is ages 20 and above, we can tell the a lot of the population will be impacted by this virus.

We will look at the impact of the COVID-19 virus in different states and what factors could drive the increase or decrease in cases or deaths.

Timeseries Analysis for Confirmed and Deaths





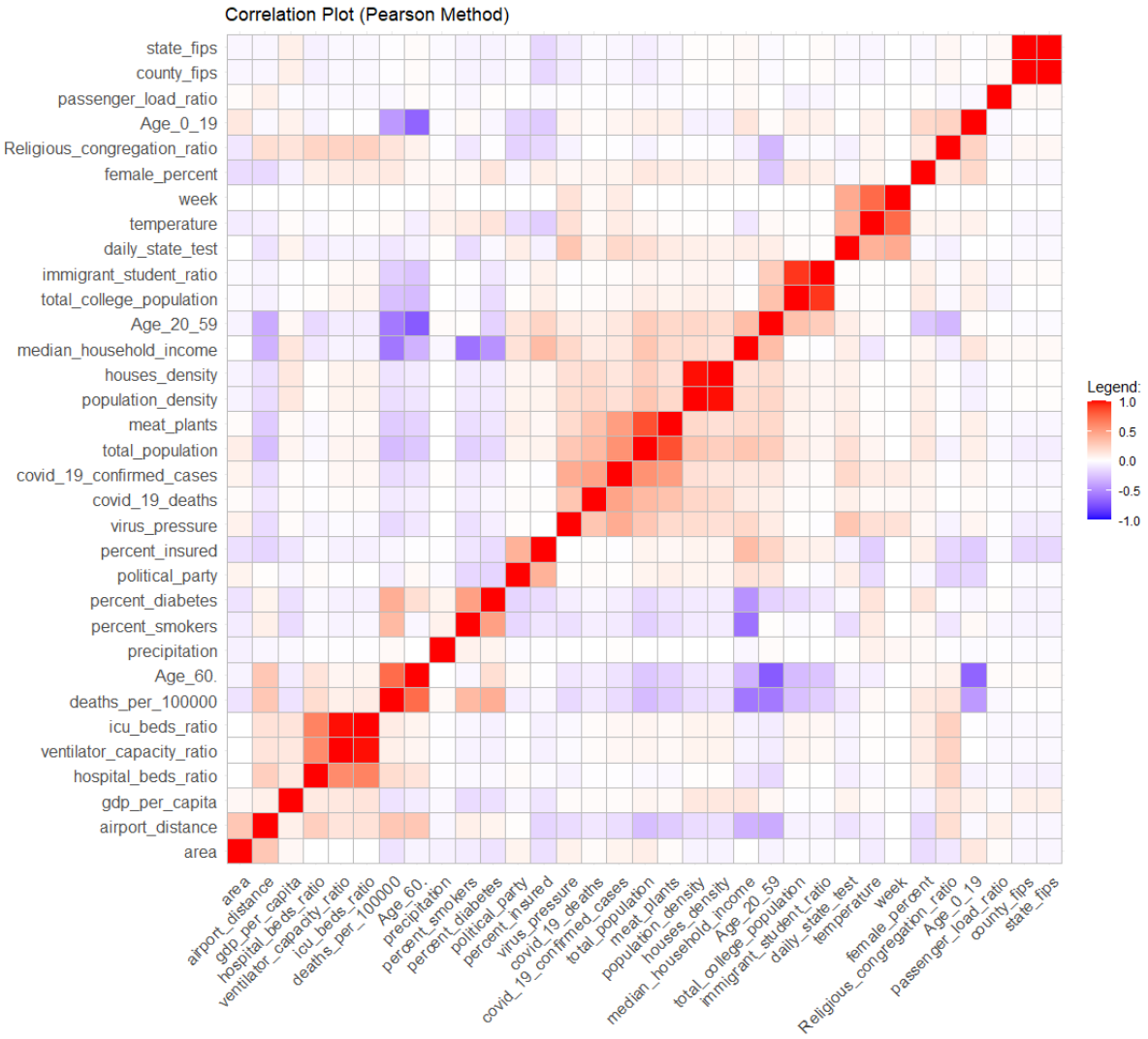
From the timeseries above, we can infer that there were 2 surges of the covid19 virus across 9 months. Evidently, the first surge was more severe as cases increased from 12 in February to 112k in March. Proportionally, the death count has a delayed response with confirmed cases as it shoots up from 1,793 in March to 38k in April. The death count continually increases all the way to almost 44k in May, which is the peak of the pandemic (in terms of death) for the US in this dataset. Confirmed cases hovers around the same number until the month of June but increases once again thereafter, which is when the second surge of covid takes place. In July, the death toll increased from 18k to 33k in August, which is the peak of the pandemic (in terms of confirmed cases) with a count of 1.5 million.

The Centers for Disease Control and Prevention (CDC 2022) reports that in the month of March, President Trump declared a state of emergency and required mass testing nationwide as cases exponentially increase. On March 19 California, one of the number 1 state in terms of confirmed cases and deaths, issues a "stay-at-home" order as confirmed cases steadily increased from the month of March onwards. In addition to this, social distancing measures were tightened starting from April, which is another possible explanation of covid-19 confirmed cases slowed down and plateaued. In June, the World Health Organization declared that the virus can be airborne (AJMC 2021). From this, we see the 2nd surge of covid-19 and the confirmed cases and deaths increase exponentially again.

References:
Centers for Disease Control and Prevention, "CDC Museum COVID-19 Timeline," Smithsonian Institution January 5 2022, https://www.cdc.gov/museum/timeline/covid19.html

AJMC Staff, "A Timeline of COVID-19 Developments in 2020," The Center for Biosimilars January 1 2021, https://www.ajmc.com/view/a-timeline-of-covid19-developments-in-2020

A. Correlation Plot of All Variables



According to the correlation plot and coefficients, the variable covid_19_confirmed_cases have the highest correlation coefficient with covid19_deaths with a value of 0.64. The proceeding variable that has a high correlation coefficient with confirmed cases is total_population with a coefficient of 0.60. In addition to these, we can infer from the correlation plot that the relationship between these variables is positive. This means that if covid_19_deaths or total_population is high, then covid_19_confirmed_cases will likely increase as well. However, it is important to note that this does not immediately imply causality between the two variables. This merely shows that they have a relationship with one another.

For the succeeding analysis, we will use the result of the correlation plot as our basis which variables we will dig deeper. This way, we can narrow down the impact on cases and deaths. Based on common domain knowledge, we will check which factors we think can affect the cases and deaths. This means that the other variables may not have good correlation value but are still worthy of the analysis.

Confirmed Cases Analysis

A. Correlation Values

	[,1]
week.x	0.100660092
county_fips.x	-0.048698548
covid_19_confirmed_cases	1.000000000
covid_19_deaths	0.641141351
state_fips	-0.048634042
social_distancing_total_grade	0.084377505
daily_state_test	0.214811983
precipitation	0.012948648
temperature	0.117847563
virus_pressure	0.474153200
total_population	0.605453079
female_percent	0.067056324
area	0.060751863
population_density	0.170690338
hospital_beds_ratio	-0.011051323
ventilator_capacity_ratio	0.039574184
icu_beds_ratio	0.038195423
houses_density	0.142151770
total_college_population	0.046455330
percent_smokers	-0.094027015
percent_diabetes	-0.074695840
Religious_congregation_ratio	-0.008801956
political_party	0.005980894
airport_distance	-0.149413142
passenger_load_ratio	-0.016092317
meat_plants	0.548638489
median_household_income	0.126032298
percent_insured	-0.012344338
deaths_per_100000	-0.158198359
gdp_per_capita	0.026470138
Age_0_19	0.059133151
Age_20_59	0.131870985
Age_60.	-0.134433313
immigrant_student_ratio	0.025098413

Figure 1: Correlation values versus confirmed cases

In the following section (Figure 1), we will be analyzing the dataset according to covid19 confirmed cases and deaths separately. We will examine the specific variables that may or may not have an effect on these 2 variables based on theory. For example, we can say that total_college_population has an effect on covid19 confirmed cases because education possibly has an important role on people's views on getting vaccinated, and thus would lead to less deaths. The same thing can be said for meat plants and GDP per capita. In terms of meat plants, we can theoretically say that diet has an effect on a person's ability to fight or get covid. In terms of GDP per capita, we can infer that people's incomes dictate how much medicine they can afford as well. Therefore, in this next section, we will explore if these variables truly contribute to confirmed cases.

B. Top 5 per Location

On figure 2, the top 5 states in terms of number of covid-19 cases are California, Texas, Florida, New York, and Illinois. Arizona comes in at number 6. When compared to confirmed cases, these states are also part of the top 5 of those variables, which makes sense. In theory, if there are more cases, there will most likely be more deaths as well.

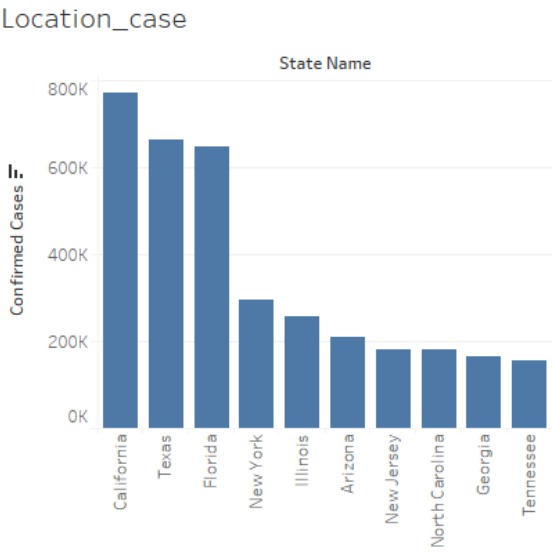


Figure 2: Confirmed cases per state

Top 5 states in terms of gdp_per_capita		Top 5 states in terms of meat plants	
Texas	624,087	California	23,835
Kansas	170,617	Texas	16,485
Iowa	158,757	Illinois	14,455
Nebraska	140,420	Pennsylvania	14,105
Minnesota	120,658	Florida	11,970

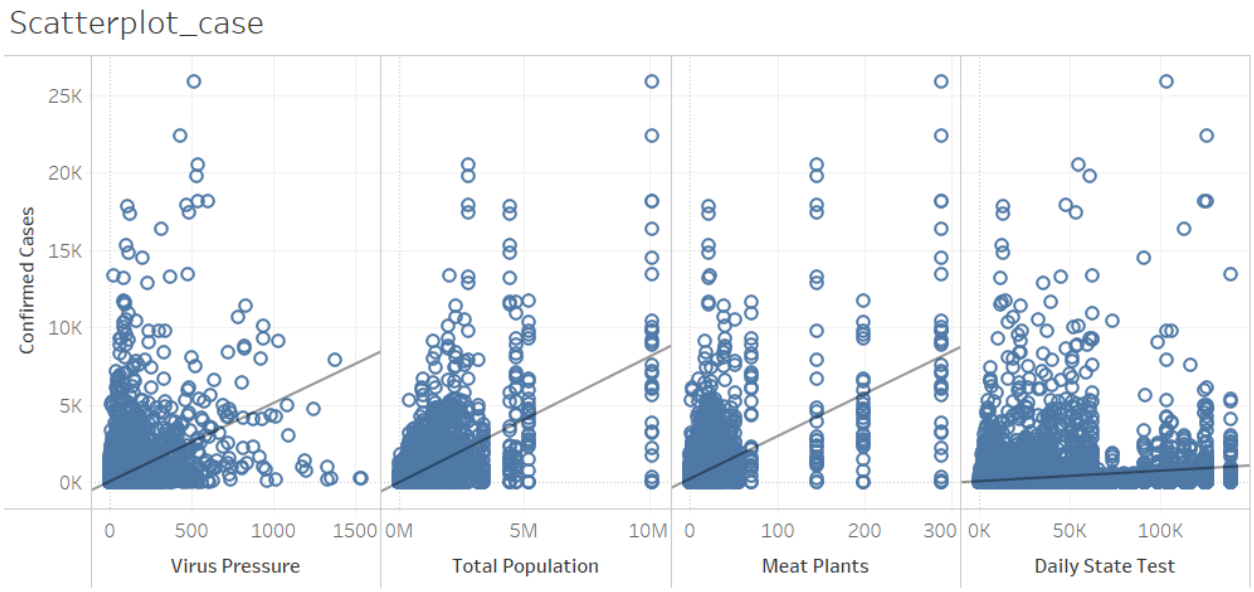
Top 5 states in terms of total_college_population	
Texas	2,254
Kansas	1,420
Virginia	1,272
Missouri	1,255
North Carolina	1,238

Based on the lists above, we can get a clearer picture of which variables have an effect on confirmed cases. If the top 5 states of these variables contribute to confirmed cases, then they should also be near the right side of our bar graph. After further analysis, we can say that among these 3 variables, meat_plants would have to be the variable that contributes the most to confirmed cases. We can see that among the top 5 states that have the greatest number of meat plants, the majority of them have really high confirmed cases. For example, California, Texas, Illinois, and Florida are in the top 5 in terms of confirmed cases, while at the same time in the top of 5 in terms of meat plants. This gives us reason that meat plants will possibly have a strong contributing factor to confirmed cases. The same cannot be said for gdp_per_capita and total_college_population. The top 5 states in both of these variables have really low confirmed cases relative to the other states. Therefore, we can infer that these 2 variables do not contribute to confirmed cases as much as meat plants.

With further examination, looking at the correlation coefficients of these variables tells the same story. The correlation coefficient of gdp per capita and total college population are 0.026 and 0.046 respectively, which are relatively low when compared to the correlation coefficient of meat plants, which is 0.548. Thus, this confirms our theory that diet may have an important impact on confirmed cases. This can be confirmed through other highly correlated variables with covid 19 confirmed cases. Both virus pressure and daily state test have relatively high correlation coefficients with values of 0.474 and 0.214, respectively. As seen, the top 5 states in these 2 variables are also part of the top 10 states in terms of confirmed cases which means that they have more of an impact on covid 19 confirmed cases than other variables.

Top 5 states in terms of virus pressure		Top 5 states in terms of daily_state_test	
California	111,277	Texas	153,050,644
Texas	89,580	California	107,312,343
Florida	83,631	New York	75,702,551
Arizona	37,871	Illinois	52,506,145
New York	34,634	Florida	41,236,536

C. Selected Scatter Plots versus Confirmed Cases



These 4 variables have the highest correlation coefficients to covid-19 confirmed cases. As seen in the correlation coefficients table, virus pressure, total population, meat plants, and daily state test have correlation coefficients of 0.474, 0.60, 0.54, and 0.21, respectively. The scatterplots shown above give us a visual representation of these individual relationships. The slopes of the scatterplots show that the relationship is increasing and positive. This means that from the data, if virus pressure, total population, meat plants, and daily state test individually increase, then confirmed cases will likely increase as well. In addition to this, the slope of the scatterplot is steeper if the correlation coefficient is higher, which means that confirmed cases increase at a higher rate with the variables of higher coefficients.

Death Cases Analysis

- **Correlation Plot versus deaths cases**

	[,1]
week.x	0.0383753424
county_fips.x	-0.0278140972
covid_19_confirmed_cases	0.6411413514
covid_19_deaths	1.0000000000
state_fips	-0.0276728379
social_distancing_total_grade	0.0307510810
daily_state_test	0.1054815463
precipitation	0.0091544272
temperature	0.0457891628
virus_pressure	0.4011166551
total_population	0.4576261827
female_percent	0.0656503880
area	0.0217860453
population_density	0.2727449059
hospital_beds_ratio	-0.0077721036
ventilator_capacity_ratio	0.0292181277
icu_beds_ratio	0.0288622243
houses_density	0.2380982452
total_college_population	0.0312815124
percent_smokers	-0.0836150216
percent_diabetes	-0.0575498945
Religious_congregation_ratio	-0.0001965108
political_party	0.0308086655
airport_distance	-0.1260215367
passenger_load_ratio	-0.0101387059
meat_plants	0.4131992069
median_household_income	0.1229562343
percent_insured	0.0172492832
deaths_per_100000	-0.1148515848
gdp_per_capita	0.0301774686
Age_0_19	0.0244814998
Age_20_59	0.1048739340
Age_60.	-0.0897724387
immigrant_student_ratio	0.0156103948

Figure 3: Correlation values vs death

On figure 3, from the correlation coefficients of all variables against covid 19 deaths, the most correlated variable is covid 19 confirmed cases. The following most correlated variable has a value of 0.457, which is also total population similar to confirmed cases. Further, the relationship of these variables are significantly positive. In addition to this, we can utilize the same process to verify the theoretical relationships to covid19 deaths, and investigate which variables truly have a relationship with covid19 deaths. In theory, being a smoker and/or having diabetes would mean you are less healthy than the individuals who don't smoke or don't have diabetes. This would also mean that you are more susceptible to death due to covid 19:

- **Top 5 per location**

On figure 4, the top 5 states in terms of covid-19 deaths are California, Texas, Florida, New York, and New Jersey. Illinois comes in at number 6. When compared to confirmed cases, these states are also part of the top 5 of that variable, which makes sense. In theory, if there are more cases, there will most likely be more deaths as well.

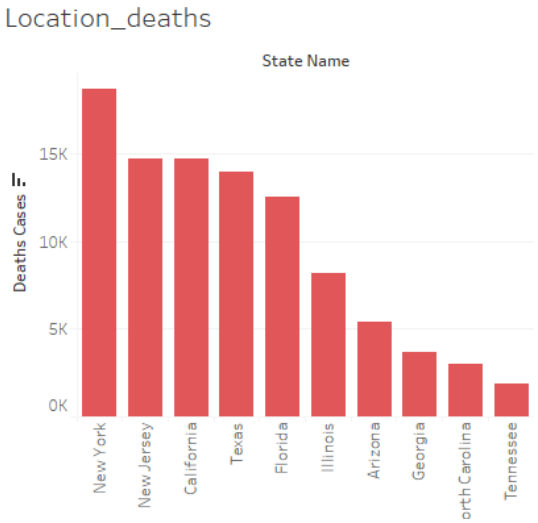


Figure 4: Death cases per state

Top 5 states in terms of percent smoker		Top 5 states in terms of percent diabetes	
Texas	96,017	Texas	73,619
Missouri	70,424	Missouri	44,447
Tennessee	58,168	North Carolina	39,718
Kansas	54,518	Kansas	37,660
North Carolina	53,284	Tennessee	37,387

Interestingly, the top 5 states of percent smoker and diabetes are identical just in different order. Therefore, we can interpret them together in terms of covid 19 deaths. In theory, these variables may have a significant effect on covid 19 deaths. However, we can see from the tables above that only the state of Texas is in the top 5 in terms of covid 19 deaths, while the other 4 states in the list have relatively lower death counts. This gives us reason that in reality, percent smoker and percent diabetes do not have a contributing factor to covid-19 death.

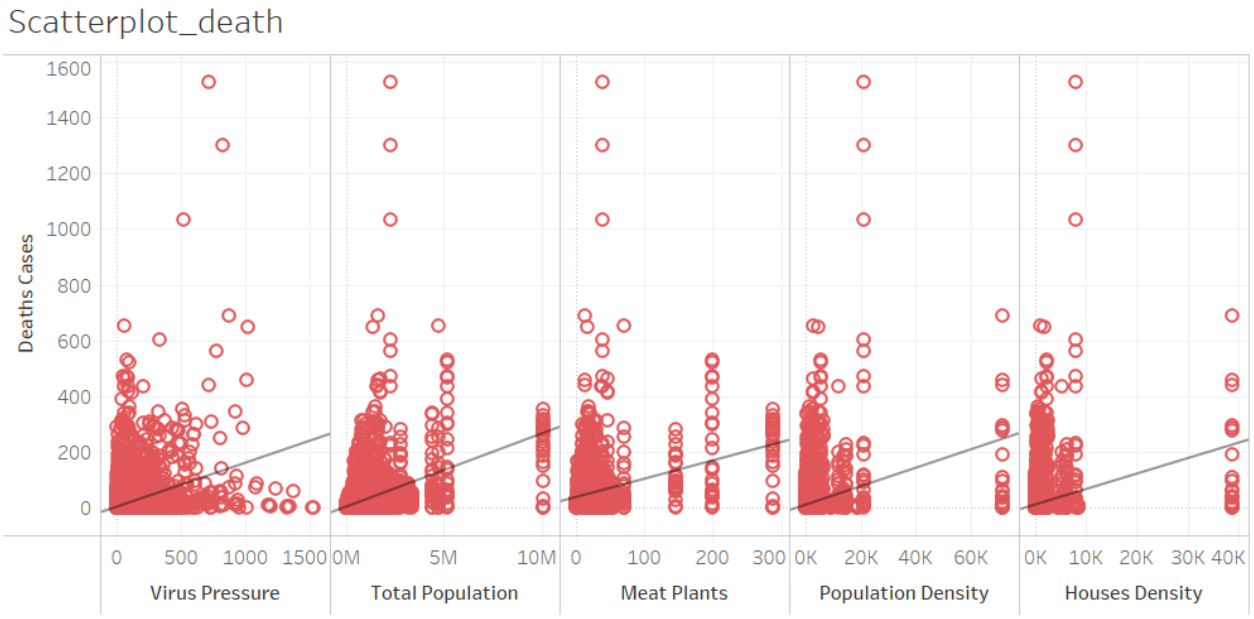
Top 5 states in terms of hospital beds ratio		Top 5 states in terms of ventilator capacity ratio	
Kansas	20	Kansas	2
Texas	12	Texas	2
Minnesota	10	Nebraska	1
Iowa	9	Iowa	1
Nebraska	9	North Carolina	1

Top 5 states in terms of icu beds ratio	
Kansas	2
Texas	2
Nebraska	1
Iowa	1
North Carolina	1

Similar to the variable pairing before this, the top 5 states for hospital beds ratio, ventilator capacity ratio, and icu beds ratio are all alike with each other. Again, only Texas is the only state in the top 5 in terms of covid-19 deaths. In theory, hospital beds ratio, ventilator capacity ratio, and icu beds ratio have a significant relationship to covid-19 deaths because if these services are not available during the pandemic then the covid-19 death count will increase. However in reality, from the tables above, only the state of Texas is in the top 5 of covid-19 deaths and the other 4 states are significantly low. Therefore, they do not contribute heavily to covid-19 deaths.

These hypotheses can be confirmed from the correlation coefficients. Percent smokers and percent diabetes have correlation coefficients of -0.08 and -0.05 respectively. Hospital beds ratio, ventilator capacity ratio, and icu beds ratio have correlation coefficients of -0.007, 0.029, and 0.028, respectively. With their correlation coefficients being significantly low, there is no surprise that the top 5 states in these respective variables do not appear in the top 5 states in terms of covid-19 deaths.

- **Scatter plot other vs deaths**



The variables chosen from the above scatterplots are of the highest correlation coefficients in relation to covid-19 deaths. Virus pressure, total population, meat plants, population density, and houses density have correlation coefficients of 0.40, 0.457, 0.41, 0.27, 0.23, respectively. The scatterplots above show the visual relationship between these variables individually to covid-19 deaths. In addition, the slope of these scatterplots are also positive as they have an upward slope. This means that covid-19 death counts are likely to increase if these variables increase individually. Furthermore, the slopes of these variables are steeper if the individual correlation coefficients are higher, which is similar to the situation in confirmed cases.

Inferential Analysis

From the descriptive analysis, we know that confirmed cases and deaths have very high correlation at 64% followed by total population at 60%. We found that confirmed cases are highly correlated with the following variables: virus pressure, total population, meat plants and daily state tests. For death cases the following variables are highly correlated as well: virus pressure, total population, population density and houses density. However, this analysis only showed that they have relationship. We will now look at if the following variables are statistically significant. Do they really impact the increase in confirmed and death cases?

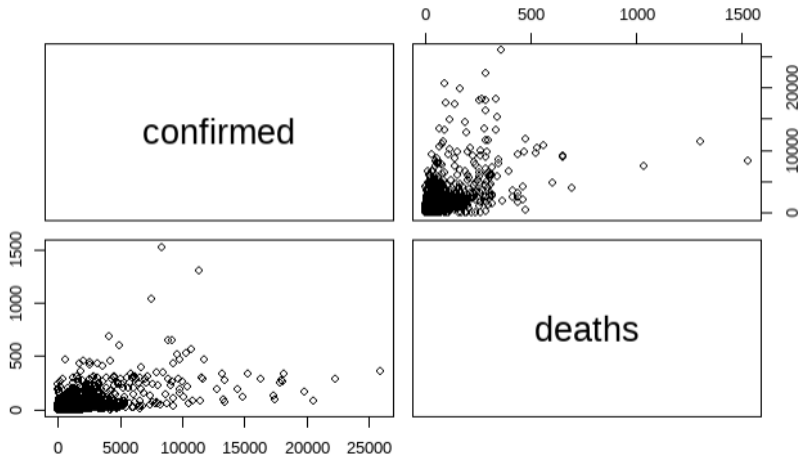
On the 1st part of the analysis, we know that living in high population density states like California, Texas, Florida, and New York can increase your chance of getting the virus. While, living in less population density states like Alaska, Wyoming and North Dakota have lesser chance of getting the virus. From this, we will look at what factors are driving the increase in cases for both groups (higher versus lower population density states). We then check if a relationship exists between these groups.

Overview

Before we proceed with the inferential analysis of the data, we checked the distribution of our response variables: confirmed and death cases. The boxplot (see figure A in appendix C) showed several points outside the whiskers for both confirmed and death cases. The results showed that the data is not normally distributed. When checking the distribution of the data, it is not normally distributed, same is true for most of the remaining variables (see figure B in appendix C). For confirmed and death cases histogram are highly skewed to the right. The QQ plot (see figure C in appendix C) and Kolmogorov-Smirnov Test (see figure D in appendix C) tells the same.

We checked what us affecting the distribution, we observed that 36.68% (or 30,200) of the data in the confirmed cases are equal to zero and 77.20% (or 63,551) of the death cases are equal to zero. When the two variables are combined, there are a total of 36.4% (or 30,021) are equal to zero and either of them will result to 77.4% (or 63,730) is equal to zero. This means that the data has a lot of zero recorded cases or deaths per country per week from the start of the observations in January to September of 2020.

We tried implementing a cut off start point on March 11, 2020, where WHO officially announced the spread of COVID-19 as a pandemic. The result showed that 21% (or 13,842) of the data is equal to zero for confirmed cases and 77.19% (or 47,097) of death cases are equal to zero. This means that even during the start of the pandemic, there were zero recorded cases or deaths per country per week. Zero cases where not only recorded before the WHO announcement but also after the announcement. You can see from the graph on the left the scatter plot distribution of confirmed and death cases. All the observations are concentrated on the lower left portion.



With this, we tried to cut off some the extreme points from the data to create a bit reliable model later. We used the Mahalanobis Distance technique. From this, it suggested to remove 1,271 observations outside the 95% confidence interval. The new dataset has now 81,049 observations from 82,320.

General Analysis

From the full model with **confirmed cases** as the response variable (see figure E from appendix C), we can see that all variables are statistically significant but when checked for multicollinearity it, several variables have VIF value of more than 5 like population density at 94.63, ventilator at 53.52, icu bed ratio at 58.71, houses density at 90.73, age 0 to 19 at 99.3, age 20 to 59 at 114.29, age 60+ at 212.71 and immigration student at 7.15.

After removing certain variables that have multicollinearity such as houses density, ventilator, age 0 to 19 and immigration student, the number of significant variables were reduced. The variables hospital bed and college population became less significant in the model. Comparing the model from the descriptive part, the variable meat plants resulted in negative beta which is opposite. This means that, as number of meat plants decreases the number of confirmed cases increase.

From the full model with **deaths cases** as the response variable (see figure G from appendix C), almost all were statistically significant except the following variables: hospital beds, college population, percent smokers, religious congregation ratio, passenger load, income, percent insured, age 0 to 19, age 20 to 59, age 60 plus and immigration student. When running VIF for multicollinearity, the result showed almost the same with the confirmed cases full model.

After removing certain variables that have multicollinearity such as houses density, ventilator, age 0 to 19 and immigration student, the number of significant variables were reduced. The variables temperature, hospital bed, college population percent smokers, religious congregation ratio, passenger load, percent insured, and age 60+ became less significant in the model. Similar to findings in confirmed case, when comparing the model from the descriptive part, the variable meat plants resulted in negative beta which is opposite. This means that, as number of meat plants decreases the number of death cases increase.

Confirmed Cases Analysis

Top 5 states:

1. California
2. Texas
3. Florida
4. New York
5. Illinois

We filtered the dataset based on the performance of top 5 states. We were able to get 7,953 observations. We run linear regression on full and reduced model based on stepwise selection and after removal of multicollinearity. Below is the result.

Full model

```
Call:
lm(formula = confirmed ~ . - date - county_fips - state_fips -
    mahal - badmahal, data = ConfirmedT5)

Residuals:
    Min      1Q  Median      3Q     Max
-645.66  -39.07   -6.63   21.50  793.68

Coefficients:
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                -2.414e+02  3.428e+02  -0.704 0.481428
deaths                      1.735e+01  2.635e-01  65.840  < 2e-16 ***
social_dist                 1.027e+00  5.315e-01   1.931 0.053460 .
daily_state_test            1.163e-03  5.223e-05  22.260  < 2e-16 ***
precipitation               3.629e-02  2.293e-02   1.583 0.113556
temperature                -4.305e-01  1.949e-01  -2.209 0.027187 *
virus_pressure              5.738e-01  1.871e-02  30.659  < 2e-16 ***
total_population            3.907e-05  4.886e-06   7.996 1.47e-15 ***
female_percent             -9.612e+01  8.030e+01  -1.197 0.231325
area                        4.832e-05  9.217e-04   0.052 0.958195
population_density          2.601e-02  3.352e-03   7.759 9.59e-15 ***
hosp_beds                  -3.130e+03  1.008e+03  -3.105 0.001909 **
ventilator                 -4.286e+03  4.055e+04  -0.106 0.915810
icu_beds_ratio              6.314e+04  4.664e+04   1.354 0.175842
houses_density             -4.969e-02  6.336e-03  -7.843 4.97e-15 ***
college_pop                 4.046e+01  6.777e+00   5.971 2.46e-09 ***
percent_smokers             4.303e-01  8.473e-01   0.508 0.611567
percent_diabetes            2.193e-01  4.256e-01   0.515 0.606351
Religious_congregation_ratio  3.796e-01  9.935e-02   3.821 0.000134 ***
political_party            -7.029e+01  8.295e+00  -8.474  < 2e-16 ***
airport_distance           -2.745e-02  3.034e-02  -0.905 0.365534
pass_load                   1.088e+00  3.092e+00   0.352 0.724829
meat_plants                -8.861e-01  1.625e-01  -5.453 5.09e-08 ***
income                      4.944e-04  1.466e-04   3.372 0.000750 ***
percent_insured             2.038e+00  6.938e-01   2.937 0.003322 **
deaths_per_100000           1.202e-02  1.110e-02   1.083 0.278954
gdp_per_capita              2.796e-01  7.525e-02   3.716 0.000204 ***
Age_0_19                    4.936e+00  3.475e+00   1.420 0.155522
Age_20_59                  -1.158e+00  3.500e+00  -0.331 0.740722
Age_60                     -5.926e-01  3.444e+00  -0.172 0.863392
immig_student              -7.544e+02  1.632e+02  -4.623 3.84e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 94.56 on 7922 degrees of freedom
Multiple R-squared:  0.6478,    Adjusted R-squared:  0.6464
F-statistic: 485.7 on 30 and 7922 DF,  p-value: < 2.2e-16
```

Reduced model

```
Call:
lm(formula = confirmed ~ +virus_pressure + daily_state_test +
    total_population + airport_distance + ventilator + Age_0_19 +
    income + meat_plants + college_pop + Religious_congregation_ratio +
    percent_insured + social_dist + pass_load + hosp_beds + gdp_per_capita,
    data = ConfirmedT5)

Residuals:
     Min       1Q   Median       3Q      Max
-1063.84   -52.97   -12.63    24.85   840.80

Coefficients:
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                 2.120e+02  3.138e+01   6.755 1.53e-11 ***
virus_pressure              8.130e-01  2.279e-02  35.680  < 2e-16 ***
daily_state_test            1.340e-03  4.532e-05  29.577  < 2e-16 ***
total_population            1.149e-04  5.313e-06  21.622  < 2e-16 ***
airport_distance           -2.906e-01  3.130e-02  -9.285  < 2e-16 ***
ventilator                  8.506e+04  9.177e+03   9.268  < 2e-16 ***
Age_0_19                    4.848e+00  4.365e-01  11.107  < 2e-16 ***
income                      5.513e-04  1.273e-04   4.331 1.50e-05 ***
meat_plants                -2.746e+00  1.933e-01 -14.204  < 2e-16 ***
college_pop                 1.306e+01  2.704e+00   4.830 1.39e-06 ***
Religious_congregation_ratio  4.831e-01  1.203e-01   4.017 5.95e-05 ***
percent_insured            -4.461e+00  3.763e-01 -11.857  < 2e-16 ***
social_dist                 1.850e+00  6.417e-01   2.883  0.00395 **
pass_load                   3.560e+00  3.611e+00   0.986  0.32414
hosp_beds                  -2.207e+03  1.017e+03  -2.169  0.03010 *
gdp_per_capita              1.452e-03  6.484e-02   0.022  0.98213
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 119.5 on 7937 degrees of freedom
Multiple R-squared:  0.4361,    Adjusted R-squared:  0.435
F-statistic: 409.2 on 15 and 7937 DF,  p-value: < 2.2e-16
```

Regression Model	R-squared	Adjusted R-squared	RMSE	MAE
Full model	0.64	0.64	94.56	53.43
Reduced model	0.43	0.43	119.5	68.98

From the initial inspection of the results, the statistical measures indicate that the full model performs much better than the reduced model. The adjusted R-square value of the full model is much almost 20% higher than the adjusted R-square value of the reduced model. Further, a lower RMSE and MAE is desirable. In the case of our models, both the RMSE and MAE of the full model are lower than that of the reduced model. Although the statistical measures look better for the full model, it is observable that there are numerous statistically insignificant variables in the full model. On the other hand, the reduced model has only 2 variables that are not statistically significant. The reason why the R-squared and adjusted R-squared values are higher for the full model is because the full model includes more variables. As we know, the R-squared values will increase when there are more observations.

Bottom 5 states:

1. Alaska
2. Wyoming
3. New Hampshire
4. West Virginia
5. North Dakota

We filtered the dataset based on the performance of bottom 5 states. We were able to get 3,010 observations. We run linear regression on full and reduced model based on stepwise selection and after removal of multicollinearity. Below is the result.

Full model

```
Call:
lm(formula = confirmed ~ . - date - county_fips - state_fips -
    mahal - badmahal, data = ConfirmedB5)

Residuals:
    Min      1Q  Median      3Q     Max
-122.46   -8.01   -0.46    5.65  384.30

Coefficients: (1 not defined because of singularities)
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                 6.975e+01  1.360e+02   0.513 0.608000
deaths                      1.439e+01  6.236e-01  23.075  < 2e-16 ***
social_dist                 4.846e-01  1.934e-01   2.506 0.012255 *
daily_state_test            4.587e-03  4.488e-04  10.220  < 2e-16 ***
precipitation              -3.569e-02  1.858e-02  -1.921 0.054808 .
temperature                -8.498e-02  7.430e-02  -1.144 0.252838
virus_pressure              1.308e+00  2.560e-01   5.107 3.48e-07 ***
total_population            2.495e-04  2.378e-05  10.490  < 2e-16 ***
female_percent             -3.431e+01  4.008e+01  -0.856 0.391993
area                       -1.208e-04  1.704e-04  -0.709 0.478422
population_density          8.727e-02  7.551e-02   1.156 0.247916
hosp_beds                  -7.298e+02  1.884e+02  -3.873 0.000110 ***
ventilator                  2.963e+04  8.352e+03   3.548 0.000394 ***
icu_beds_ratio             -2.185e+04  9.265e+03  -2.359 0.018396 *
houses_density             -2.164e-01  1.603e-01  -1.350 0.176997
college_pop                -4.165e+00  3.523e+00  -1.182 0.237217
percent_smokers            -5.013e-01  2.228e-01  -2.250 0.024547 *
percent_diabetes           -2.190e-01  2.058e-01  -1.064 0.287294
Religious_congregation_ratio  3.239e-02  2.932e-02   1.105 0.269376
political_party                    NA         NA      NA       NA
airport_distance            5.816e-03  8.913e-03   0.653 0.514083
pass_load                   9.274e-03  4.552e-02   0.204 0.838577
meat_plants                 1.330e+00  6.104e-01   2.179 0.029434 *
income                      9.549e-06  9.473e-05   0.101 0.919715
percent_insured            -1.066e-01  2.015e-01  -0.529 0.596807
deaths_per_100000          -4.977e-03  3.671e-03  -1.356 0.175304
gdp_per_capita             -4.066e-02  1.672e-02  -2.431 0.015119 *
Age_0_19                   -6.308e-01  1.327e+00  -0.476 0.634448
Age_20_59                  -1.280e-01  1.297e+00  -0.099 0.921397
Age_60                     -6.627e-01  1.310e+00  -0.506 0.613009
immig_student               8.914e+01  7.635e+01   1.167 0.243109
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 24.11 on 2980 degrees of freedom
Multiple R-squared:  0.4562,    Adjusted R-squared:  0.451
F-statistic: 86.22 on 29 and 2980 DF,  p-value: < 2.2e-16
```

Reduced model

```
Call:
lm(formula = confirmed ~ +deaths + total_population + daily_state_test +
    percent_diabetes + virus_pressure + houses_density + deaths_per_100000 +
    ventilator + hosp_beds + percent_smokers + gdp_per_capita +
    social_dist + female_percent + meat_plants + precipitation,
    data = ConfirmedB5)

Residuals:
    Min      1Q  Median      3Q     Max
-124.94   -8.02   -0.73    5.81  383.97

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)        5.171e+01  1.507e+01   3.432 0.000608 ***
deaths             1.450e+01  6.185e-01  23.445  < 2e-16 ***
total_population   2.600e-04  2.055e-05  12.652  < 2e-16 ***
daily_state_test   4.321e-03  2.954e-04  14.629  < 2e-16 ***
percent_diabetes  -2.746e-01  1.867e-01  -1.471 0.141513
virus_pressure     1.193e+00  2.456e-01   4.857 1.26e-06 ***
houses_density    -4.215e-02  1.575e-02  -2.677 0.007477 **
deaths_per_100000 -8.548e-03  2.206e-03  -3.875 0.000109 ***
ventilator         1.005e+04  1.578e+03   6.371 2.17e-10 ***
hosp_beds         -7.041e+02  1.773e+02  -3.972 7.29e-05 ***
percent_smokers   -4.758e-01  1.354e-01  -3.513 0.000449 ***
gdp_per_capita    -4.689e-02  1.378e-02  -3.402 0.000677 ***
social_dist        5.979e-01  1.834e-01   3.261 0.001122 **
female_percent    -8.366e+01  3.122e+01  -2.680 0.007411 **
meat_plants        1.343e+00  5.531e-01   2.428 0.015235 *
precipitation     -3.491e-02  1.800e-02  -1.939 0.052602 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 24.11 on 2994 degrees of freedom
Multiple R-squared:  0.4537,    Adjusted R-squared:  0.451
F-statistic: 165.8 on 15 and 2994 DF,  p-value: < 2.2e-16
```

Regression Model	R-squared	Adjusted R-squared	RMSE	MAE
Full model	0.456	0.451	24.11	11.34
Reduced model	0.453	0.451	24.11	11.29

The same conclusions can be drawn for the bottom 5 states for confirmed cases. However, in this case, the 4 statistical measures do not decrease as much compared to the case of top 5 states in confirmed cases as previously shown. This confirms our assumptions that the reduced model is superior because even if we filter out statistically insignificant variables, the reduced model still performs as well as the full model. In addition to this, the results, and coefficients from both the top 5 and bottom 5 states make sense in theory. For example, the coefficient of daily_state_test is positive in both models. This means that as the number of daily_state_tests increase, so will the count for confirmed cases.

Another interesting variable is social_distancing. For the bottom 5 states, social_distancing has a much higher positive coefficient compared to that from the top 5 states. This can imply that the top 5 states should learn from the bottom 5 states and improve their social distancing measures as this would be a helpful way to alleviate covid19 confirmed cases.

However, there are also variables that have an opposite effect when comparing the top 5 and bottom 5 states. An example of this would be the variable meat_plants. In the case of the top 5 states, the coefficient for meat_plants is negative. However, in the case of the bottom 5 states, the coefficient for

meat_plants is positive. Variables such as these that have contradicting coefficients may need some further investigation. A possible explanation for this is that the top 5 states have more meat plants.

With this, we checked the if there is a relationship between the top and bottom 5 states by using one-way ANOVA. We first created a new variable for each data frame and label top and bottom based on their category. After this, we run one-way ANOVA for the rank (top and bottom 5 states categories) with the number of confirmed cases. The result showed a p-value that is less than 0.05. This means we will need to reject the null hypothesis that both groups are equal. This means, that there is no relationship between top and bottom 5 states in terms confirmed cases.

```
# anova
summary(aov(confirmed~rank, data = Confirmed_rank))
```

```
               Df    Sum Sq Mean Sq F value Pr(>F)
rank            1   8519678 8519678   457.1 <2e-16 ***
Residuals   10961 204317940   18640
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
p value is less than 0.05, so we reject null hypothesis that both groups are equal.
```

Death Cases Analysis

Top 5 states

1. New York
2. New Jersey
3. California
4. Texas
5. Florida

We filtered the dataset based on the performance of top 5 states. We were able to get 7,953 observations. We run linear regression on full and reduced model based on stepwise selection and after removal of multicollinearity. Below is the result.

Full model

```
Call:
lm(formula = deaths ~ . - date - county_fips - state_fips - mahal -
    badmahal, data = DeathsT5)

Residuals:
     Min       1Q   Median       3Q      Max
-16.2420  -0.8893  -0.3200   0.3339  29.9135

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                 -3.509e+00  8.403e+00  -0.418 0.676205
confirmed                    2.007e-02  2.582e-04  77.758  < 2e-16 ***
social_dist                 -2.024e-02  1.394e-02  -1.452 0.146508
daily_state_test            -2.865e-05  1.684e-06 -17.010  < 2e-16 ***
precipitation                2.433e-03  6.737e-04   3.611 0.000306 ***
temperature                  9.194e-02  5.927e-03  15.511  < 2e-16 ***
virus_pressure              -2.051e-03  5.888e-04  -3.483 0.000498 ***
total_population             7.319e-07  1.359e-07   5.385 7.39e-08 ***
female_percent               5.261e+00  1.762e+00   2.985 0.002838 **
area                         1.959e-05  2.877e-05   0.681 0.495930
population_density          -2.753e-04  9.495e-05  -2.899 0.003750 **
hosp_beds                    6.847e+01  2.588e+01   2.645 0.008171 **
ventilator                   1.683e+02  6.214e+02   0.271 0.786583
icu_beds_ratio              -4.040e+02  7.327e+02  -0.551 0.581356
houses_density               5.133e-04  1.781e-04   2.882 0.003957 **
college_pop                 -3.656e-01  1.340e-01  -2.728 0.006380 **
percent_smokers              5.332e-02  1.699e-02   3.138 0.001707 **
percent_diabetes            -2.685e-03  8.740e-03  -0.307 0.758661
Religious_congregation_ratio 6.973e-04  2.379e-03   0.293 0.769464
political_party              2.236e+00  1.705e-01  13.113  < 2e-16 ***
airport_distance            -2.793e-03  6.828e-04  -4.090 4.34e-05 ***
pass_load                    3.137e-03  1.012e-02   0.310 0.756616
meat_plants                 -1.109e-02  5.370e-03  -2.065 0.038953 *
income                       3.519e-06  3.434e-06   1.025 0.305541
percent_insured             -5.153e-02  1.131e-02  -4.558 5.22e-06 ***
deaths_per_100000           -1.041e-05  2.341e-04  -0.044 0.964552
gdp_per_capita               1.283e-04  2.159e-04   0.594 0.552425
Age_0_19                     2.068e-02  8.434e-02   0.245 0.806339
Age_20_59                    2.805e-02  8.433e-02   0.333 0.739420
Age_60                       5.292e-02  8.360e-02   0.633 0.526705
immig_student                6.336e+00  2.580e+00   2.456 0.014066 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.201 on 12176 degrees of freedom
Multiple R-squared:  0.4761,    Adjusted R-squared:  0.4748
F-statistic: 368.8 on 30 and 12176 DF,  p-value: < 2.2e-16
```

Reduced model

```
Call:
lm(formula = deaths ~ +confirmed + total_population + daily_state_test +
    temperature + Age_20_59 + precipitation + airport_distance +
    virus_pressure + hosp_beds + percent_smokers + percent_insured +
    Age_60 + meat_plants, data = DeathsT5)

Residuals:
     Min       1Q   Median       3Q      Max
-16.3600  -0.8093  -0.3268   0.2339  30.4127

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)       -2.209e+00  7.213e-01  -3.062  0.00220 **
confirmed          1.975e-02  2.559e-04  77.168  < 2e-16 ***
total_population   5.474e-07  1.236e-07   4.430 9.51e-06 ***
daily_state_test  -1.923e-05  1.508e-06 -12.746  < 2e-16 ***
temperature        5.586e-02  5.234e-03  10.671  < 2e-16 ***
Age_20_59         -6.321e-02  1.130e-02  -5.593 2.28e-08 ***
precipitation      2.038e-03  6.758e-04   3.016  0.00257 **
airport_distance  -1.683e-03  5.513e-04  -3.052  0.00228 **
virus_pressure    -1.621e-03  5.785e-04  -2.803  0.00508 **
hosp_beds          4.539e+01  1.582e+01   2.870  0.00411 **
percent_smokers   -9.267e-03  1.230e-02  -0.753  0.45125
percent_insured    6.324e-02  6.113e-03  10.346  < 2e-16 ***
Age_60             8.429e-04  7.643e-03   0.110  0.91218
meat_plants        1.550e-03  5.120e-03   0.303  0.76206
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.228 on 12193 degrees of freedom
Multiple R-squared:  0.4667,    Adjusted R-squared:  0.4661
F-statistic: 820.7 on 13 and 12193 DF,  p-value: < 2.2e-16
```

Regression Model	R-squared	Adjusted R-squared	RMSE	MAE
Full model	0.4761	0.478	3.201	1.546
Reduced model	0.4667	0.4661	3.228	1.511

The statistical measures indicate that the full model for deaths performed better than the reduced model except for MAE. Although the R-squared, Adjusted R-squared, and RMSE are all more favorable in the full model, it cannot be automatically assumed that it is better than the reduced model. After further investigation there are numerous statistically insignificant variables included in the full model. After filtering out some of these variables using the stepwise selection method, we are left with only 3 insignificant variables in the reduced model. In addition to this, the same conclusions can be drawn from the confirmed cases. Both the R-squared and Adjusted R-squared values are higher in the reduced model simply because there are more variables and observations in the full model compared to the reduced model. This will inevitably increase the R-squared and adjusted R-squared values.

Bottom 5 states

1. Alaska
2. Wyoming
3. Vermont
4. Hawaii
5. Maine

We filtered the dataset based on the performance of bottom 5 states. We were able to get 1,885 observations. We run linear regression on full and reduced model based on stepwise selection and after removal of multicollinearity. Below is the result.

Full model

```
Call:
lm(formula = deaths ~ . - date - county_fips - state_fips - mahal -
    badmahal, data = DeathsB5)

Residuals:
    Min      1Q  Median      3Q     Max
-7.5316 -0.1506 -0.0363  0.0671  7.1162

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                  7.160e-02  5.488e+00   0.013   0.9896
confirmed                    1.411e-02  5.678e-04  24.860  < 2e-16 ***
social_dist                 -3.647e-02  5.602e-03  -6.510 9.63e-11 ***
daily_state_test            -2.445e-05  1.858e-05  -1.316   0.1883
precipitation               -1.200e-04  6.297e-04  -0.191   0.8489
temperature                 -2.763e-03  1.939e-03  -1.425   0.1544
virus_pressure              -1.536e-02  1.021e-02  -1.504   0.1328
total_population             3.436e-07  5.195e-07   0.661   0.5085
female_percent               2.027e+00  2.612e+00   0.776   0.4378
area                         3.810e-06  8.836e-06   0.431   0.6664
population_density          -5.183e-03  1.069e-03  -4.850 1.34e-06 ***
hosp_beds                   -7.299e+00  1.183e+01  -0.617   0.5374
ventilator                   5.520e+02  5.701e+02   0.968   0.3331
icu_beds_ratio              -3.627e+02  6.455e+02  -0.562   0.5743
houses_density               1.450e-02  2.520e-03   5.756 1.01e-08 ***
college_pop                 -1.849e-01  1.669e-01  -1.108   0.2682
percent_smokers             -2.572e-02  1.469e-02  -1.750   0.0802 .
percent_diabetes             3.043e-02  1.212e-02   2.512   0.0121 *
Religious_congregation_ratio -1.780e-03  2.457e-03  -0.724   0.4690
political_party              9.845e-03  5.644e-02   0.174   0.8616
airport_distance            -2.109e-04  4.677e-04  -0.451   0.6521
pass_load                    2.907e-03  2.270e-02   0.128   0.8981
meat_plants                 -1.096e-02  1.415e-02  -0.775   0.4386
income                      -1.579e-06  3.385e-06  -0.466   0.6410
percent_insured             -5.927e-03  8.702e-03  -0.681   0.4959
deaths_per_100000           -2.872e-05  1.677e-04  -0.171   0.8641
gdp_per_capita               7.760e-05  1.273e-03   0.061   0.9514
Age_0_19                     4.421e-03  6.138e-02   0.072   0.9426
Age_20_59                    4.401e-03  5.346e-02   0.082   0.9344
Age_60                      -1.691e-02  5.740e-02  -0.295   0.7684
immig_student                5.249e+00  3.990e+00   1.316   0.1885
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.5975 on 1854 degrees of freedom
Multiple R-squared:  0.3831,    Adjusted R-squared:  0.3731
F-statistic: 38.38 on 30 and 1854 DF,  p-value: < 2.2e-16
```

Reduced model

```
Call:
lm(formula = deaths ~ +confirmed + female_percent + social_dist +
    Age_60 + temperature + airport_distance + gdp_per_capita,
    data = DeathsB5)

Residuals:
    Min      1Q  Median      3Q     Max
-8.0221 -0.1443 -0.0514  0.0289  7.2352

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)      -2.7280087  0.6216608  -4.388 1.21e-05 ***
confirmed         0.0148675  0.0005038  29.512  < 2e-16 ***
female_percent    6.4735686  1.2755469   5.075 4.26e-07 ***
social_dist      -0.0285662  0.0052994  -5.390 7.92e-08 ***
Age_60           -0.0082490  0.0039346  -2.097 0.036168 *
temperature      -0.0055754  0.0014574  -3.826 0.000135 ***
airport_distance -0.0007928  0.0002335  -3.395 0.000701 ***
gdp_per_capita    0.0016603  0.0007314   2.270 0.023318 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.6083 on 1877 degrees of freedom
Multiple R-squared:  0.3528,    Adjusted R-squared:  0.3503
F-statistic: 146.1 on 7 and 1877 DF,  p-value: < 2.2e-16
```

Regression Model	R-squared	Adjusted R-squared	RMSE	MAE
Full model	0.383	0.373	0.597	0.239
Reduced model	0.352	0.350	0.608	0.229

Similar to the previous results from the top 5 in terms of death counts, the statistical models indicate that the full model performs better than the reduced model except for MAE. However, as mentioned, the R-squared and adjusted R-squared values are higher for the full model simply because there are more observations in the full model. In addition, all the variables in the reduced model for the bottom 5 states in terms of death counts are statistically significant.

With this, we checked the if there is a relationship between the top and bottom 5 states by using one-way ANOVA. We first created a new variable for each data frame and label top and bottom based on their category. After this, we run one-way ANOVA for the rank (top and bottom 5 states categories) with the number of death cases. The result showed a p-value that is less than 0.05. This means we will need to reject the null hypothesis that both groups are equal. This means, that

```
# anova
summary(aov(deaths~rank, data = Deaths_rank))
```

```
             Df Sum Sq Mean Sq F value Pr(>F)
rank          1   3426    3426   201.7 <2e-16 ***
Residuals 14090 239257      17
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
p value is less than 0.05, so we reject null hypothesis that both groups are equal.
```

there is no relationship between top and bottom 5 states in terms death cases.

Conclusion

In conclusion, the reduced model is almost always better than the full model even though the statistical measures indicate otherwise. After running the stepwise selection method for the top 5 and bottom 5 states for both confirmed cases and death counts, the reduced models contain statistically significant variables only. This is the main reason why R-squared and adjusted R-squared decrease for the reduced model because observations were removed. Although they are lower for the reduced model, the differences are minimal and can almost be neglected especially after filtering out statistically insignificant variables. In addition to this, the RMSE and MAE of the reduced model (in some cases) is higher than the full model, which confirms our findings. Furthermore, the coefficients from the regression output can be interpreted in numerous ways depending on how one looks at it. There are a lot of moving parts (such as the total population, social distancing measures, etc.) when it comes to the relationships between these variables and thus, they may sometimes contradict each other when talking about the top 5 and bottom 5 states for both confirmed cases and deaths alike.

This confirmed it when we run one-way ANOVA test between top and bottom 5 states, it showed that there is no relationship between 2 groups. Thus, we can say that both groups performed different in terms of distribution of confirmed and death cases.

Attachments

- weekfinal1.xlsx
- Deaths_rank.xlsx
- Confirmed_rank.xlsx
- Week_finalT.xlsx

Appendix A

Removed pre-identified variable using MS Excel Office 365

Parameters	**Affected Variables**
Components of 'social_distancing_total_grade'	* social_distancing_encounters_grade * social_distancing_travel_distance_grade
Components of 'total_college_population'	* less_than_high_school_diploma * high_school_diploma_only * some_college_or_higher
Unnecessary variables	* latitude * longitude
Combined in 'Age_0_19'	* age_0_4 * age_5_9 * age_10_14 * age_15_19
Combined in 'Age_20_59'	* age_20_24 * age_25_29 * age_30_34 * age_35_19 * age_40_44 * age_45_49 * age_50_54

	* age_55_59
Combined in 'Age_60+'	* age_60_64 * age_65_69 * age_70_74 * age_75_74 * age_80_84 * age_85_or_higher

Appendix B

Variable Types and Descriptions

Variables	**Type**	**Scale of Measurement**	**Description**
date	Numerical: Discrete	Interval	date formatted as day-month-year
county_fips	Categorical	Nominal	code for each unique county
count_name	Categorical	Nominal	name of county per state
state_fips	Categorical	Nominal	code for each unique state
state_name	Categorical	Nominal	name of each state
covid_19_confirmed_cases	Numerical: Discrete	Ratio	number of daily confirmed COVID cases
covid_19_deaths	Numerical: Discrete	Ratio	number of daily COVID deaths
social_distancing_total_grade	Categorical	Ordinal	average numerical score of unnecessary activities
daily_state_test	Numerical: Continuous	Ratio	number of tests performed daily in each county
precipitation	Numerical: Continuous	Ratio	daily precipitation
temperature	Numerical: Continuous	Interval	daily average temperature

Variables	**Type**	**Scale of Measurement**	**Description**
virus_pressure	Numerical: Continuous	Ratio	measures virus transmission from neighboring counties based on their covid cases
total_population	Numerical: Discrete	Ratio	population of each county
female_percent	Numerical: Continuous	Ratio	total percentage of females over whole population
area	Numerical: Continuous	Ratio	area in square miles per county
population_density	Numerical: Continuous	Ratio	population per square mile per county
hospital_beds_ratio	Numerical: Continuous	Ratio	number of hospital beds over total population
ventilator_capacity_ratio	Numerical: Continuous	Ratio	number of total ventilators divided by total population
icu_beds_ratio	Numerical: Continuous	Ratio	number of ICU beds divided by total population
houses_density	Numerical: Continuous	Ratio	number of housing units per square mile
total_college_population	Numerical: Discrete	Ratio	number of college students over total population
percent_smokers	Numerical: Continuous	Ratio	percentage of adult smokers

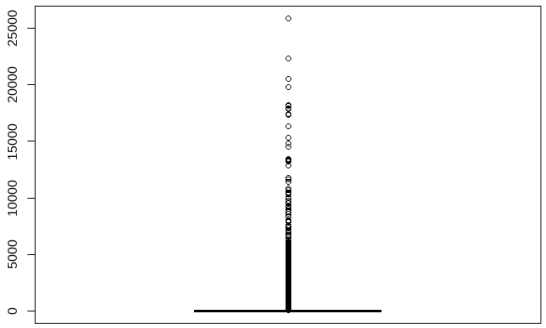
Variables	**Type**	**Scale of Measurement**	**Description**
percent_diabetes	Numerical: Continuous	Ratio	percentage of diabetic adults
religious_congregration_ratio	Numerical: Continuous	Ratio	number of active members of active religious congregations over total population
political_party	Categorical	Nominal	political party of the state's governor (0 - Republican, 1 - Democratic)
airport_distance	Numerical: Continuous	Ratio	distance to the nearest international airport (daily passenger load > 10)
passenger_load_ratio	Numerical: Continuous	Ratio	average daily passenger load of nearest international airport over total population
meat_plants	Numerical: Discrete	Ratio	number of meat processing plants
median_household_income	Numerical: Discrete	Ratio	average household income
percent_insured	Numerical: Continuous	Ratio	percentage of health insured residents
deaths_per_100000	Numerical: Continuous	Ratio	deaths per 100,000 residents
gdp_per_capita	Numerical: Continuous	Ratio	gross domestic product per capita
Age_0_19	Numerical: Discrete	Ratio	age group of children and young adults
Age_20_59	Numerical: Discrete	Ratio	age group of adults

Variables	**Type**	**Scale of Measurement**	**Description**
Age_60	Numerical: Discrete	Ratio	age group of elderly
immigrant_student_ratio	Numerical: Continuous	Ratio	total number of students who study in the county but come from another state over total population

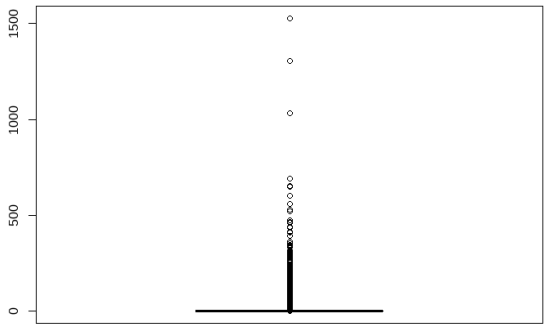
Appendix C

Inferential Analysis R code results and graphs

Figure A

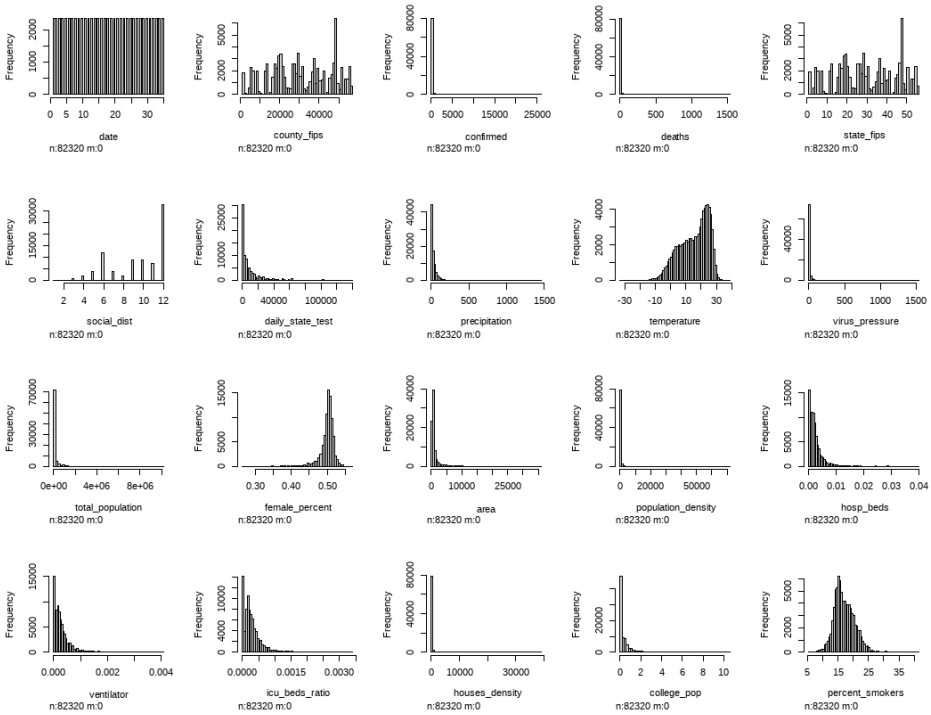


Confirmed Cases Boxplot



Death Cases Boxplot

Figure B



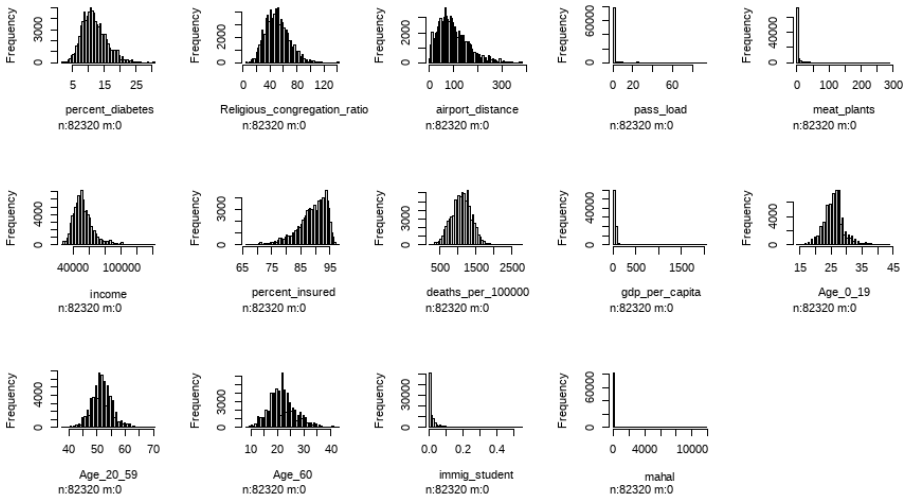
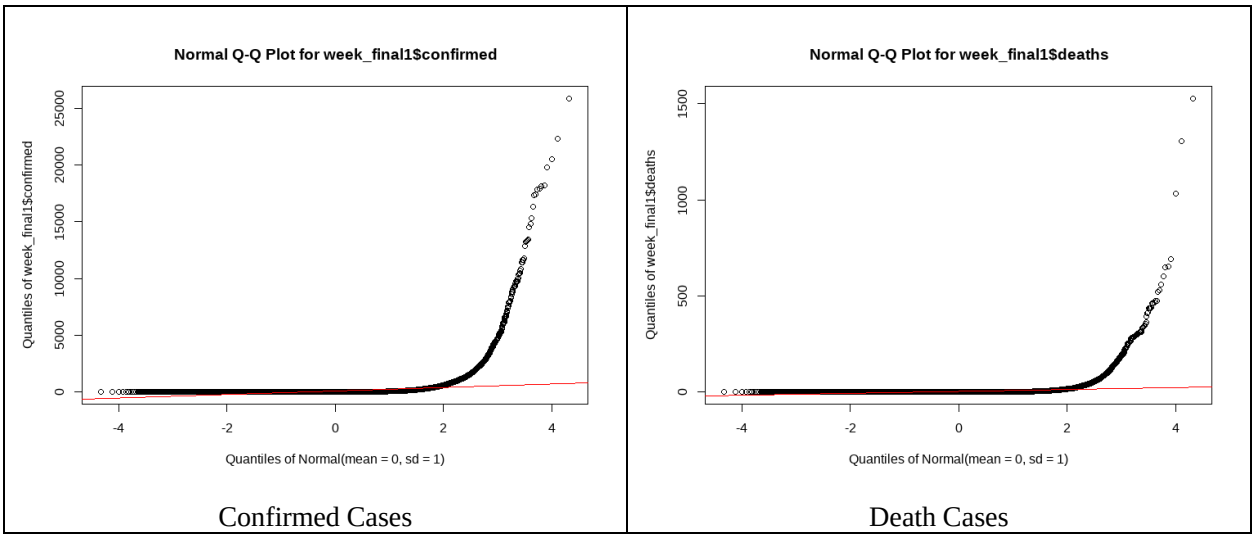


Figure C



Confirmed Cases | Death Cases

Figure D

Test for normality using Kolmogorov-Smirnov test. Null hypothesis = sample is normal distribution. The result for both showed p-value less than 0.05, therefore we reject the null hypothesis.

```
> ks.test(week_final1$confirmed, "pnorm")
Warning in ks.test(week_final1$confirmed, "p
  default ks.test() cannot compute correct p
 see help page for one-sample Kolmogorov tes

        One-sample Kolmogorov-Smirnov test

data:  week_final1$confirmed
D = 0.54462, p-value < 2.2e-16
alternative hypothesis: two-sided
```

Confirmed Cases

```
> ks.test(week_final1$deaths, "pnorm")
Warning in ks.test(week_final1$deaths, "pnorm
  default ks.test() cannot compute correct p-
 see help page for one-sample Kolmogorov test

        One-sample Kolmogorov-Smirnov test

data:  week_final1$deaths
D = 0.5, p-value < 2.2e-16
alternative hypothesis: two-sided
```

Death Cases

Figure E

```
Call:
lm(formula = confirmed ~ . - deaths - date - county_fips - state_fips -
    political_party - mahal - badmahal, data = week_finalT)

Residuals:
     Min       1Q   Median       3Q      Max
-1449.59   -28.78    -8.46    12.91   950.08

Coefficients:
                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                5.342e+01  8.359e+01   0.639 0.522757
social_dist                1.981e+00  1.269e-01  15.610  < 2e-16 ***
daily_state_test           5.587e-04  2.179e-05  25.645  < 2e-16 ***
precipitation              2.928e-02  7.903e-03   3.705 0.000211 ***
temperature                1.732e+00  3.655e-02  47.386  < 2e-16 ***
virus_pressure             1.070e+00  1.122e-02  95.384  < 2e-16 ***
total_population           1.285e-04  1.990e-06  64.589  < 2e-16 ***
female_percent             3.153e+02  1.694e+01  18.610  < 2e-16 ***
area                       1.421e-03  1.965e-04   7.230 4.85e-13 ***
population_density         3.326e-02  1.983e-03  16.776  < 2e-16 ***
hosp_beds                 -4.681e+02  1.277e+02  -3.664 0.000248 ***
ventilator                -2.442e+04  5.779e+03  -4.225 2.39e-05 ***
icu_beds_ratio             5.614e+04  6.704e+03   8.375  < 2e-16 ***
houses_density            -6.182e-02  3.806e-03 -16.242  < 2e-16 ***
college_pop                4.635e+00  1.062e+00   4.362 1.29e-05 ***
percent_smokers            3.983e-01  1.323e-01   3.009 0.002618 **
percent_diabetes          -7.741e-01  9.431e-02  -8.208 2.27e-16 ***
Religious_congregation_ratio  2.015e-01  1.999e-02  10.077  < 2e-16 ***
airport_distance          -8.271e-02  6.056e-03 -13.657  < 2e-16 ***
pass_load                 -2.175e-01  5.688e-02  -3.823 0.000132 ***
meat_plants               -1.028e+00  7.847e-02 -13.103  < 2e-16 ***
income                    -3.069e-04  3.792e-05  -8.093 5.92e-16 ***
percent_insured            6.948e-01  7.110e-02   9.772  < 2e-16 ***
deaths_per_100000         -2.937e-02  2.065e-03 -14.225  < 2e-16 ***
gdp_per_capita            -1.740e-02  4.600e-03  -3.784 0.000155 ***
Age_0_19                  -3.105e+00  8.362e-01  -3.713 0.000205 ***
Age_20_59                 -1.991e+00  8.341e-01  -2.387 0.016974 *
Age_60                    -3.685e+00  8.294e-01  -4.443 8.88e-06 ***
immig_student             -1.324e+02  2.339e+01  -5.660 1.52e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 81.87 on 81020 degrees of freedom
Multiple R-squared:  0.3904,    Adjusted R-squared:  0.3901
F-statistic:  1853 on 28 and 81020 DF,  p-value: < 2.2e-16
```

Figure F

```
Call:
lm(formula = confirmed ~ . - deaths - date - county_fips - state_fips -
    political_party - mahal - badmahal - houses_density - ventilator -
    Age_0_19 - immig_student, data = week_finalT)

Residuals:
     Min       1Q   Median       3Q      Max
-1460.83   -28.92    -8.61    12.78   949.05

Coefficients:
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                -2.714e+02  1.503e+01 -18.060  < 2e-16 ***
social_dist                 1.944e+00  1.271e-01  15.298  < 2e-16 ***
daily_state_test            5.647e-04  2.182e-05  25.875  < 2e-16 ***
precipitation               2.862e-02  7.917e-03   3.615 0.000300 ***
temperature                 1.721e+00  3.662e-02  47.013  < 2e-16 ***
virus_pressure              1.076e+00  1.123e-02  95.841  < 2e-16 ***
total_population            1.351e-04  1.958e-06  68.990  < 2e-16 ***
female_percent              3.266e+02  1.691e+01  19.321  < 2e-16 ***
area                        1.254e-03  1.964e-04   6.388 1.69e-10 ***
population_density          1.253e-03  2.232e-04   5.611 2.02e-08 ***
hosp_beds                  -3.046e+02  1.217e+02  -2.502 0.012362 *
icu_beds_ratio              2.853e+04  1.163e+03  24.538  < 2e-16 ***
college_pop                -5.364e-01  4.368e-01  -1.228 0.219414
percent_smokers             4.137e-01  1.325e-01   3.122 0.001797 **
percent_diabetes           -7.880e-01  9.428e-02  -8.358  < 2e-16 ***
Religious_congregation_ratio  2.186e-01  1.999e-02  10.938  < 2e-16 ***
airport_distance           -8.152e-02  6.056e-03 -13.461  < 2e-16 ***
pass_load                  -2.133e-01  5.698e-02  -3.744 0.000181 ***
meat_plants                -9.441e-01  7.839e-02 -12.044  < 2e-16 ***
income                     -2.703e-04  3.766e-05  -7.176 7.23e-13 ***
percent_insured             6.676e-01  7.107e-02   9.393  < 2e-16 ***
deaths_per_100000          -2.909e-02  2.060e-03 -14.127  < 2e-16 ***
gdp_per_capita             -1.678e-02  4.561e-03  -3.680 0.000234 ***
Age_20_59                   1.291e+00  1.538e-01   8.391  < 2e-16 ***
Age_60                     -5.985e-01  1.202e-01  -4.980 6.36e-07 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 82.03 on 81024 degrees of freedom
Multiple R-squared:  0.3879,    Adjusted R-squared:  0.3877
F-statistic:  2140 on 24 and 81024 DF,  p-value: < 2.2e-16
```

Figure G

```
Call:
lm(formula = deaths ~ . - date - county_fips - state_fips - political_party -
    mahal - badmahal, data = week_finalT)

Residuals:
     Min       1Q   Median       3Q      Max
-15.9575  -0.4110  -0.1799   0.0620  30.9525

Coefficients:
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                -4.311e+00  2.362e+00  -1.825 0.068025 .
confirmed                   1.745e-02  9.929e-05 175.760  < 2e-16 ***
social_dist                -3.282e-02  3.591e-03  -9.138  < 2e-16 ***
daily_state_test           -4.682e-06  6.183e-07  -7.574 3.67e-14 ***
precipitation               7.722e-04  2.234e-04   3.457 0.000546 ***
temperature                 2.116e-03  1.047e-03   2.021 0.043265 *
virus_pressure              4.228e-03  3.343e-04  12.647  < 2e-16 ***
total_population            1.659e-06  5.768e-08  28.762  < 2e-16 ***
female_percent              5.130e+00  4.798e-01  10.691  < 2e-16 ***
area                        4.674e-05  5.555e-06   8.415  < 2e-16 ***
population_density          2.047e-04  5.613e-05   3.647 0.000265 ***
hosp_beds                  -5.656e+00  3.611e+00  -1.566 0.117256
ventilator                 -3.883e+02  1.633e+02  -2.377 0.017439 *
icu_beds_ratio              5.396e+02  1.895e+02   2.847 0.004418 **
houses_density             -3.491e-04  1.077e-04  -3.239 0.001198 **
college_pop                -6.583e-03  3.003e-02  -0.219 0.826485
percent_smokers             7.148e-03  3.741e-03   1.911 0.056017 .
percent_diabetes            6.965e-03  2.666e-03   2.612 0.008998 **
Religious_congregation_ratio 1.233e-04  5.654e-04   0.218 0.827325
airport_distance           -2.065e-03  1.714e-04 -12.047  < 2e-16 ***
pass_load                   1.299e-03  1.608e-03   0.808 0.419248
meat_plants                -1.758e-02  2.220e-03  -7.917 2.46e-15 ***
income                      2.133e-06  1.072e-06   1.989 0.046662 *
percent_insured             8.638e-04  2.011e-03   0.430 0.667481
deaths_per_100000           2.711e-04  5.843e-05   4.640 3.49e-06 ***
gdp_per_capita              4.164e-04  1.300e-04   3.203 0.001362 **
Age_0_19                    7.865e-03  2.363e-02   0.333 0.739314
Age_20_59                   2.001e-02  2.357e-02   0.849 0.395913
Age_60                      1.322e-02  2.344e-02   0.564 0.572908
immig_student              -2.655e-01  6.611e-01  -0.402 0.687942
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.314 on 81019 degrees of freedom
Multiple R-squared:  0.4511,    Adjusted R-squared:  0.4509
F-statistic:  2296 on 29 and 81019 DF,  p-value: < 2.2e-16
```

Figure H.1

```
Call:
lm(formula = confirmed ~ . - date - county_fips - state_fips -
    mahal - badmahal, data = ConfirmedT5)

Residuals:
    Min      1Q  Median      3Q     Max
-645.66  -39.07   -6.63   21.50  793.68

Coefficients:
                             Estimate Std. Error t value Pr(>|t|)
(Intercept)                -2.414e+02  3.428e+02  -0.704 0.481428
deaths                      1.735e+01  2.635e-01  65.840  < 2e-16 ***
social_dist                 1.027e+00  5.315e-01   1.931 0.053460 .
daily_state_test            1.163e-03  5.223e-05  22.260  < 2e-16 ***
precipitation               3.629e-02  2.293e-02   1.583 0.113556
temperature                -4.305e-01  1.949e-01  -2.209 0.027187 *
virus_pressure              5.738e-01  1.871e-02  30.659  < 2e-16 ***
total_population            3.907e-05  4.886e-06   7.996 1.47e-15 ***
female_percent             -9.612e+01  8.030e+01  -1.197 0.231325
area                        4.832e-05  9.217e-04   0.052 0.958195
population_density          2.601e-02  3.352e-03   7.759 9.59e-15 ***
hosp_beds                  -3.130e+03  1.008e+03  -3.105 0.001909 **
ventilator                 -4.286e+03  4.055e+04  -0.106 0.915810
icu_beds_ratio              6.314e+04  4.664e+04   1.354 0.175842
houses_density             -4.969e-02  6.336e-03  -7.843 4.97e-15 ***
college_pop                 4.046e+01  6.777e+00   5.971 2.46e-09 ***
percent_smokers             4.303e-01  8.473e-01   0.508 0.611567
percent_diabetes            2.193e-01  4.256e-01   0.515 0.606351
Religious_congregation_ratio 3.796e-01  9.935e-02   3.821 0.000134 ***
political_party            -7.029e+01  8.295e+00  -8.474  < 2e-16 ***
airport_distance           -2.745e-02  3.034e-02  -0.905 0.365534
pass_load                   1.088e+00  3.092e+00   0.352 0.724829
meat_plants                -8.861e-01  1.625e-01  -5.453 5.09e-08 ***
income                      4.944e-04  1.466e-04   3.372 0.000750 ***
percent_insured             2.038e+00  6.938e-01   2.937 0.003322 **
deaths_per_100000           1.202e-02  1.110e-02   1.083 0.278954
gdp_per_capita              2.796e-01  7.525e-02   3.716 0.000204 ***
Age_0_19                    4.936e+00  3.475e+00   1.420 0.155522
Age_20_59                  -1.158e+00  3.500e+00  -0.331 0.740722
Age_60                     -5.926e-01  3.444e+00  -0.172 0.863392
immig_student              -7.544e+02  1.632e+02  -4.623 3.84e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 94.56 on 7922 degrees of freedom
Multiple R-squared:  0.6478,    Adjusted R-squared:  0.6464
F-statistic: 485.7 on 30 and 7922 DF,  p-value: < 2.2e-16
```

Appendix D

Cleaning and Transformation Codes

Library used

```
library(tidyverse) # for data manipulation
library(olsrr) # for residuals plot
library(equatiomatic) # to generate lm equation using TeX code
library(ggcorrplot) # correlation plot
library(caret) # for RMSE and MAE
library(plotly) # for interactive graph
library(hrbrthemes) # theme components for ggplot2
library(dlookr) # for diagnose outlier
library(lattice) # multiple columns boxplots
library(leaps) # for variable selection
library(trackdown) # collaborate Rmarkdown document through Google Drive

# set working directory
setwd("C:/Users/emili/OneDrive - Langara College/02 DANA 4810 --
Quantitatitve/Project")
```

Load Dataset

```
# load clean revised dataset
covid_c <- read.csv("C:/Users/emili/OneDrive - Langara College/02 DANA 4810 -
- Quantitatitve/Project/Covid_cleanish1.csv")
```

Investigate Dataset

```
# row and column count
cat("Total number of rows:", nrow(covid_c),"\n")

## Total number of rows: 562128

cat("Total number of variables/columns:", ncol(covid_c))

## Total number of variables/columns: 36

head(covid_c)

##    ï..date county_fips     county_name state_fips state_name
## 1 27-04-20       56013  Fremont County         56    Wyoming
## 2 25-04-20       56013  Fremont County         56    Wyoming
## 3 05-07-20       56005 Campbell County         56    Wyoming
## 4 16-03-20       56013  Fremont County         56    Wyoming
## 5 26-04-20       56013  Fremont County         56    Wyoming
## 6 10-05-20       56013  Fremont County         56    Wyoming
##   covid_19_confirmed_cases covid_19_deaths social_distancing_total_grade
```

```
## 1                       15              0                            C
## 2                       10              0                            C
## 3                        7              0                           D+
## 4                        7              0                           D+
## 5                        7              0                            C
## 6                        7              0                           D+
##   daily_state_test precipitation temperature virus_pressure
total_population
## 1                8           1.0        7.18              0
39531
## 2              101           0.0        4.68              0
39531
## 3               28           0.0       21.30              0
46140
## 4                0           0.0       -1.46              0
39531
## 5               13           4.6        6.78              0
39531
## 6               17           0.0        4.90              0
39531
##   female_percent    area population_density hospital_beds_ratio
## 1      0.4984696 9183.81           4.304423         0.002352584
## 2      0.4984696 9183.81           4.304423         0.002352584
## 3      0.4846337 4802.71           9.607076         0.004659731
## 4      0.4984696 9183.81           4.304423         0.002352584
## 5      0.4984696 9183.81           4.304423         0.002352584
## 6      0.4984696 9183.81           4.304423         0.002352584
##   ventilator_capacity_ratio icu_beds_ratio houses_density
## 1               0.001340720    0.001113051         1.9625
## 2               0.001340720    0.001113051         1.9625
## 3               0.000368444    0.000303424         4.2303
## 4               0.001340720    0.001113051         1.9625
## 5               0.001340720    0.001113051         1.9625
## 6               0.001340720    0.001113051         1.9625
##   total_college_population percent_smokers percent_diabetes
## 1                0.4240217        19.39994              9.9
## 2                0.4240217        19.39994              9.9
## 3                0.0000000        18.48914              7.5
## 4                0.4240217        19.39994              9.9
## 5                0.4240217        19.39994              9.9
## 6                0.4240217        19.39994              9.9
##   Religious_congregation_ratio political_party airport_distance
## 1                           33               0         176.8667
## 2                           33               0         176.8667
## 3                           35               0         166.5740
## 4                           33               0         176.8667
## 5                           33               0         176.8667
## 6                           33               0         176.8667
##   passenger_load_ratio meat_plants median_household_income percent_insured
## 1          0.000455339           0                   51204        79.88766
```

```
## 2          0.000455339           0                   51204        79.88766
## 3          0.000498483           0                   78112        87.15840
## 4          0.000455339           0                   51204        79.88766
## 5          0.000455339           0                   51204        79.88766
## 6          0.000455339           0                   51204        79.88766
##   deaths_per_100000 gdp_per_capita Age_0_19 Age_20_59 Age_60.
## 1            1130.8          39.82       29        52      22
## 2            1130.8          39.82       29        52      22
## 3             587.3         130.06       31        60       9
## 4            1130.8          39.82       29        52      22
## 5            1130.8          39.82       29        52      22
## 6            1130.8          39.82       29        52      22
##   immigrant_student_ratio
## 1              0.01495029
## 2              0.01495029
## 3              0.00000000
## 4              0.01495029
## 5              0.01495029
## 6              0.01495029
```

Cleaning and Transformation

```
# rename date column
covid_c <- covid_c %>%
  rename(date = ï..date)

# format date variable as.date format
covid_c$date <- as.Date(covid_c$date,"%d-%m-%y")

# check data format and column name
head(covid_c)
```

```
##         date county_fips     county_name state_fips state_name
## 1 2020-04-27       56013  Fremont County         56    Wyoming
## 2 2020-04-25       56013  Fremont County         56    Wyoming
## 3 2020-07-05       56005 Campbell County         56    Wyoming
## 4 2020-03-16       56013  Fremont County         56    Wyoming
## 5 2020-04-26       56013  Fremont County         56    Wyoming
## 6 2020-05-10       56013  Fremont County         56    Wyoming
##   covid_19_confirmed_cases covid_19_deaths social_distancing_total_grade
## 1                       15              0                             C
## 2                       10              0                             C
## 3                        7              0                            D+
## 4                        7              0                            D+
## 5                        7              0                             C
## 6                        7              0                            D+
##   daily_state_test precipitation temperature virus_pressure
total_population
## 1                8           1.0        7.18              0
39531
```

```
## 2              101           0.0        4.68              0
39531
## 3               28           0.0       21.30              0
46140
## 4                0           0.0       -1.46              0
39531
## 5               13           4.6        6.78              0
39531
## 6               17           0.0        4.90              0
39531
##   female_percent    area population_density hospital_beds_ratio
## 1      0.4984696 9183.81           4.304423         0.002352584
## 2      0.4984696 9183.81           4.304423         0.002352584
## 3      0.4846337 4802.71           9.607076         0.004659731
## 4      0.4984696 9183.81           4.304423         0.002352584
## 5      0.4984696 9183.81           4.304423         0.002352584
## 6      0.4984696 9183.81           4.304423         0.002352584
##   ventilator_capacity_ratio icu_beds_ratio houses_density
## 1               0.001340720    0.001113051         1.9625
## 2               0.001340720    0.001113051         1.9625
## 3               0.000368444    0.000303424         4.2303
## 4               0.001340720    0.001113051         1.9625
## 5               0.001340720    0.001113051         1.9625
## 6               0.001340720    0.001113051         1.9625
##   total_college_population percent_smokers percent_diabetes
## 1                0.4240217        19.39994              9.9
## 2                0.4240217        19.39994              9.9
## 3                0.0000000        18.48914              7.5
## 4                0.4240217        19.39994              9.9
## 5                0.4240217        19.39994              9.9
## 6                0.4240217        19.39994              9.9
##   Religious_congregation_ratio political_party airport_distance
## 1                           33               0         176.8667
## 2                           33               0         176.8667
## 3                           35               0         166.5740
## 4                           33               0         176.8667
## 5                           33               0         176.8667
## 6                           33               0         176.8667
##   passenger_load_ratio meat_plants median_household_income percent_insured
## 1          0.000455339           0                   51204        79.88766
## 2          0.000455339           0                   51204        79.88766
## 3          0.000498483           0                   78112        87.15840
## 4          0.000455339           0                   51204        79.88766
## 5          0.000455339           0                   51204        79.88766
## 6          0.000455339           0                   51204        79.88766
##   deaths_per_100000 gdp_per_capita Age_0_19 Age_20_59 Age_60.
## 1            1130.8          39.82       29        52      22
## 2            1130.8          39.82       29        52      22
## 3             587.3         130.06       31        60       9
## 4            1130.8          39.82       29        52      22
```

```
## 5            1130.8          39.82       29        52      22
## 6            1130.8          39.82       29        52      22
##   immigrant_student_ratio
## 1              0.01495029
## 2              0.01495029
## 3              0.00000000
## 4              0.01495029
## 5              0.01495029
## 6              0.01495029

# group data per week per county
library(dplyr)
covid_c <- covid_c %>%
  mutate(week = cut.Date(date, breaks = "1 week", labels = FALSE)) %>%
  arrange(date)

unique(covid_c$week) # get unique numbers in week

##  [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
24 25
## [26] 26 27 28 29 30 31 32 33 34 35

# change categorical variable to numeric equivalent
unique(covid_c$social_distancing_total_grade) # check unique variables

##  [1] "F"  "D"  "C"  "D+" "D-" "C-" "B-" "B"  "A-" "C+" "A"  "B+"

covid_c1 <- covid_c %>% mutate(social_distancing_total_grade =
as.numeric(as.factor(covid_c$social_distancing_total_grade)))
unique(covid_c1$social_distancing_total_grade) # check unique variables as
numeric

##  [1] 12  9  6 11 10  7  4  3  2  8  1  5
```

No A+ grading was recorded.

```
# drop columns in dataset: date, county_name, state_name
covid_c1 <- subset(covid_c1, select = -c(date, county_name, state_name))

# Group the observations together by week by county based on mean but
separate covid_19_confirmed_cases and covid_19_deaths from the res
# dataframe 1
week_meancounty_cd <- subset(covid_c1, select = c(week, county_fips,
covid_19_confirmed_cases, covid_19_deaths))
week_meancounty_cd <- aggregate(.~ week + county_fips, data =
week_meancounty_cd, sum)
# dataframe 2
week_meancounty <- subset(covid_c1, select = -c(covid_19_confirmed_cases,
covid_19_deaths))
week_meancounty <- aggregate(.~ week + county_fips, data = week_meancounty,
mean)
```

```
# Check if sum of original dataframe and aggregated are the same
sum(week_meancounty_cd$covid_19_confirmed_cases)

## [1] 5866205

sum(covid_c1$covid_19_confirmed_cases)

## [1] 5866205

# Merge 2 dataframe 1 and 2 by row names
week_final <- merge(week_meancounty_cd, week_meancounty, by = 0)

# drop duplicate variable names and rename final dataset for analysis
week_final <- subset(week_final, select = -c(Row.names, week.y,
county_fips.y))
```

Total observations are 82,320

```
# round to whole digit social_distancing_total_grade so you can covert later
easily to categorical
week_final$social_distancing_total_grade <-
round(week_final$social_distancing_total_grade, digits = 0)
```

NEXT TO DO: fix proportion of age group to equal to 100%

```
# fix age distribution per age group by getting the ratio of the total of
total percent
week_final <- week_final %>%
  mutate(Age_0_19 = Age_0_19/(Age_0_19 + Age_20_59 + Age_60.)*100) %>%
  mutate(Age_20_59 = Age_20_59/(Age_0_19 + Age_20_59 + Age_60.)*100) %>%
  mutate(Age_60. = Age_60./(Age_0_19 + Age_20_59 + Age_60.)*100)

# rename variables by removing '.x' and '.'
week_final <- week_final %>%
  rename(date = week.x) %>%
  rename(county_fips = county_fips.x) %>%
  rename(Age_60 = Age_60.)

# remove splitted dataframe
rm(week_meancounty, week_meancounty_cd)
```

Appendix E

Descriptive Analysis Codes

Library used

```
library(tidyverse) # for data manipulation
library(olsrr) # for residuals plot
library(equatiomatic) # to generate lm equation using TeX code
library(ggcorrplot) # correlation plot
library(caret) # for RMSE and MAE
library(plotly) # for interactive graph
library(hrbrthemes) # theme components for ggplot2
library(dlookr) # for diagnose outlier
library(lattice) # multiple columns boxplots
library(leaps) # for variable selection
library(trackdown) # collaborate Rmarkdown document through Google Drive

# set working directory
setwd("C:/Users/emili/OneDrive - Langara College/02 DANA 4810 -- Quantitatitv
e/Project")
```

Load Aggregated Dataset from Github

```
week_final1 <- read.csv("https://raw.githubusercontent.com/emiliosagre/COVID1
9-US/main/week_final1.csv")
```

Investigate Dataset

```
# row and column count
cat("Total number of rows:", nrow(week_final1),"\n")

## Total number of rows: 82320

cat("Total number of variables/columns:", ncol(week_final1))

## Total number of variables/columns: 34
```

Check for Outliers

```
summary(week_final1)

##       date        county_fips    covid_19_confirmed_cases covid_19_deaths
##  Min.   : 1   Min.   : 1003   Min.   :    0.00         Min.   :   0.00
##  1st Qu.: 9   1st Qu.:19041   1st Qu.:    0.00         1st Qu.:   0.00
##  Median :18   Median :29162   Median :    3.00         Median :   0.00
##  Mean   :18   Mean   :30309   Mean   :   71.26         Mean   :   2.03
##  3rd Qu.:27   3rd Qu.:45046   3rd Qu.:   26.00         3rd Qu.:   0.00
##  Max.   :35   Max.   :56039   Max.   :25882.00         Max.   :1528.00
##    state_fips    social_distancing_total_grade daily_state_test
```

```
##  Min.   : 1.00   Min.   : 1.000                Min.   :     0.0
##  1st Qu.:19.00   1st Qu.: 7.000                1st Qu.:   332.6
##  Median :29.00   Median :10.000                Median :  4132.7
##  Mean   :30.22   Mean   : 9.552                Mean   :  9986.6
##  3rd Qu.:45.00   3rd Qu.:12.000                3rd Qu.: 11659.6
##  Max.   :56.00   Max.   :12.000                Max.   :138859.4
##  precipitation       temperature      virus_pressure      total_population
##  Min.   :   0.000   Min.   :-32.314   Min.   :   0.0000   Min.   :    1227
##  1st Qu.:   4.286   1st Qu.:  8.174   1st Qu.:   0.0357   1st Qu.:   13119
##  Median :  17.200   Median : 17.343   Median :   1.3333   Median :   32398
##  Mean   :  28.991   Mean   : 15.446   Mean   :   9.9183   Mean   :  124755
##  3rd Qu.:  39.629   3rd Qu.: 23.449   3rd Qu.:   6.6735   3rd Qu.:   87010
##  Max.   :1446.000   Max.   : 38.074   Max.   :1535.5000   Max.   :10105518
##  female_percent        area         population_density hospital_beds_ratio
##  Min.   :0.2684   Min.   :    2.5   Min.   :    0.22   Min.   :0.0000000
##  1st Qu.:0.4946   1st Qu.:  471.7   1st Qu.:   18.39   1st Qu.:0.0008365
##  Median :0.5031   Median :  651.7   Median :   48.13   Median :0.0017630
##  Mean   :0.4994   Mean   : 1086.4   Mean   :  257.72   Mean   :0.0025211
##  3rd Qu.:0.5100   3rd Qu.:  974.7   3rd Qu.:  136.96   3rd Qu.:0.0030786
##  Max.   :0.5687   Max.   :35572.6   Max.   :71340.39   Max.   :0.0399348
##  ventilator_capacity_ratio icu_beds_ratio      houses_density
##  Min.   :0.0000000         Min.   :0.0000000   Min.   :    0.08
##  1st Qu.:0.0001048         1st Qu.:0.0001188   1st Qu.:    9.28
##  Median :0.0002189         Median :0.0002285   Median :   23.22
##  Mean   :0.0003105         Mean   :0.0003046   Mean   :  113.82
##  3rd Qu.:0.0003991         3rd Qu.:0.0003918   3rd Qu.:   60.83
##  Max.   :0.0040732         Max.   :0.0033943   Max.   :38819.49
##  total_college_population percent_smokers  percent_diabetes
##  Min.   : 0.000000        Min.   : 5.909   Min.   : 1.80
##  1st Qu.: 0.000000        1st Qu.:14.801   1st Qu.: 9.10
##  Median : 0.005462        Median :16.673   Median :11.40
##  Mean   : 0.387971        Mean   :17.169   Mean   :11.87
##  3rd Qu.: 0.506748        3rd Qu.:19.341   3rd Qu.:14.10
##  Max.   :10.586403        Max.   :41.491   Max.   :31.00
##  Religious_congregation_ratio political_party  airport_distance
##  Min.   :  5.00               Min.   :0.0000   Min.   :  2.675
##  1st Qu.: 39.00               1st Qu.:0.0000   1st Qu.: 53.906
##  Median : 50.00               Median :0.0000   Median : 87.143
##  Mean   : 51.14               Mean   :0.4575   Mean   : 98.660
##  3rd Qu.: 62.00               3rd Qu.:1.0000   3rd Qu.:133.886
##  Max.   :141.00               Max.   :1.0000   Max.   :383.144
##  passenger_load_ratio  meat_plants      median_household_income percent_in
sured
##  Min.   : 0.00002     Min.   :  0.000   Min.   : 26278          Min.   :66
.25
##  1st Qu.: 0.00157     1st Qu.:  0.000   1st Qu.: 44565          1st Qu.:86
.24
##  Median : 0.00610     Median :  1.000   Median : 51121          Median :89
.78
##  Mean   : 0.80283     Mean   :  2.963   Mean   : 53410          Mean   :88
```

```
.94
##  3rd Qu.: 0.04684     3rd Qu.:  3.000   3rd Qu.: 59243          3rd Qu.:92
.83
##  Max.   :93.58695     Max.   :288.000   Max.   :140382          Max.   :97
.74
##  deaths_per_100000 gdp_per_capita       Age_0_19       Age_20_59
##  Min.   : 235.4    Min.   :  10.61   Min.   :14.14   Min.   :37.70
##  1st Qu.: 919.1    1st Qu.:  29.31   1st Qu.:24.00   1st Qu.:49.61
##  Median :1109.2    Median :  39.12   Median :26.00   Median :51.63
##  Mean   :1103.0    Mean   :  47.70   Mean   :26.20   Mean   :51.78
##  3rd Qu.:1287.8    3rd Qu.:  52.15   3rd Qu.:28.00   3rd Qu.:54.00
##  Max.   :2790.7    Max.   :2027.95   Max.   :43.56   Max.   :70.41
##      Age_60      immigrant_student_ratio
##  Min.   : 8.00   Min.   :0.0000000
##  1st Qu.:18.88   1st Qu.:0.0000000
##  Median :21.92   Median :0.0002023
##  Mean   :22.02   Mean   :0.0157857
##  3rd Qu.:25.00   3rd Qu.:0.0201942
##  Max.   :43.00   Max.   :0.5400094

diagnose(week_final1)

## # A tibble: 34 x 6
##    variables        types missing_count missing_percent unique_count uniqu
e_rate
##    <chr>            <chr>         <int>           <dbl>        <int>
<dbl>
##  1 date             inte~             0               0           35    0.
000425
##  2 county_fips      inte~             0               0         2352    0.
0286
##  3 covid_19_confir~ inte~             0               0         1737    0.
0211
##  4 covid_19_deaths  inte~             0               0          261    0.
00317
##  5 state_fips       inte~             0               0           50    0.
000607
##  6 social_distanci~ inte~             0               0           12    0.
000146
##  7 daily_state_test nume~             0               0         1515    0.
0184
##  8 precipitation    nume~             0               0         5002    0.
0608
##  9 temperature      nume~             0               0        13737    0.
167
## 10 virus_pressure   nume~             0               0        16790    0.
204
## # ... with 24 more rows
```

No missing values in the data.

```
# library dlookr
# convert to dataframe
covid_outlier <- as.data.frame(diagnose_outlier(week_final1))

# get difference between outlier with mean and without mean
covid_outlier$difference <- (covid_outlier$with_mean - covid_outlier$without_
mean)

# sort difference in descending order
covid_outlier %>% arrange(desc(covid_outlier,difference))
```

```
##                        variables outliers_cnt outliers_ratio outliers_mean
## 1                 virus_pressure        10155    12.33600583  6.152980e+01
## 2      ventilator_capacity_ratio         5250     6.37755102  1.346640e-03
## 3                total_population        10745    13.05272109  6.792133e+05
## 4       total_college_population         6160     7.48299320  2.440349e+00
## 5                     temperature           28     0.03401361 -1.918184e+01
## 6                      state_fips            0     0.00000000           NaN
## 7  social_distancing_total_grade            0     0.00000000           NaN
## 8   Religious_congregation_ratio          700     0.85034014  1.063500e+02
## 9                   precipitation         4807     5.83940719  1.396803e+02
## 10            population_density        11095    13.47789116  1.508432e+03
## 11               political_party            0     0.00000000           NaN
## 12               percent_smokers          735     0.89285714  2.881225e+01
## 13               percent_insured         1575     1.91326531  7.339556e+01
## 14              percent_diabetes         1085     1.31802721  2.376129e+01
## 15          passenger_load_ratio        16380    19.89795918  3.988672e+00
## 16       median_household_income         3780     4.59183673  9.459195e+04
## 17                     meat_plants         6895     8.37585034  1.920305e+01
## 18       immigrant_student_ratio         7035     8.54591837  9.519714e-02
## 19                icu_beds_ratio         5320     6.46258503  1.229842e-03
## 20                houses_density        10850    13.18027211  6.701818e+02
## 21           hospital_beds_ratio         5495     6.67517007  1.129817e-02
## 22                gdp_per_capita         3885     4.71938776  1.956587e+02
## 23                female_percent         6335     7.69557823  4.544444e-01
## 24             deaths_per_100000          700     0.85034014  1.474400e+03
## 25                          date            0     0.00000000           NaN
## 26              daily_state_test         7084     8.60544218  5.346615e+04
## 27               covid_19_deaths        18769    22.80004859  8.904683e+00
## 28      covid_19_confirmed_cases        12218    14.84207969  4.314966e+02
## 29                   county_fips            0     0.00000000           NaN
## 30                          area        10185    12.37244898  4.072637e+03
## 31              airport_distance         1960     2.38095238  2.872448e+02
## 32                       Age_60         1365     1.65816327  3.508528e+01
## 33                    Age_20_59         2205     2.67857143  5.561758e+01
## 34                     Age_0_19         2695     3.27380952  3.148534e+01
##       with_mean without_mean    difference
## 1  9.918332e+00 2.655607e+00  7.262724e+00
## 2  3.105403e-04 2.399614e-04  7.057897e-05
## 3  1.247548e+05 4.151818e+04  8.323657e+04
```

```
## 4  3.879712e-01 2.219701e-01  1.660011e-01
## 5  1.544597e+01 1.545775e+01 -1.178217e-02
## 6  3.021556e+01 3.021556e+01  0.000000e+00
## 7  9.552259e+00 9.552259e+00  0.000000e+00
## 8  5.114201e+01 5.066852e+01  4.734819e-01
## 9  2.899104e+01 2.212660e+01  6.864439e+00
## 10 2.577202e+02 6.289195e+01  1.948283e+02
## 11 4.574830e-01 4.574830e-01  0.000000e+00
## 12 1.716937e+01 1.706448e+01  1.048909e-01
## 13 8.894042e+01 8.924364e+01 -3.032159e-01
## 14 1.186688e+01 1.170801e+01  1.588655e-01
## 15 8.028250e-01 1.143621e-02  7.913888e-01
## 16 5.340991e+04 5.142788e+04  1.982024e+03
## 17 2.963010e+00 1.478422e+00  1.484588e+00
## 18 1.578568e-02 8.365082e-03  7.420596e-03
## 19 3.045541e-04 2.406252e-04  6.392895e-05
## 20 1.138233e+02 2.936149e+01  8.446186e+01
## 21 2.521076e-03 1.893284e-03  6.277923e-04
## 22 4.769686e+01 4.036809e+01  7.328768e+00
## 23 4.993922e-01 5.031396e-01 -3.747380e-03
## 24 1.103045e+03 1.099860e+03  3.184861e+00
## 25 1.800000e+01 1.800000e+01  0.000000e+00
## 26 9.986594e+03 5.892687e+03  4.093907e+03
## 27 2.030272e+00 0.000000e+00  2.030272e+00
## 28 7.126099e+01 8.475921e+00  6.278507e+01
## 29 3.030864e+04 3.030864e+04  0.000000e+00
## 30 1.086409e+03 6.647723e+02  4.216364e+02
## 31 9.865959e+01 9.405995e+01  4.599638e+00
## 32 2.202343e+01 2.180319e+01  2.202388e-01
## 33 5.178345e+01 5.167792e+01  1.055265e-01
## 34 2.620292e+01 2.602413e+01  1.787897e-01

covid_outlier

##                         variables outliers_cnt outliers_ratio outliers_mean
## 1                            date            0     0.00000000           NaN
## 2                     county_fips            0     0.00000000           NaN
## 3       covid_19_confirmed_cases        12218    14.84207969  4.314966e+02
## 4                 covid_19_deaths        18769    22.80004859  8.904683e+00
## 5                      state_fips            0     0.00000000           NaN
## 6  social_distancing_total_grade            0     0.00000000           NaN
## 7                daily_state_test         7084     8.60544218  5.346615e+04
## 8                   precipitation         4807     5.83940719  1.396803e+02
## 9                     temperature           28     0.03401361 -1.918184e+01
## 10                virus_pressure        10155    12.33600583  6.152980e+01
## 11              total_population        10745    13.05272109  6.792133e+05
## 12                female_percent         6335     7.69557823  4.544444e-01
## 13                          area        10185    12.37244898  4.072637e+03
## 14            population_density        11095    13.47789116  1.508432e+03
## 15           hospital_beds_ratio         5495     6.67517007  1.129817e-02
```

```
## 16     ventilator_capacity_ratio         5250     6.37755102  1.346640e-03
## 17                 icu_beds_ratio         5320     6.46258503  1.229842e-03
## 18                 houses_density        10850    13.18027211  6.701818e+02
## 19      total_college_population         6160     7.48299320  2.440349e+00
## 20                 percent_smokers          735     0.89285714  2.881225e+01
## 21               percent_diabetes         1085     1.31802721  2.376129e+01
## 22  Religious_congregation_ratio          700     0.85034014  1.063500e+02
## 23                 political_party            0     0.00000000           NaN
## 24               airport_distance         1960     2.38095238  2.872448e+02
## 25          passenger_load_ratio        16380    19.89795918  3.988672e+00
## 26                     meat_plants         6895     8.37585034  1.920305e+01
## 27       median_household_income         3780     4.59183673  9.459195e+04
## 28                 percent_insured         1575     1.91326531  7.339556e+01
## 29              deaths_per_100000          700     0.85034014  1.474400e+03
## 30                 gdp_per_capita         3885     4.71938776  1.956587e+02
## 31                       Age_0_19         2695     3.27380952  3.148534e+01
## 32                      Age_20_59         2205     2.67857143  5.561758e+01
## 33                         Age_60         1365     1.65816327  3.508528e+01
## 34       immigrant_student_ratio         7035     8.54591837  9.519714e-02
##       with_mean without_mean    difference
## 1  1.800000e+01 1.800000e+01  0.000000e+00
## 2  3.030864e+04 3.030864e+04  0.000000e+00
## 3  7.126099e+01 8.475921e+00  6.278507e+01
## 4  2.030272e+00 0.000000e+00  2.030272e+00
## 5  3.021556e+01 3.021556e+01  0.000000e+00
## 6  9.552259e+00 9.552259e+00  0.000000e+00
## 7  9.986594e+03 5.892687e+03  4.093907e+03
## 8  2.899104e+01 2.212660e+01  6.864439e+00
## 9  1.544597e+01 1.545775e+01 -1.178217e-02
## 10 9.918332e+00 2.655607e+00  7.262724e+00
## 11 1.247548e+05 4.151818e+04  8.323657e+04
## 12 4.993922e-01 5.031396e-01 -3.747380e-03
## 13 1.086409e+03 6.647723e+02  4.216364e+02
## 14 2.577202e+02 6.289195e+01  1.948283e+02
## 15 2.521076e-03 1.893284e-03  6.277923e-04
## 16 3.105403e-04 2.399614e-04  7.057897e-05
## 17 3.045541e-04 2.406252e-04  6.392895e-05
## 18 1.138233e+02 2.936149e+01  8.446186e+01
## 19 3.879712e-01 2.219701e-01  1.660011e-01
## 20 1.716937e+01 1.706448e+01  1.048909e-01
## 21 1.186688e+01 1.170801e+01  1.588655e-01
## 22 5.114201e+01 5.066852e+01  4.734819e-01
## 23 4.574830e-01 4.574830e-01  0.000000e+00
## 24 9.865959e+01 9.405995e+01  4.599638e+00
## 25 8.028250e-01 1.143621e-02  7.913888e-01
## 26 2.963010e+00 1.478422e+00  1.484588e+00
## 27 5.340991e+04 5.142788e+04  1.982024e+03
## 28 8.894042e+01 8.924364e+01 -3.032159e-01
## 29 1.103045e+03 1.099860e+03  3.184861e+00
## 30 4.769686e+01 4.036809e+01  7.328768e+00
```

```
## 31 2.620292e+01 2.602413e+01  1.787897e-01
## 32 5.178345e+01 5.167792e+01  1.055265e-01
## 33 2.202343e+01 2.180319e+01  2.202388e-01
## 34 1.578568e-02 8.365082e-03  7.420596e-03
```

Data showed a lot of outliers we will not remove any of them.

Correlation for covid_19_confirmed_cases and covid_19_deaths with other variables

A. Confirmed Cases

```
# covid_19_confirmed_cases
cor_confirmed <- as.data.frame(cor(week_final1[ , colnames(week_final1) != "c
ovid_19_confirmed_cases"],  # Calculate correlations
                week_final1$covid_19_confirmed_cases))

# sort difference in descending order
cor_confirmed <- cor_confirmed %>% arrange(desc(cor_confirmed,v1))

head(cor_confirmed, 10) # top 10 most correlated
```

```
##                                V1
## covid_19_deaths         0.6411414
## total_population        0.6054531
## meat_plants             0.5486385
## virus_pressure          0.4741532
## daily_state_test        0.2148120
## population_density      0.1706903
## houses_density          0.1421518
## Age_20_59               0.1317190
## median_household_income 0.1260323
## temperature             0.1178476
```

```
tail(cor_confirmed, 10)
```

```
##                               V1
## hospital_beds_ratio  -0.01105132
## percent_insured      -0.01234432
## passenger_load_ratio -0.01609232
## state_fips           -0.04863404
## county_fips          -0.04869855
## percent_diabetes     -0.07469584
## percent_smokers      -0.09402702
## Age_60               -0.13482410
## airport_distance     -0.14941314
## deaths_per_100000    -0.15819836
```

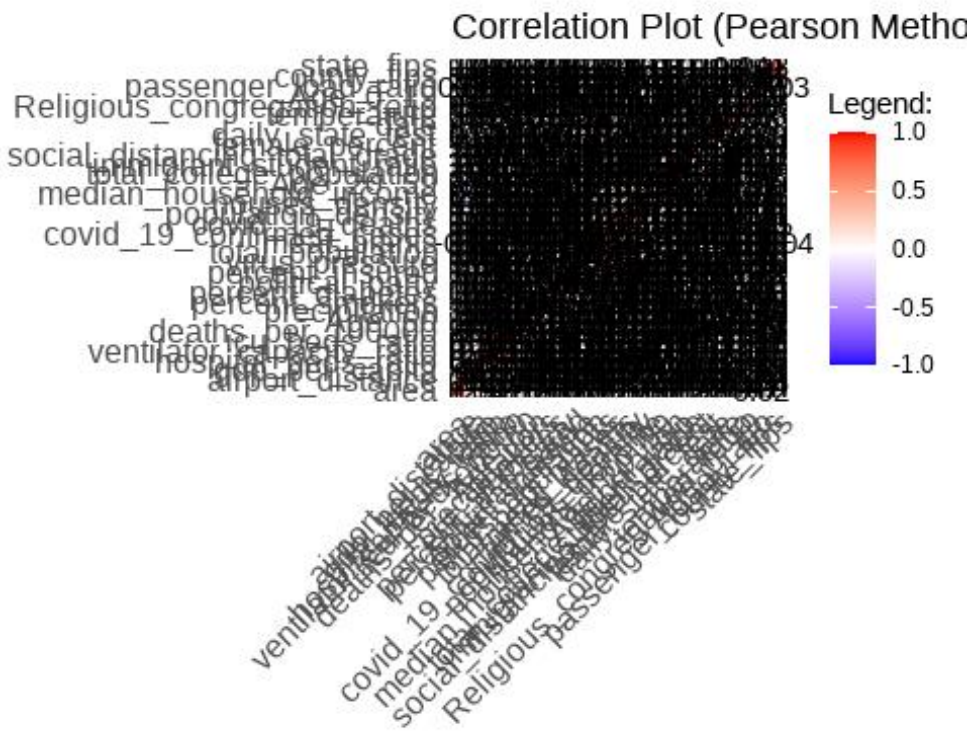
B. Deaths

```
# covid_19_confirmed_cases
cor_deaths <- as.data.frame(cor(week_final1[ , colnames(week_final1) != "covi
```

```
d_19_deaths"],  # Calculate correlations
                week_final1$covid_19_deaths))

# sort difference in descending order
cor_deaths <- cor_deaths %>% arrange(desc(cor_deaths,v1))

head(cor_confirmed, 10) # top 10 most correlated
```

```
##                                V1
## covid_19_deaths         0.6411414
## total_population        0.6054531
## meat_plants             0.5486385
## virus_pressure          0.4741532
## daily_state_test        0.2148120
## population_density      0.1706903
## houses_density          0.1421518
## Age_20_59               0.1317190
## median_household_income 0.1260323
## temperature             0.1178476
```

```
# correlation plot of all variables using pearson method with values
ggcorrplot(cor(week_final1[,unlist(lapply(week_final1,is.numeric))], method =
"pearson"), hc.order = TRUE, insig ="blank", lab =TRUE,
  title = "Correlation Plot (Pearson Method)", legend.title = "Legend:")
```



Appendix F

Inferential Analysis Codes

set working directory

```
setwd("C:/Users/emili/OneDrive - Langara College/02 DANA 4810 -- Quantitatitve/Project/FINAL")
```

Library used *

```
library(tidyverse) # for data manipulation
library(olsrr) # for residuals plot
library(dplyr)
library(equatiomatic) # to generate lm equation using TeX code
library(ggcorrplot) # correlation plot
library(caret) # for RMSE and MAE
library(plotly) # for interactive graph
library(hrbrthemes) # theme components for ggplot2
library(dlookr) # for diagnose outlier
library(lattice) # multiple columns boxplots
library(leaps) # for variable selection
library(trackdown) # collaborate Rmarkdown document through Google Drive
library(corrplot)
```

Load Aggregated Dataset

```
week_final1 <- read.csv("https://raw.githubusercontent.com/emiliosagre/COVID19-US/main/week_final1.csv")
```

Dataset shape

```
# row and column count
cat("Total number of rows:", nrow(week_final1),"\n")

## Total number of rows: 82320

cat("Total number of variables/columns:", ncol(week_final1))

## Total number of variables/columns: 34
```

General Analysis

```
# rename date column
week_final1 <- week_final1 %>%
  rename(confirmed = covid_19_confirmed_cases) %>%
  rename(deaths = covid_19_deaths) %>%
  rename(social_dist = social_distancing_total_grade) %>%
```

```
  rename(hosp_beds = hospital_beds_ratio) %>%
  rename(college_pop = total_college_population) %>%
  rename(ventilator = ventilator_capacity_ratio) %>%
  rename(pass_load = passenger_load_ratio) %>%
  rename(income = median_household_income) %>%
  rename(immig_student = immigrant_student_ratio)
```

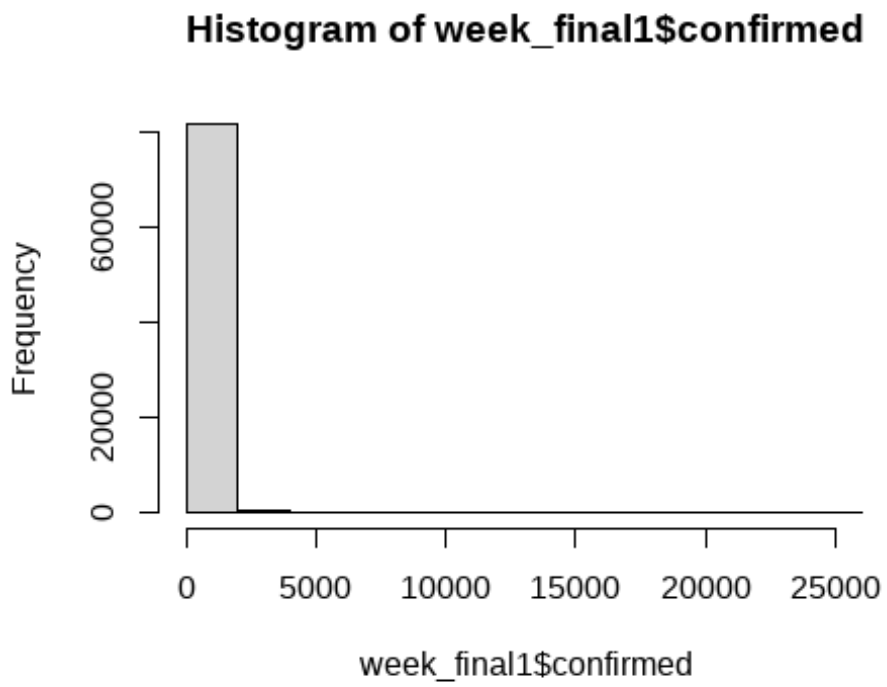
Check summary of statistics

```
summary(week_final1$confirmed)

##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
##     0.00     0.00     3.00    71.26    26.00 25882.00

summary(week_final1$deaths)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    0.00    0.00    0.00    2.03    0.00 1528.00
```

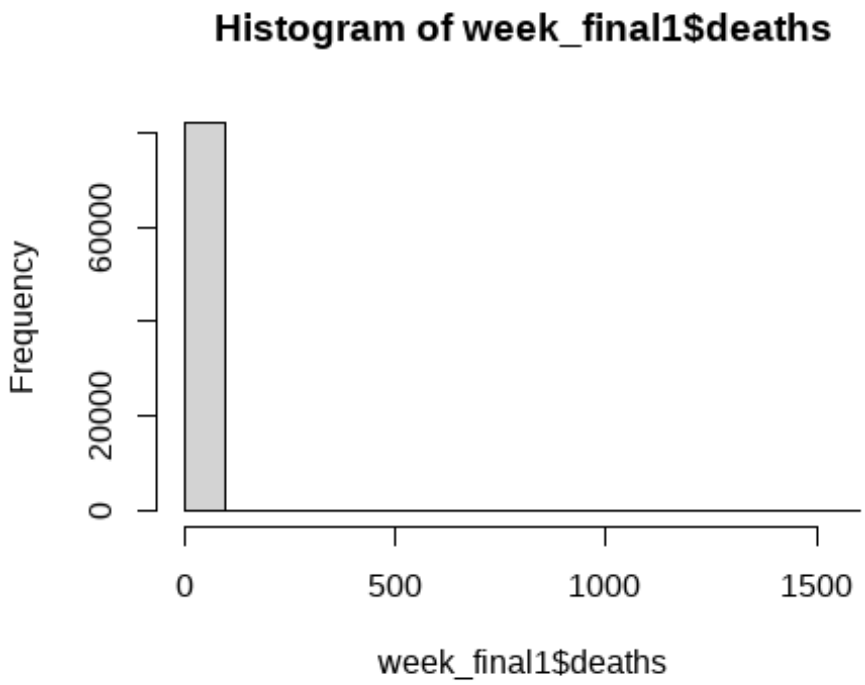
values are within limit but median is near Q1 and max value is very large and very far from the mean for both

check histogram

```
# test for normality using histogram
hist(week_final1$confirmed, bins = 30)
```

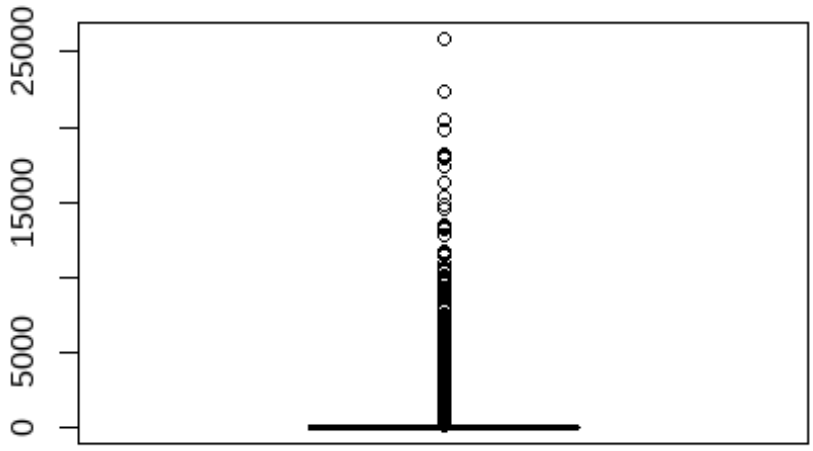



```
hist(week_final1$deaths, bins = 30)
```

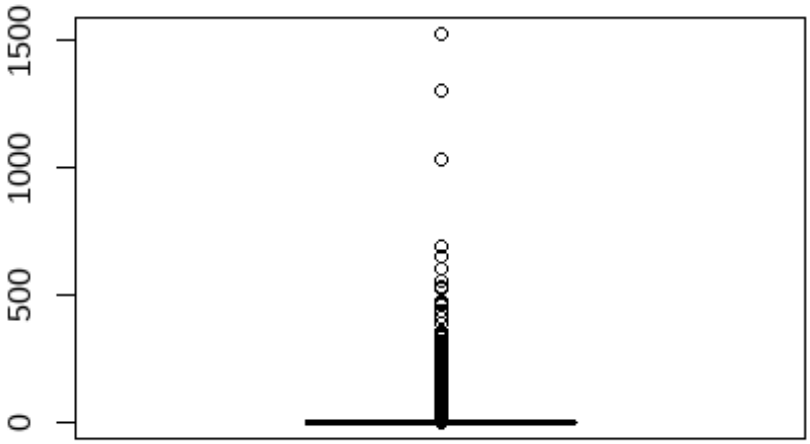


The data is heavily skewed to the right

```
boxplot(week_final1$confirmed)
```

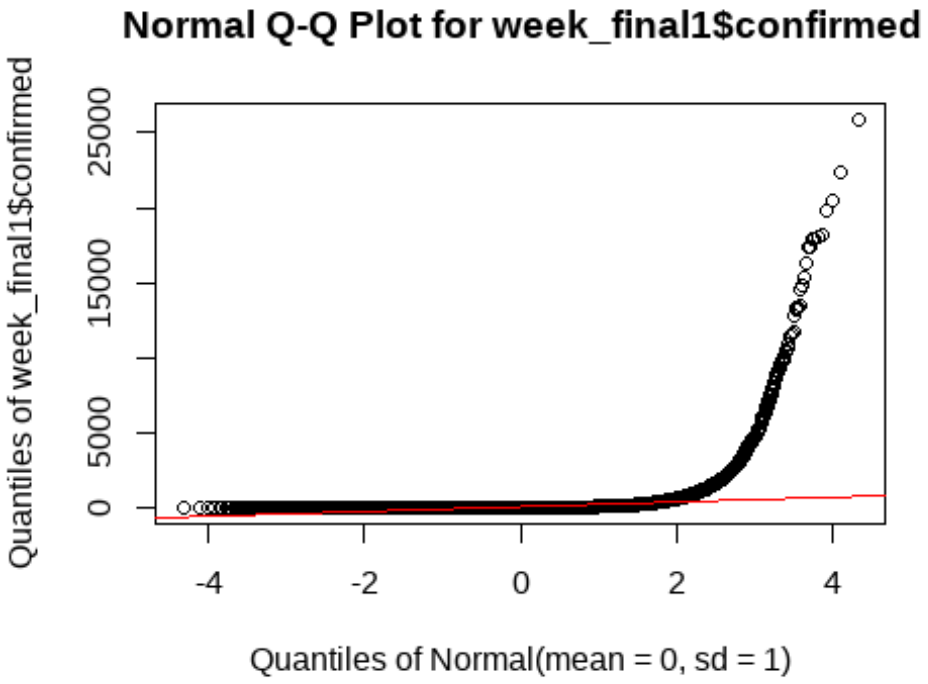


```
boxplot(week_final1$deaths)
```

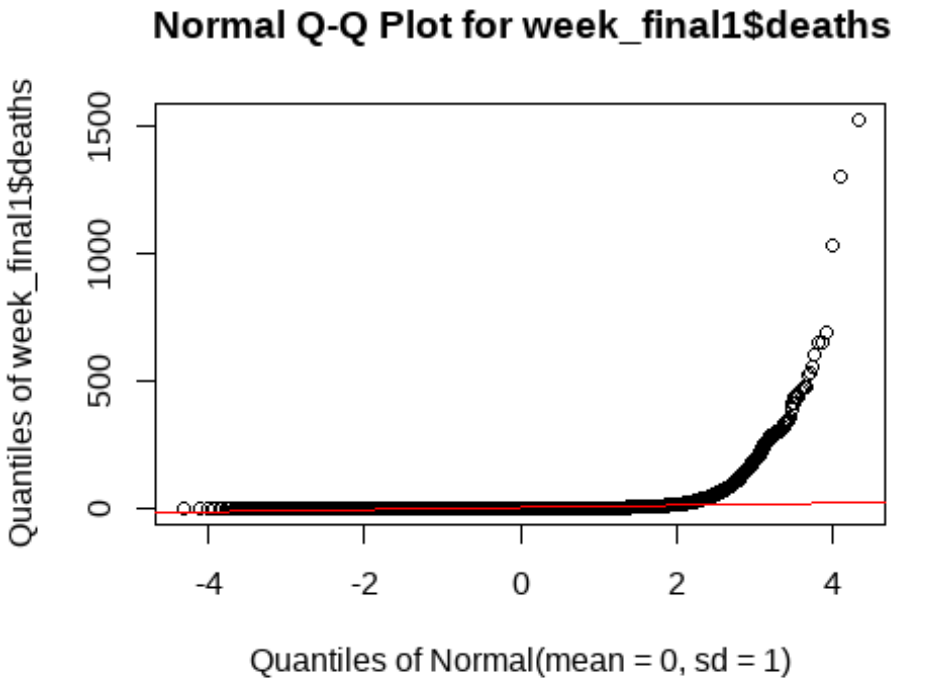


> all points are near the lower value

```
# test for normality using QQ plot
library(EnvStats)

## Warning: package 'EnvStats' was built under R version 4.1.3

##
## Attaching package: 'EnvStats'

## The following objects are masked from 'package:dlookr':
##
##     kurtosis, skewness

## The following objects are masked from 'package:stats':
##
##     predict, predict.lm

## The following object is masked from 'package:base':
##
##     print.default

qqPlot(week_final1$confirmed, add.line = TRUE, line.col = "red")
```




```
qqPlot(week_final1$deaths, add.line = TRUE, line.col = "red")
```



```
# test for normality using Kolmogorov-Smirnov test
# null hypothesis = sample is normal distribution

library(dgof)

##
## Attaching package: 'dgof'

## The following object is masked from 'package:stats':
##
##     ks.test

ks.test(week_final1$confirmed, "pnorm")

## Warning in ks.test(week_final1$confirmed, "pnorm"): default ks.test() cann
ot compute correct p-values with ties;
##  see help page for one-sample Kolmogorov test for discrete distributions.

##
##  One-sample Kolmogorov-Smirnov test
##
## data:  week_final1$confirmed
## D = 0.54462, p-value < 2.2e-16
## alternative hypothesis: two-sided

ks.test(week_final1$deaths, "pnorm")

## Warning in ks.test(week_final1$deaths, "pnorm"): default ks.test() cannot
compute correct p-values with ties;
##  see help page for one-sample Kolmogorov test for discrete distributions.

##
##  One-sample Kolmogorov-Smirnov test
##
## data:  week_final1$deaths
## D = 0.5, p-value < 2.2e-16
## alternative hypothesis: two-sided
```

both variables are not normally distributed.

check what's affecting this distribution

```
# count number of zero
week_final1 %>% count(confirmed == 0) # zeros = 30,200 / 82,320 or 36.6%

##   confirmed == 0     n
## 1          FALSE 52120
## 2           TRUE 30200

week_final1 %>% count(deaths == 0) # zeros = 63,551 / 82,320 or 77.19%
```

```
##   deaths == 0     n
## 1       FALSE 18769
## 2        TRUE 63551

# number of zeros combined
week_final1 %>% count(deaths == 0 & confirmed == 0) # zeros = 30,021 / 82,320
or 36.4%

##   deaths == 0 & confirmed == 0     n
## 1                        FALSE 52299
## 2                         TRUE 30021

# number of zeros with deaths or confirmed
week_final1 %>% count(deaths == 0 | confirmed == 0) # 63,730 / 82,320 or 77.4
%

##   deaths == 0 | confirmed == 0     n
## 1                        FALSE 18590
## 2                         TRUE 63730
```

There a too many zeros in our data set that we can't just drop them. Better to analyse independently confirmed and deaths

check for outliers

```
# library(dlookr)
# diagnose_outlier(week_final1, confirmed, deaths)
outliersdf <- as.data.frame(diagnose_outlier(week_final1))
outliersdf$diff <- (outliersdf$with_mean - outliersdf$without_mean)


# library(dplyr)
# in terms of highest difference with and without outliers mean
outliersdf %>%
  arrange(desc(diff)) %>% slice(1:15)

##            variables outliers_cnt outliers_ratio outliers_mean    with_me
an
## 1    total_population        10745     13.0527211  6.792133e+05 1.247548e+
05
## 2    daily_state_test         7084      8.6054422  5.346615e+04 9.986594e+
03
## 3              income         3780      4.5918367  9.459195e+04 5.340991e+
04
## 4                area        10185     12.3724490  4.072637e+03 1.086409e+
03
## 5  population_density        11095     13.4778912  1.508432e+03 2.577202e+
02
## 6      houses_density        10850     13.1802721  6.701818e+02 1.138233e+
02
## 7           confirmed        12218     14.8420797  4.314966e+02 7.126099e+
01
```

```
## 8      gdp_per_capita         3885      4.7193878  1.956587e+02 4.769686e+
01
## 9      virus_pressure        10155     12.3360058  6.152980e+01 9.918332e+
00
## 10      precipitation         4807      5.8394072  1.396803e+02 2.899104e+
01
## 11   airport_distance         1960      2.3809524  2.872448e+02 9.865959e+
01
## 12  deaths_per_100000          700      0.8503401  1.474400e+03 1.103045e+
03
## 13             deaths        18769     22.8000486  8.904683e+00 2.030272e+
00
## 14        meat_plants         6895      8.3758503  1.920305e+01 2.963010e+
00
## 15          pass_load        16380     19.8979592  3.988672e+00 8.028250e-
01
##    without_mean         diff
## 1  4.151818e+04 8.323657e+04
## 2  5.892687e+03 4.093907e+03
## 3  5.142788e+04 1.982024e+03
## 4  6.647723e+02 4.216364e+02
## 5  6.289195e+01 1.948283e+02
## 6  2.936149e+01 8.446186e+01
## 7  8.475921e+00 6.278507e+01
## 8  4.036809e+01 7.328768e+00
## 9  2.655607e+00 7.262724e+00
## 10 2.212660e+01 6.864439e+00
## 11 9.405995e+01 4.599638e+00
## 12 1.099860e+03 3.184861e+00
## 13 0.000000e+00 2.030272e+00
## 14 1.478422e+00 1.484588e+00
## 15 1.143621e-02 7.913888e-01
```

```
# highest number of outliers
outliersdf %>%
  arrange(desc(outliers_cnt)) %>% slice(1:15)
```

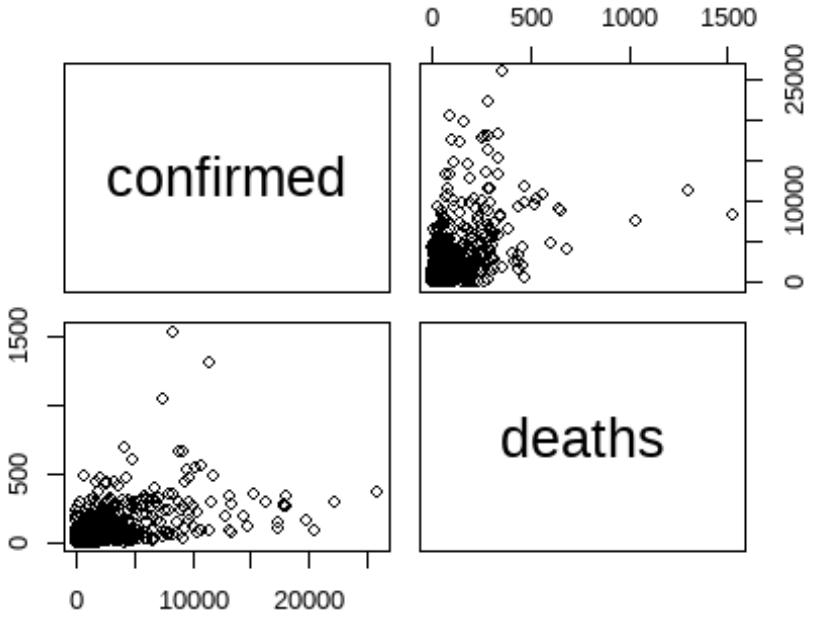
```
##             variables outliers_cnt outliers_ratio outliers_mean    with_me
an
## 1              deaths        18769      22.800049  8.904683e+00 2.030272e+
00
## 2           pass_load        16380      19.897959  3.988672e+00 8.028250e-
01
## 3           confirmed        12218      14.842080  4.314966e+02 7.126099e+
01
## 4  population_density        11095      13.477891  1.508432e+03 2.577202e+
02
## 5      houses_density        10850      13.180272  6.701818e+02 1.138233e+
02
## 6    total_population        10745      13.052721  6.792133e+05 1.247548e+
```

```
05
## 7                area        10185      12.372449  4.072637e+03 1.086409e+
03
## 8      virus_pressure        10155      12.336006  6.152980e+01 9.918332e+
00
## 9    daily_state_test         7084       8.605442  5.346615e+04 9.986594e+
03
## 10      immig_student         7035       8.545918  9.519714e-02 1.578568e-
02
## 11        meat_plants         6895       8.375850  1.920305e+01 2.963010e+
00
## 12     female_percent         6335       7.695578  4.544444e-01 4.993922e-
01
## 13        college_pop         6160       7.482993  2.440349e+00 3.879712e-
01
## 14          hosp_beds         5495       6.675170  1.129817e-02 2.521076e-
03
## 15     icu_beds_ratio         5320       6.462585  1.229842e-03 3.045541e-
04
##    without_mean          diff
## 1  0.000000e+00  2.030272e+00
## 2  1.143621e-02  7.913888e-01
## 3  8.475921e+00  6.278507e+01
## 4  6.289195e+01  1.948283e+02
## 5  2.936149e+01  8.446186e+01
## 6  4.151818e+04  8.323657e+04
## 7  6.647723e+02  4.216364e+02
## 8  2.655607e+00  7.262724e+00
## 9  5.892687e+03  4.093907e+03
## 10 8.365082e-03  7.420596e-03
## 11 1.478422e+00  1.484588e+00
## 12 5.031396e-01 -3.747380e-03
## 13 2.219701e-01  1.660011e-01
## 14 1.893284e-03  6.277923e-04
## 15 2.406252e-04  6.392895e-05
```

data shows that there are too many outliers

```
# let start our analysis during the time WHO declared COVID-19 as pandemic in
Mar 11, 2020 or week 7 from 1st case
week_final2 <- week_final1 %>% filter(date > 7)
nrow(week_final2) # 65,856 rows. 16,464 rows removed

## [1] 65856

week_final2 %>% count(confirmed == 0 | deaths == 0)

##   confirmed == 0 | deaths == 0     n
## 1                        FALSE 18581
## 2                         TRUE 47275
```

```
week_final2 %>% count(confirmed == 0) # zeros = 21.0% from 36.5%

##   confirmed == 0     n
## 1          FALSE 52014
## 2           TRUE 13842

week_final2 %>% count(deaths == 0) # zeros = 71.51 from 77.19%

##   deaths == 0     n
## 1       FALSE 18759
## 2        TRUE 47097

pairs(week_final1[3:4])
```



data are concentraed on the lower left

Get the Mahalanobis Distance

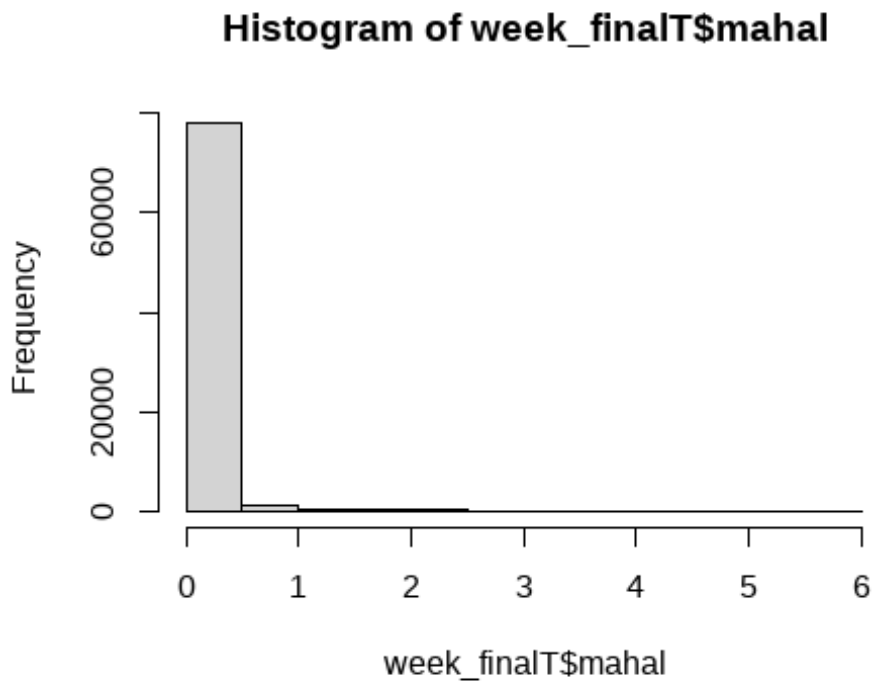
```
# get mahalnobis distance for response variable confirmed and deaths only as
they are skewed to the right
week_final1$mahal <- mahalanobis(week_final1[,c(3:4)],
                                 colMeans(week_final1[,c(3:4)]),
                                 cov(week_final1[,c(3:4)]))

# check summary of statistics for mahalanobis distance
summary(week_final1$mahal)

##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
##     0.000     0.023     0.028     2.000     0.028 11756.365
```

data is concentrated around mean of 2

```
# determine cut off score as reference
cutoff <- qchisq(1 - 0.05, ncol(week_final1[,3:4]))
cutoff

## [1] 5.991465

week_final1$badmahal <- as.numeric(week_final1$mahal > cutoff)
table(week_final1$badmahal) # 1 = yes, 0 = no

##
##     0     1
## 81049  1271
```

there are 1,271 outside the cut off score based on chi-square limit of 95%

```
# remove
week_finalT <- week_final1 %>% filter(badmahal == 0)
hist(week_finalT$mahal)
```




```
summary(week_finalT$mahal)

##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
## 0.000004 0.023170 0.027922 0.102839 0.027922 5.977876

summary(week_finalT$confirmed)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    0.00    0.00    3.00   38.29   23.00 1122.00

summary(week_finalT$deaths)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   0.000   0.000   0.000   0.909   0.000  41.000
```

Run linear regression after removing outliers

```
model_co <- lm(formula = confirmed ~ .-deaths -date -county_fips -state_fips
-political_party -mahal - badmahal, data = week_finalT)
summary(model_co)

##
## Call:
## lm(formula = confirmed ~ . - deaths - date - county_fips - state_fips -
##     political_party - mahal - badmahal, data = week_finalT)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1449.59   -28.78    -8.46    12.91   950.08
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   5.342e+01  8.359e+01   0.639 0.522757
## social_dist                   1.981e+00  1.269e-01  15.610  < 2e-16 ***
## daily_state_test              5.587e-04  2.179e-05  25.645  < 2e-16 ***
## precipitation                 2.928e-02  7.903e-03   3.705 0.000211 ***
## temperature                   1.732e+00  3.655e-02  47.386  < 2e-16 ***
## virus_pressure                1.070e+00  1.122e-02  95.384  < 2e-16 ***
## total_population              1.285e-04  1.990e-06  64.589  < 2e-16 ***
## female_percent                3.153e+02  1.694e+01  18.610  < 2e-16 ***
## area                          1.421e-03  1.965e-04   7.230 4.85e-13 ***
## population_density            3.326e-02  1.983e-03  16.776  < 2e-16 ***
## hosp_beds                    -4.681e+02  1.277e+02  -3.664 0.000248 ***
## ventilator                   -2.442e+04  5.779e+03  -4.225 2.39e-05 ***
## icu_beds_ratio                5.614e+04  6.704e+03   8.375  < 2e-16 ***
## houses_density               -6.182e-02  3.806e-03 -16.242  < 2e-16 ***
## college_pop                   4.635e+00  1.062e+00   4.362 1.29e-05 ***
## percent_smokers               3.983e-01  1.323e-01   3.009 0.002618 **
## percent_diabetes             -7.741e-01  9.431e-02  -8.208 2.27e-16 ***
## Religious_congregation_ratio  2.015e-01  1.999e-02  10.077  < 2e-16 ***
## airport_distance             -8.271e-02  6.056e-03 -13.657  < 2e-16 ***
## pass_load                    -2.175e-01  5.688e-02  -3.823 0.000132 ***
## meat_plants                  -1.028e+00  7.847e-02 -13.103  < 2e-16 ***
## income                       -3.069e-04  3.792e-05  -8.093 5.92e-16 ***
## percent_insured               6.948e-01  7.110e-02   9.772  < 2e-16 ***
## deaths_per_100000            -2.937e-02  2.065e-03 -14.225  < 2e-16 ***
## gdp_per_capita               -1.740e-02  4.600e-03  -3.784 0.000155 ***
## Age_0_19                     -3.105e+00  8.362e-01  -3.713 0.000205 ***
```

```
## Age_20_59                    -1.991e+00  8.341e-01  -2.387 0.016974 *
## Age_60                       -3.685e+00  8.294e-01  -4.443 8.88e-06 ***
## immig_student                -1.324e+02  2.339e+01  -5.660 1.52e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 81.87 on 81020 degrees of freedom
## Multiple R-squared:  0.3904, Adjusted R-squared:  0.3901
## F-statistic:  1853 on 28 and 81020 DF,  p-value: < 2.2e-16

ols_vif_tol(model_co)

##                       Variables   Tolerance        VIF
## 1                    social_dist 0.731335042   1.367362
## 2              daily_state_test 0.696973125   1.434776
## 3                 precipitation 0.932651646   1.072212
## 4                   temperature 0.686923628   1.455766
## 5                virus_pressure 0.836791625   1.195041
## 6              total_population 0.299495801   3.338945
## 7                female_percent 0.632689749   1.580554
## 8                          area 0.773815666   1.292297
## 9            population_density 0.010597434  94.362466
## 10                    hosp_beds 0.506585091   1.974002
## 11                   ventilator 0.018682627  53.525662
## 12               icu_beds_ratio 0.017032674  58.710689
## 13               houses_density 0.011020938  90.736381
## 14                  college_pop 0.127479237   7.844415
## 15              percent_smokers 0.410402836   2.436630
## 16             percent_diabetes 0.630960106   1.584886
## 17 Religious_congregation_ratio 0.710343978   1.407769
## 18             airport_distance 0.603276340   1.657615
## 19                    pass_load 0.970112360   1.030808
## 20                  meat_plants 0.366071424   2.731707
## 21                       income 0.316793905   3.156626
## 22              percent_insured 0.671047975   1.490206
## 23            deaths_per_100000 0.249095246   4.014529
## 24               gdp_per_capita 0.875355088   1.142394
## 25                     Age_0_19 0.010067602  99.328522
## 26                    Age_20_59 0.008749029 114.298401
## 27                       Age_60 0.004701055 212.718195
## 28                immig_student 0.139744521   7.155916

model_co1 <- lm(formula = confirmed ~ .-deaths -date -county_fips -state_fips
-political_party -mahal - badmahal -houses_density -ventilator -Age_0_19 -imm
ig_student, data = week_finalT)
summary(model_co1)

##
## Call:
## lm(formula = confirmed ~ . - deaths - date - county_fips - state_fips -
##     political_party - mahal - badmahal - houses_density - ventilator -
```

```
##     Age_0_19 - immig_student, data = week_finalT)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1460.83   -28.92    -8.61    12.78   949.05
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 -2.714e+02  1.503e+01 -18.060  < 2e-16 ***
## social_dist                  1.944e+00  1.271e-01  15.298  < 2e-16 ***
## daily_state_test             5.647e-04  2.182e-05  25.875  < 2e-16 ***
## precipitation                2.862e-02  7.917e-03   3.615 0.000300 ***
## temperature                  1.721e+00  3.662e-02  47.013  < 2e-16 ***
## virus_pressure               1.076e+00  1.123e-02  95.841  < 2e-16 ***
## total_population             1.351e-04  1.958e-06  68.990  < 2e-16 ***
## female_percent               3.266e+02  1.691e+01  19.321  < 2e-16 ***
## area                         1.254e-03  1.964e-04   6.388 1.69e-10 ***
## population_density           1.253e-03  2.232e-04   5.611 2.02e-08 ***
## hosp_beds                   -3.046e+02  1.217e+02  -2.502 0.012362 *
## icu_beds_ratio               2.853e+04  1.163e+03  24.538  < 2e-16 ***
## college_pop                 -5.364e-01  4.368e-01  -1.228 0.219414
## percent_smokers              4.137e-01  1.325e-01   3.122 0.001797 **
## percent_diabetes            -7.880e-01  9.428e-02  -8.358  < 2e-16 ***
## Religious_congregation_ratio 2.186e-01  1.999e-02  10.938  < 2e-16 ***
## airport_distance            -8.152e-02  6.056e-03 -13.461  < 2e-16 ***
## pass_load                   -2.133e-01  5.698e-02  -3.744 0.000181 ***
## meat_plants                 -9.441e-01  7.839e-02 -12.044  < 2e-16 ***
## income                      -2.703e-04  3.766e-05  -7.176 7.23e-13 ***
## percent_insured              6.676e-01  7.107e-02   9.393  < 2e-16 ***
## deaths_per_100000           -2.909e-02  2.060e-03 -14.127  < 2e-16 ***
## gdp_per_capita              -1.678e-02  4.561e-03  -3.680 0.000234 ***
## Age_20_59                    1.291e+00  1.538e-01   8.391  < 2e-16 ***
## Age_60                      -5.985e-01  1.202e-01  -4.980 6.36e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 82.03 on 81024 degrees of freedom
## Multiple R-squared:  0.3879, Adjusted R-squared:  0.3877
## F-statistic:  2140 on 24 and 81024 DF,  p-value: < 2.2e-16

ols_vif_tol(model_co1)

##                       Variables Tolerance      VIF
## 1                   social_dist 0.7320661 1.365997
## 2              daily_state_test 0.6973556 1.433989
## 3                 precipitation 0.9329417 1.071878
## 4                   temperature 0.6871159 1.455359
## 5                virus_pressure 0.8378075 1.193592
## 6              total_population 0.3105596 3.219994
## 7                female_percent 0.6378733 1.567710
```

```
## 8                           area 0.7778670 1.285567
## 9             population_density 0.8393574 1.191388
## 10                     hosp_beds 0.5600136 1.785671
## 11                icu_beds_ratio 0.5683951 1.759340
## 12                   college_pop 0.7571691 1.320709
## 13                percent_smokers 0.4109351 2.433474
## 14               percent_diabetes 0.6338090 1.577762
## 15 Religious_congregation_ratio 0.7134481 1.401644
## 16               airport_distance 0.6057801 1.650764
## 17                     pass_load 0.9708470 1.030028
## 18                   meat_plants 0.3682931 2.715229
## 19                        income 0.3224151 3.101592
## 20                percent_insured 0.6743367 1.482939
## 21              deaths_per_100000 0.2513216 3.978965
## 22                 gdp_per_capita 0.8935999 1.119069
## 23                      Age_20_59 0.2582821 3.871736
## 24                         Age_60 0.2248554 4.447302
```

```
model_do <- lm(formula = deaths ~ . -date -county_fips -state_fips -political
_party -mahal - badmahal, data = week_finalT)
summary(model_do)
```

```
##
## Call:
## lm(formula = deaths ~ . - date - county_fips - state_fips - political_part
y -
##     mahal - badmahal, data = week_finalT)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -15.9575  -0.4110  -0.1799   0.0620  30.9525
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   -4.311e+00  2.362e+00  -1.825 0.068025 .
## confirmed                      1.745e-02  9.929e-05 175.760  < 2e-16 ***
## social_dist                   -3.282e-02  3.591e-03  -9.138  < 2e-16 ***
## daily_state_test              -4.682e-06  6.183e-07  -7.574 3.67e-14 ***
## precipitation                  7.722e-04  2.234e-04   3.457 0.000546 ***
## temperature                    2.116e-03  1.047e-03   2.021 0.043265 *
## virus_pressure                 4.228e-03  3.343e-04  12.647  < 2e-16 ***
## total_population               1.659e-06  5.768e-08  28.762  < 2e-16 ***
## female_percent                 5.130e+00  4.798e-01  10.691  < 2e-16 ***
## area                           4.674e-05  5.555e-06   8.415  < 2e-16 ***
## population_density             2.047e-04  5.613e-05   3.647 0.000265 ***
## hosp_beds                     -5.656e+00  3.611e+00  -1.566 0.117256
## ventilator                    -3.883e+02  1.633e+02  -2.377 0.017439 *
## icu_beds_ratio                 5.396e+02  1.895e+02   2.847 0.004418 **
## houses_density                -3.491e-04  1.077e-04  -3.239 0.001198 **
## college_pop                   -6.583e-03  3.003e-02  -0.219 0.826485
```

```
## percent_smokers               7.148e-03  3.741e-03   1.911 0.056017 .
## percent_diabetes              6.965e-03  2.666e-03   2.612 0.008998 **
## Religious_congregation_ratio  1.233e-04  5.654e-04   0.218 0.827325
## airport_distance             -2.065e-03  1.714e-04 -12.047  < 2e-16 ***
## pass_load                     1.299e-03  1.608e-03   0.808 0.419248
## meat_plants                  -1.758e-02  2.220e-03  -7.917 2.46e-15 ***
## income                        2.133e-06  1.072e-06   1.989 0.046662 *
## percent_insured               8.638e-04  2.011e-03   0.430 0.667481
## deaths_per_100000             2.711e-04  5.843e-05   4.640 3.49e-06 ***
## gdp_per_capita                4.164e-04  1.300e-04   3.203 0.001362 **
## Age_0_19                      7.865e-03  2.363e-02   0.333 0.739314
## Age_20_59                     2.001e-02  2.357e-02   0.849 0.395913
## Age_60                        1.322e-02  2.344e-02   0.564 0.572908
## immig_student                -2.655e-01  6.611e-01  -0.402 0.687942
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.314 on 81019 degrees of freedom
## Multiple R-squared:  0.4511, Adjusted R-squared:  0.4509
## F-statistic:  2296 on 29 and 81019 DF,  p-value: < 2.2e-16

ols_vif_tol(model_do)

##                        Variables   Tolerance        VIF
## 1                      confirmed 0.609642378   1.640306
## 2                    social_dist 0.729142170   1.371475
## 3              daily_state_test 0.691361224   1.446422
## 4                 precipitation 0.932493629   1.072393
## 5                   temperature 0.668399383   1.496111
## 6                virus_pressure 0.752311151   1.329237
## 7              total_population 0.284830047   3.510866
## 8                female_percent 0.629996673   1.587310
## 9                          area 0.773316665   1.293131
## 10           population_density 0.010560749  94.690257
## 11                    hosp_beds 0.506501152   1.974329
## 12                   ventilator 0.018678511  53.537458
## 13               icu_beds_ratio 0.017017942  58.761512
## 14               houses_density 0.010985171  91.031812
## 15                  college_pop 0.127449301   7.846257
## 16              percent_smokers 0.410356965   2.436903
## 17             percent_diabetes 0.630435811   1.586204
## 18 Religious_congregation_ratio 0.709454815   1.409533
## 19             airport_distance 0.601890680   1.661431
## 20                    pass_load 0.969937356   1.030994
## 21                   meat_plants 0.365297346   2.737496
## 22                        income 0.316538039   3.159178
## 23              percent_insured 0.670258022   1.491963
## 24            deaths_per_100000 0.248474672   4.024555
## 25               gdp_per_capita 0.875200432   1.142595
## 26                     Age_0_19 0.010065889  99.345424
```

```
## 27                    Age_20_59 0.008748413 114.306441
## 28                       Age_60 0.004699910 212.770025
## 29                immig_student 0.139689286   7.158745

model_do1 <- lm(formula = deaths ~ . -date -county_fips -state_fips -politica
l_party -mahal - badmahal
                -houses_density -ventilator -Age_0_19 -immig_student, data =
week_finalT)
summary(model_do1)

##
## Call:
## lm(formula = deaths ~ . - date - county_fips - state_fips - political_part
y -
##     mahal - badmahal - houses_density - ventilator - Age_0_19 -
##     immig_student, data = week_finalT)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -15.9913  -0.4096  -0.1791   0.0583  30.9688
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  -3.650e+00  4.248e-01  -8.593  < 2e-16 ***
## confirmed                     1.747e-02  9.910e-05 176.322  < 2e-16 ***
## social_dist                  -3.290e-02  3.590e-03  -9.165  < 2e-16 ***
## daily_state_test             -4.644e-06  6.182e-07  -7.513 5.85e-14 ***
## precipitation                 7.608e-04  2.233e-04   3.406 0.000658 ***
## temperature                   2.029e-03  1.047e-03   1.938 0.052639 .
## virus_pressure                4.234e-03  3.343e-04  12.667  < 2e-16 ***
## total_population              1.694e-06  5.684e-08  29.796  < 2e-16 ***
## female_percent                5.201e+00  4.780e-01  10.882  < 2e-16 ***
## area                          4.590e-05  5.541e-06   8.285  < 2e-16 ***
## population_density            2.365e-05  6.298e-06   3.755 0.000173 ***
## hosp_beds                    -3.069e+00  3.434e+00  -0.894 0.371587
## icu_beds_ratio                9.610e+01  3.292e+01   2.919 0.003511 **
## college_pop                  -1.588e-02  1.232e-02  -1.289 0.197489
## percent_smokers               7.241e-03  3.739e-03   1.937 0.052760 .
## percent_diabetes              6.961e-03  2.661e-03   2.616 0.008895 **
## Religious_congregation_ratio  2.227e-04  5.643e-04   0.395 0.693072
## airport_distance             -2.050e-03  1.710e-04 -11.989  < 2e-16 ***
## pass_load                     1.284e-03  1.607e-03   0.799 0.424535
## meat_plants                  -1.709e-02  2.213e-03  -7.720 1.18e-14 ***
## income                        2.333e-06  1.063e-06   2.195 0.028160 *
## percent_insured               7.474e-04  2.006e-03   0.373 0.709466
## deaths_per_100000             2.779e-04  5.817e-05   4.777 1.78e-06 ***
## gdp_per_capita                4.481e-04  1.287e-04   3.482 0.000498 ***
## Age_20_59                     1.363e-02  4.341e-03   3.139 0.001696 **
## Age_60                        5.650e-03  3.390e-03   1.667 0.095602 .
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.314 on 81023 degrees of freedom
## Multiple R-squared:  0.451,  Adjusted R-squared:  0.4508
## F-statistic:  2662 on 25 and 81023 DF,  p-value: < 2.2e-16

ols_vif_tol(model_do1)

##                       Variables Tolerance      VIF
## 1                     confirmed 0.6120822 1.633767
## 2                   social_dist 0.7299578 1.369942
## 3               daily_state_test 0.6916406 1.445838
## 4                  precipitation 0.9327912 1.072051
## 5                    temperature 0.6688703 1.495058
## 6                 virus_pressure 0.7524984 1.328907
## 7               total_population 0.2933286 3.409146
## 8                 female_percent 0.6349478 1.574933
## 9                           area 0.7774754 1.286214
## 10           population_density 0.8390314 1.191851
## 11                    hosp_beds 0.5599704 1.785809
## 12                icu_beds_ratio 0.5642024 1.772414
## 13                   college_pop 0.7571550 1.320734
## 14                percent_smokers 0.4108857 2.433767
## 15              percent_diabetes 0.6332630 1.579123
## 16 Religious_congregation_ratio 0.7123962 1.403713
## 17              airport_distance 0.6044284 1.654456
## 18                    pass_load 0.9706790 1.030207
## 19                  meat_plants 0.3676349 2.720090
## 20                       income 0.3222103 3.103563
## 21               percent_insured 0.6736032 1.484554
## 22             deaths_per_100000 0.2507041 3.988765
## 23                gdp_per_capita 0.8934506 1.119256
## 24                     Age_20_59 0.2580578 3.875101
## 25                        Age_60 0.2247866 4.448664

bothfit.pod <- ols_step_both_p(model_do, pent = 0.05, prem = 0.05, progress =
TRUE, details = FALSE)

## Stepwise Selection Method
## --------------------------
##
## Candidate Terms:
##
## 1. confirmed
## 2. social_dist
## 3. daily_state_test
## 4. precipitation
## 5. temperature
## 6. virus_pressure
## 7. total_population
## 8. female_percent
```

```
## 9. area
## 10. population_density
## 11. hosp_beds
## 12. ventilator
## 13. icu_beds_ratio
## 14. houses_density
## 15. college_pop
## 16. percent_smokers
## 17. percent_diabetes
## 18. Religious_congregation_ratio
## 19. airport_distance
## 20. pass_load
## 21. meat_plants
## 22. income
## 23. percent_insured
## 24. deaths_per_100000
## 25. gdp_per_capita
## 26. Age_0_19
## 27. Age_20_59
## 28. Age_60
## 29. immig_student
##
## We are selecting variables based on p value...
##
## Variables Entered/Removed:
##
## - Age_60 added
## - female_percent added
## - Age_60 added
## - area added
## - income added
## - gdp_per_capita added
## - precipitation added
## - icu_beds_ratio added
## - percent_diabetes added
## - temperature added
## - college_pop added
##
## No more variables to be added/removed.
##
##
## Final Model Output
## ------------------
##
##                          Model Summary
## ----------------------------------------------------------------
## R                       0.672       RMSE                 2.314
## R-Squared               0.451       Coef. Var          254.549
## Adj. R-Squared          0.451       MSE                  5.354
## Pred R-Squared          0.450       MAE                  0.907
```

```
## ----------------------------------------------------------------
##  RMSE: Root Mean Square Error
##  MSE: Mean Square Error
##  MAE: Mean Absolute Error
##
##                                    ANOVA
## ------------------------------------------------------------------------
-
##                   Sum of
##                  Squares           DF    Mean Square       F          Sig.
## ------------------------------------------------------------------------
-
## Regression    356386.041          18      19799.225     3697.84    0.0000
## Residual      433856.239        81030          5.354
## Total         790242.281        81048
## ------------------------------------------------------------------------
-
##
##                                        Parameter Estimates
## ------------------------------------------------------------------------
----------------------
##               model      Beta    Std. Error    Std. Beta       t        Sig
lower      upper
## ------------------------------------------------------------------------
----------------------
##        (Intercept)    -3.176         0.339                  -9.372    0.00
0    -3.840     -2.512
##          confirmed     0.017         0.000        0.587    179.223    0.00
0     0.017      0.018
##        social_dist    -0.034         0.004       -0.029     -9.557    0.00
0    -0.041     -0.027
##   daily_state_test     0.000         0.000       -0.022     -7.804    0.00
0     0.000      0.000
##     virus_pressure     0.004         0.000        0.039     13.060    0.00
0     0.004      0.005
##   total_population     0.000         0.000        0.141     29.307    0.00
0     0.000      0.000
## population_density     0.000         0.000        0.096      3.812    0.00
0     0.000      0.000
##     houses_density     0.000         0.000       -0.083     -3.387    0.00
1    -0.001      0.000
##   airport_distance    -0.002         0.000       -0.041    -12.720    0.00
0    -0.002     -0.002
##        meat_plants    -0.018         0.002       -0.035     -8.233    0.00
0    -0.022     -0.014
##  deaths_per_100000     0.000         0.000        0.029      7.750    0.00
0     0.000      0.000
##          Age_20_59     0.012         0.003        0.014      3.727    0.00
0     0.006      0.019
##     female_percent     5.312         0.454        0.036     11.692    0.00
```

```
0     4.422      6.203
##                area     0.000         0.000        0.024      8.336    0.00
0     0.000      0.000
##     gdp_per_capita     0.000         0.000        0.010      3.521    0.00
0     0.000      0.001
##       precipitation     0.001         0.000        0.010      3.812    0.00
0     0.000      0.001
##     icu_beds_ratio    72.629        26.088        0.008      2.784    0.00
5    21.498    123.761
##   percent_diabetes     0.007         0.002        0.008      2.745    0.00
6     0.002      0.011
##         college_pop    -0.023         0.012       -0.006     -1.982    0.04
7    -0.047      0.000
## ---------------------------------------------------------------------------
----------------------
```

Confirmed Cases per States

Top 5 states: California, Texas, Florida, New York, Illinois

```
ConfirmedT5 <- week_finalT %>% filter(state_fips == 6 | state_fips == 12 | st
ate_fips == 17 | state_fips == 36 | state_fips == 17)
unique(ConfirmedT5$state_fips) # checking
```

```
## [1] 12 17  6 36
```

```
# 7,953 observations
```

```
model_T5 <- lm(formula = confirmed ~ .-date -county_fips -state_fips -mahal -
badmahal, data = ConfirmedT5)
summary(model_T5)
```

```
##
## Call:
## lm(formula = confirmed ~ . - date - county_fips - state_fips -
##     mahal - badmahal, data = ConfirmedT5)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -645.66  -39.07   -6.63   21.50  793.68
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   -2.414e+02  3.428e+02  -0.704 0.481428
## deaths                         1.735e+01  2.635e-01  65.840  < 2e-16 ***
## social_dist                    1.027e+00  5.315e-01   1.931 0.053460 .
## daily_state_test               1.163e-03  5.223e-05  22.260  < 2e-16 ***
## precipitation                  3.629e-02  2.293e-02   1.583 0.113556
## temperature                   -4.305e-01  1.949e-01  -2.209 0.027187 *
## virus_pressure                 5.738e-01  1.871e-02  30.659  < 2e-16 ***
## total_population               3.907e-05  4.886e-06   7.996 1.47e-15 ***
```

```
## female_percent                -9.612e+01  8.030e+01  -1.197 0.231325
## area                           4.832e-05  9.217e-04   0.052 0.958195
## population_density             2.601e-02  3.352e-03   7.759 9.59e-15 ***
## hosp_beds                     -3.130e+03  1.008e+03  -3.105 0.001909 **
## ventilator                    -4.286e+03  4.055e+04  -0.106 0.915810
## icu_beds_ratio                 6.314e+04  4.664e+04   1.354 0.175842
## houses_density                -4.969e-02  6.336e-03  -7.843 4.97e-15 ***
## college_pop                    4.046e+01  6.777e+00   5.971 2.46e-09 ***
## percent_smokers                4.303e-01  8.473e-01   0.508 0.611567
## percent_diabetes               2.193e-01  4.256e-01   0.515 0.606351
## Religious_congregation_ratio   3.796e-01  9.935e-02   3.821 0.000134 ***
## political_party               -7.029e+01  8.295e+00  -8.474  < 2e-16 ***
## airport_distance              -2.745e-02  3.034e-02  -0.905 0.365534
## pass_load                      1.088e+00  3.092e+00   0.352 0.724829
## meat_plants                   -8.861e-01  1.625e-01  -5.453 5.09e-08 ***
## income                         4.944e-04  1.466e-04   3.372 0.000750 ***
## percent_insured                2.038e+00  6.938e-01   2.937 0.003322 **
## deaths_per_100000              1.202e-02  1.110e-02   1.083 0.278954
## gdp_per_capita                 2.796e-01  7.525e-02   3.716 0.000204 ***
## Age_0_19                       4.936e+00  3.475e+00   1.420 0.155522
## Age_20_59                     -1.158e+00  3.500e+00  -0.331 0.740722
## Age_60                        -5.926e-01  3.444e+00  -0.172 0.863392
## immig_student                 -7.544e+02  1.632e+02  -4.623 3.84e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 94.56 on 7922 degrees of freedom
## Multiple R-squared:  0.6478, Adjusted R-squared:  0.6464
## F-statistic: 485.7 on 30 and 7922 DF,  p-value: < 2.2e-16

bothfit.T5 <- ols_step_both_p(model_T5, pent = 0.05, prem = 0.05, progress =
TRUE, details = FALSE)

## Stepwise Selection Method
## ---------------------------
##
## Candidate Terms:
##
## 1. deaths
## 2. social_dist
## 3. daily_state_test
## 4. precipitation
## 5. temperature
## 6. virus_pressure
## 7. total_population
## 8. female_percent
## 9. area
## 10. population_density
## 11. hosp_beds
## 12. ventilator
```

```
## 13. icu_beds_ratio
## 14. houses_density
## 15. college_pop
## 16. percent_smokers
## 17. percent_diabetes
## 18. Religious_congregation_ratio
## 19. political_party
## 20. airport_distance
## 21. pass_load
## 22. meat_plants
## 23. income
## 24. percent_insured
## 25. deaths_per_100000
## 26. gdp_per_capita
## 27. Age_0_19
## 28. Age_20_59
## 29. Age_60
## 30. immig_student
##
## We are selecting variables based on p value...
##
## Variables Entered/Removed:
##
## - virus_pressure added
## - daily_state_test added
## - total_population added
## - airport_distance added
## - ventilator added
## - Age_0_19 added
## - political_party added
## - income added
## - meat_plants added
## - college_pop added
## - Religious_congregation_ratio added
## - airport_distance added
## - immig_student added
## - percent_insured added
## - social_dist added
## - pass_load added
## - hosp_beds added
## - gdp_per_capita added
##
## No more variables to be added/removed.
##
##
## Final Model Output
## ------------------
##
##                             Model Summary
## ----------------------------------------------------------------
```

```
## R                       0.803       RMSE                  94.961
## R-Squared               0.644       Coef. Var            131.962
## Adj. R-Squared          0.643       MSE                 9017.575
## Pred R-Squared          0.640       MAE                   53.842
## ----------------------------------------------------------------
##  RMSE: Root Mean Square Error
##  MSE: Mean Square Error
##  MAE: Mean Absolute Error
##
##                                    ANOVA
## ------------------------------------------------------------------------
--
##                      Sum of
##                     Squares          DF    Mean Square       F         Sig
.
## ------------------------------------------------------------------------
--
## Regression    129577716.256          17    7622218.603    845.263    0.000
0
## Residual       71554453.661        7935       9017.575
## Total         201132169.917        7952
## ------------------------------------------------------------------------
--
##
##                                                 Parameter Estimates
## ------------------------------------------------------------------------
----------------------------------------
##                         model         Beta    Std. Error    Std. Beta
t        Sig         lower        upper
## ------------------------------------------------------------------------
----------------------------------------
##                   (Intercept)     -340.321        48.922                -
6.956    0.000     -436.222     -244.421
##                        deaths       17.378         0.261        0.507     6
6.646    0.000       16.867       17.889
##                virus_pressure        0.567         0.019        0.233     3
0.400    0.000        0.530        0.603
##             daily_state_test        0.001         0.000        0.218     2
9.747    0.000        0.001        0.001
##             total_population        0.000         0.000        0.165     1
0.568    0.000        0.000        0.000
##                    ventilator    46660.178      7485.975        0.058
6.233    0.000    31985.699    61334.657
##                       Age_0_19        4.583         0.363        0.098     1
2.640    0.000        3.872        5.294
##               political_party      -65.764         6.330       -0.174    -1
0.390    0.000      -78.172      -53.356
##                        income        0.001         0.000        0.050
5.288    0.000        0.000        0.001
##                   meat_plants       -0.958         0.156       -0.086     -
```

```
6.154    0.000       -1.263       -0.652
##                  college_pop       36.434         5.876        0.127
6.200    0.000       24.915       47.953
## Religious_congregation_ratio        0.428         0.095        0.032
4.498    0.000        0.241        0.614
##                immig_student     -699.233       154.517       -0.091     -
4.525    0.000    -1002.127     -396.339
##              percent_insured        2.028         0.581        0.058
3.492    0.000        0.890        3.166
##                  social_dist        1.531         0.515        0.022
2.976    0.003        0.523        2.540
##                   pass_load        6.105         2.935        0.015
2.080    0.038        0.351       11.859
##                   hosp_beds    -1954.238       816.198       -0.021     -
2.394    0.017    -3554.201     -354.276
##               gdp_per_capita        0.115         0.053        0.020
2.199    0.028        0.013        0.218
## ---------------------------------------------------------------------------
----------------------------------------
```

```
model_T5_step <- lm(formula = confirmed ~
                    + virus_pressure
                    + daily_state_test
                    + total_population
+ airport_distance
+ ventilator
+ Age_0_19
+ political_party
+ income
+ meat_plants
+ college_pop
+ Religious_congregation_ratio
+ immig_student
+ percent_insured
+ social_dist
+ pass_load
+ hosp_beds
+ gdp_per_capita,
data = ConfirmedT5)

summary(model_T5_step)
```

```
##
## Call:
## lm(formula = confirmed ~ +virus_pressure + daily_state_test +
##     total_population + airport_distance + ventilator + Age_0_19 +
##     political_party + income + meat_plants + college_pop + Religious_congr
egation_ratio +
##     immig_student + percent_insured + social_dist + pass_load +
##     hosp_beds + gdp_per_capita, data = ConfirmedT5)
```

```
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1072.34   -53.15   -12.64    27.52   822.71
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 -4.508e+02  6.349e+01  -7.101 1.34e-12 ***
## virus_pressure               8.391e-01  2.268e-02  36.999  < 2e-16 ***
## daily_state_test             1.379e-03  4.499e-05  30.647  < 2e-16 ***
## total_population             1.144e-04  5.262e-06  21.743  < 2e-16 ***
## airport_distance            -1.709e-01  3.264e-02  -5.235 1.69e-07 ***
## ventilator                   5.893e+04  9.336e+03   6.312 2.91e-10 ***
## Age_0_19                     6.453e+00  4.529e-01  14.248  < 2e-16 ***
## political_party             -9.818e+01  8.260e+00 -11.887  < 2e-16 ***
## income                       4.284e-04  1.265e-04   3.386 0.000712 ***
## meat_plants                 -2.580e+00  1.920e-01 -13.434  < 2e-16 ***
## college_pop                  4.612e+01  7.327e+00   6.294 3.25e-10 ***
## Religious_congregation_ratio  5.939e-01  1.195e-01   4.971 6.79e-07 ***
## immig_student               -9.386e+02  1.926e+02  -4.873 1.12e-06 ***
## percent_insured              3.188e+00  7.373e-01   4.324 1.55e-05 ***
## social_dist                  5.983e-01  6.443e-01   0.929 0.353056
## pass_load                    1.237e+01  3.662e+00   3.377 0.000735 ***
## hosp_beds                   -5.006e+02  1.018e+03  -0.492 0.623035
## gdp_per_capita               1.176e-01  6.548e-02   1.796 0.072587 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 118.4 on 7935 degrees of freedom
## Multiple R-squared:  0.447,  Adjusted R-squared:  0.4458
## F-statistic: 377.3 on 17 and 7935 DF,  p-value: < 2.2e-16

ols_vif_tol(model_T5_step)

##                        Variables Tolerance      VIF
## 1                 virus_pressure 0.8043321 1.243267
## 2               daily_state_test 0.8383056 1.192882
## 3               total_population 0.1945447 5.140207
## 4               airport_distance 0.6622137 1.510087
## 5                     ventilator 0.5194865 1.924978
## 6                       Age_0_19 0.7499205 1.333475
## 7                political_party 0.1452779 6.883360
## 8                         income 0.4621593 2.163756
## 9                    meat_plants 0.2357616 4.241574
## 10                   college_pop 0.1060903 9.425935
## 11 Religious_congregation_ratio 0.8535396 1.171592
## 12                 immig_student 0.1105729 9.043810
## 13               percent_insured 0.1541884 6.485571
## 14                   social_dist 0.8205789 1.218652
## 15                     pass_load 0.8076685 1.238132
```

```
## 16                    hosp_beds 0.5999217 1.666884
## 17               gdp_per_capita 0.5646469 1.771018
```

immig_student has high VIF of 9. Will remove this and run another model

```
model_T5_step1 <- lm(formula = confirmed ~
                     + virus_pressure
                     + daily_state_test
                     + total_population
+ airport_distance
+ ventilator
+ Age_0_19
+ income
+ meat_plants
+ college_pop
+ Religious_congregation_ratio
+ percent_insured
+ social_dist
+ pass_load
+ hosp_beds
+ gdp_per_capita,
data = ConfirmedT5)# removed political party since this is categorical nomina
l

summary(model_T5_step1)

##
## Call:
## lm(formula = confirmed ~ +virus_pressure + daily_state_test +
##     total_population + airport_distance + ventilator + Age_0_19 +
##     income + meat_plants + college_pop + Religious_congregation_ratio +
##     percent_insured + social_dist + pass_load + hosp_beds + gdp_per_capita
,
##     data = ConfirmedT5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1063.84   -52.97   -12.63    24.85   840.80
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   2.120e+02  3.138e+01   6.755 1.53e-11 ***
## virus_pressure                8.130e-01  2.279e-02  35.680  < 2e-16 ***
## daily_state_test              1.340e-03  4.532e-05  29.577  < 2e-16 ***
## total_population              1.149e-04  5.313e-06  21.622  < 2e-16 ***
## airport_distance             -2.906e-01  3.130e-02  -9.285  < 2e-16 ***
## ventilator                    8.506e+04  9.177e+03   9.268  < 2e-16 ***
## Age_0_19                      4.848e+00  4.365e-01  11.107  < 2e-16 ***
## income                        5.513e-04  1.273e-04   4.331 1.50e-05 ***
## meat_plants                  -2.746e+00  1.933e-01 -14.204  < 2e-16 ***
## college_pop                   1.306e+01  2.704e+00   4.830 1.39e-06 ***
```

```
## Religious_congregation_ratio  4.831e-01  1.203e-01   4.017 5.95e-05 ***
## percent_insured              -4.461e+00  3.763e-01 -11.857  < 2e-16 ***
## social_dist                   1.850e+00  6.417e-01   2.883  0.00395 **
## pass_load                     3.560e+00  3.611e+00   0.986  0.32414
## hosp_beds                    -2.207e+03  1.017e+03  -2.169  0.03010 *
## gdp_per_capita                1.452e-03  6.484e-02   0.022  0.98213
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 119.5 on 7937 degrees of freedom
## Multiple R-squared:  0.4361, Adjusted R-squared:  0.435
## F-statistic: 409.2 on 15 and 7937 DF,  p-value: < 2.2e-16

ols_vif_tol(model_T5_step1)

##                       Variables Tolerance      VIF
## 1                 virus_pressure 0.8122960 1.231078
## 2               daily_state_test 0.8422542 1.187290
## 3               total_population 0.1945661 5.139642
## 4               airport_distance 0.7342436 1.361946
## 5                     ventilator 0.5480946 1.824502
## 6                       Age_0_19 0.8229092 1.215201
## 7                         income 0.4655205 2.148133
## 8                    meat_plants 0.2371772 4.216257
## 9                    college_pop 0.7939595 1.259510
## 10 Religious_congregation_ratio 0.8586254 1.164652
## 11               percent_insured 0.6034627 1.657103
## 12                   social_dist 0.8433392 1.185763
## 13                     pass_load 0.8468587 1.180835
## 14                     hosp_beds 0.6127359 1.632024
## 15                 gdp_per_capita 0.5870687 1.703378

MAE(predict(model_T5, newdata = ConfirmedT5), ConfirmedT5$confirmed) # full m
odel

## [1] 53.43031

MAE(predict(model_T5_step1, newdata = ConfirmedT5), ConfirmedT5$confirmed) #
reduced model

## [1] 68.98505

anova(model_T5)

## Analysis of Variance Table
##
## Response: confirmed
##                               Df   Sum Sq  Mean Sq    F value    Pr(>F)
## deaths                         1 97159139 97159139 10864.8734 < 2.2e-16 *
**
## social_dist                    1  1460896  1460896   163.3655 < 2.2e-16 *
```

```
**
## daily_state_test                1 11407073 11407073  1275.6021 < 2.2e-16 *
**
## precipitation                   1    41253    41253     4.6131 0.0317589 *
## temperature                     1   544346   544346    60.8717 6.869e-15 *
**
## virus_pressure                  1 10943311 10943311  1223.7416 < 2.2e-16 *
**
## total_population                1  3172333  3172333   354.7478 < 2.2e-16 *
**
## female_percent                  1   111316   111316    12.4479 0.0004208 *
**
## area                            1    50661    50661     5.6651 0.0173288 *
## population_density              1    88547    88547     9.9019 0.0016572 *
*
## hosp_beds                       1    17943    17943     2.0064 0.1566711
## ventilator                      1   842221   842221    94.1818 < 2.2e-16 *
**
## icu_beds_ratio                  1      138      138     0.0155 0.9010372
## houses_density                  1   589182   589182    65.8856 5.499e-16 *
**
## college_pop                     1   215897   215897    24.1428 9.124e-07 *
**
## percent_smokers                 1    43161    43161     4.8265 0.0280547 *
## percent_diabetes                1     8108     8108     0.9067 0.3410146
## Religious_congregation_ratio    1   156995   156995    17.5561 2.820e-05 *
**
## political_party                 1   731805   731805    81.8345 < 2.2e-16 *
**
## airport_distance                1   191284   191284    21.3904 3.806e-06 *
**
## pass_load                       1     2641     2641     0.2953 0.5868664
## meat_plants                     1   437460   437460    48.9191 2.884e-12 *
**
## income                          1   371143   371143    41.5032 1.245e-10 *
**
## percent_insured                 1       89       89     0.0099 0.9207402
## deaths_per_100000               1   483852   483852    54.1070 2.089e-13 *
**
## gdp_per_capita                  1    69233    69233     7.7421 0.0054077 *
*
## Age_0_19                        1   957881   957881   107.1156 < 2.2e-16 *
**
## Age_20_59                       1      202      202     0.0225 0.8806594
## Age_60                          1      462      462     0.0516 0.8202537
## immig_student                   1   191109   191109    21.3709 3.845e-06 *
**
## Residuals                    7922 70842492     8943
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
anova(model_T5_step1)
```

```
## Analysis of Variance Table
##
## Response: confirmed
##                                Df    Sum Sq  Mean Sq   F value    Pr(>F)
## virus_pressure                  1  48294389 48294389 3379.6803 < 2.2e-16 *
**
## daily_state_test                1   7975593  7975593  558.1385 < 2.2e-16 *
**
## total_population                1  17019296 17019296 1191.0241 < 2.2e-16 *
**
## airport_distance                1   3974912  3974912  278.1675 < 2.2e-16 *
**
## ventilator                      1   1962224  1962224  137.3180 < 2.2e-16 *
**
## Age_0_19                        1   1435869  1435869  100.4833 < 2.2e-16 *
**
## income                          1    226441   226441   15.8465 6.931e-05 *
**
## meat_plants                     1   3892825  3892825  272.4230 < 2.2e-16 *
**
## college_pop                     1     49087    49087    3.4352  0.063859 .
## Religious_congregation_ratio    1     99701    99701    6.9772  0.008272 *
*
## percent_insured                 1   2599366  2599366  181.9057 < 2.2e-16 *
**
## social_dist                     1    103216   103216    7.2231  0.007212 *
*
## pass_load                       1     14963    14963    1.0471  0.306205
## hosp_beds                       1     67471    67471    4.7217  0.029814 *
## gdp_per_capita                  1         7        7    0.0005  0.982134
## Residuals                    7937 113416811    14290
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Bottom 5 states: Alaska, Wyoming, New Hampshire, West Virginia, North Dakota

```
ConfirmedB5 <- week_finalT %>% filter(state_fips == 2 | state_fips == 56 | st
ate_fips == 54 | state_fips == 38)
unique(ConfirmedB5$state_fips) # checking
```

```
## [1]  2 38 54 56
```

```
# 3,010 observations
```

```
model_B5 <- lm(formula = confirmed ~ .-date -county_fips -state_fips -mahal -
badmahal, data = ConfirmedB5)
summary(model_B5)
```

```
##
## Call:
## lm(formula = confirmed ~ . - date - county_fips - state_fips -
##     mahal - badmahal, data = ConfirmedB5)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -122.46   -8.01   -0.46    5.65  384.30
##
## Coefficients: (1 not defined because of singularities)
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  6.975e+01  1.360e+02   0.513 0.608000
## deaths                       1.439e+01  6.236e-01  23.075  < 2e-16 ***
## social_dist                  4.846e-01  1.934e-01   2.506 0.012255 *
## daily_state_test             4.587e-03  4.488e-04  10.220  < 2e-16 ***
## precipitation               -3.569e-02  1.858e-02  -1.921 0.054808 .
## temperature                 -8.498e-02  7.430e-02  -1.144 0.252838
## virus_pressure               1.308e+00  2.560e-01   5.107 3.48e-07 ***
## total_population             2.495e-04  2.378e-05  10.490  < 2e-16 ***
## female_percent              -3.431e+01  4.008e+01  -0.856 0.391993
## area                        -1.208e-04  1.704e-04  -0.709 0.478422
## population_density           8.727e-02  7.551e-02   1.156 0.247916
## hosp_beds                   -7.298e+02  1.884e+02  -3.873 0.000110 ***
## ventilator                   2.963e+04  8.352e+03   3.548 0.000394 ***
## icu_beds_ratio              -2.185e+04  9.265e+03  -2.359 0.018396 *
## houses_density              -2.164e-01  1.603e-01  -1.350 0.176997
## college_pop                 -4.165e+00  3.523e+00  -1.182 0.237217
## percent_smokers             -5.013e-01  2.228e-01  -2.250 0.024547 *
## percent_diabetes            -2.190e-01  2.058e-01  -1.064 0.287294
## Religious_congregation_ratio  3.239e-02  2.932e-02   1.105 0.269376
## political_party                      NA         NA      NA       NA
## airport_distance             5.816e-03  8.913e-03   0.653 0.514083
## pass_load                    9.274e-03  4.552e-02   0.204 0.838577
## meat_plants                  1.330e+00  6.104e-01   2.179 0.029434 *
## income                       9.549e-06  9.473e-05   0.101 0.919715
## percent_insured             -1.066e-01  2.015e-01  -0.529 0.596807
## deaths_per_100000           -4.977e-03  3.671e-03  -1.356 0.175304
## gdp_per_capita              -4.066e-02  1.672e-02  -2.431 0.015119 *
## Age_0_19                    -6.308e-01  1.327e+00  -0.476 0.634448
## Age_20_59                   -1.280e-01  1.297e+00  -0.099 0.921397
## Age_60                      -6.627e-01  1.310e+00  -0.506 0.613009
## immig_student                8.914e+01  7.635e+01   1.167 0.243109
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 24.11 on 2980 degrees of freedom
## Multiple R-squared:  0.4562, Adjusted R-squared:  0.451
## F-statistic: 86.22 on 29 and 2980 DF,  p-value: < 2.2e-16
```

```
bothfit.B5 <- ols_step_both_p(model_B5, pent = 0.05, prem = 0.05, progress =
TRUE, details = FALSE)

## Stepwise Selection Method
## ---------------------------
##
## Candidate Terms:
##
## 1. deaths
## 2. social_dist
## 3. daily_state_test
## 4. precipitation
## 5. temperature
## 6. virus_pressure
## 7. total_population
## 8. female_percent
## 9. area
## 10. population_density
## 11. hosp_beds
## 12. ventilator
## 13. icu_beds_ratio
## 14. houses_density
## 15. college_pop
## 16. percent_smokers
## 17. percent_diabetes
## 18. Religious_congregation_ratio
## 19. political_party
## 20. airport_distance
## 21. pass_load
## 22. meat_plants
## 23. income
## 24. percent_insured
## 25. deaths_per_100000
## 26. gdp_per_capita
## 27. Age_0_19
## 28. Age_20_59
## 29. Age_60
## 30. immig_student
##
## We are selecting variables based on p value...
##
## Variables Entered/Removed:

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - deaths added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison
```

```
## - total_population added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - daily_state_test added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - percent_diabetes added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - virus_pressure added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - houses_density added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - deaths_per_100000 added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - ventilator added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - hosp_beds added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - percent_smokers added
## - percent_diabetes added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - gdp_per_capita added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - social_dist added
```

```
## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - female_percent added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - meat_plants added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - icu_beds_ratio added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

## - precipitation added

## Note: model has aliased coefficients
##       sums of squares computed by model comparison

##
## No more variables to be added/removed.
##
##
## Final Model Output
## ------------------
##
##                          Model Summary
## ----------------------------------------------------------------
## R                       0.674       RMSE                24.103
## R-Squared               0.454       Coef. Var          253.786
## Adj. R-Squared          0.451       MSE                580.951
## Pred R-Squared          0.440       MAE                 11.232
## ----------------------------------------------------------------
##  RMSE: Root Mean Square Error
##  MSE: Mean Square Error
##  MAE: Mean Absolute Error
##
##                                  ANOVA
## --------------------------------------------------------------------------
##                    Sum of
##                   Squares          DF    Mean Square       F         Sig.
## --------------------------------------------------------------------------
## Regression    1446404.532          15      96426.969    165.981    0.0000
## Residual      1739365.946        2994        580.951
## Total         3185770.479        3009
## --------------------------------------------------------------------------
##
##                                        Parameter Estimates
```

```
## ------------------------------------------------------------------------
------------------------------
##              model           Beta    Std. Error    Std. Beta      t        S
ig          lower        upper
## ------------------------------------------------------------------------
------------------------------
##       (Intercept)        44.581        15.339                 2.906    0.
004        14.505       74.657
##            deaths        14.391         0.619        0.342    23.232    0.
000        13.176       15.605
##  total_population         0.000         0.000        0.275    12.493    0.
000         0.000        0.000
##  daily_state_test         0.004         0.000        0.230    14.488    0.
000         0.004        0.005
##    virus_pressure         1.214         0.246        0.076     4.935    0.
000         0.732        1.697
##    houses_density        -0.035         0.016       -0.043    -2.154    0.
031        -0.067       -0.003
## deaths_per_100000        -0.010         0.002       -0.108    -5.725    0.
000        -0.014       -0.007
##        ventilator     25145.122      7609.526        0.402     3.304    0.
001     10224.693    40065.551
##         hosp_beds      -624.490       177.486       -0.087    -3.519    0.
000      -972.497     -276.482
##   percent_smokers        -0.550         0.122       -0.075    -4.513    0.
000        -0.788       -0.311
##    gdp_per_capita        -0.045         0.014       -0.055    -3.284    0.
001        -0.072       -0.018
##       social_dist         0.561         0.183        0.050     3.059    0.
002         0.201        0.920
##    female_percent       -67.802        31.714       -0.038    -2.138    0.
033      -129.985       -5.619
##       meat_plants         1.405         0.555        0.040     2.533    0.
011         0.318        2.493
##    icu_beds_ratio    -16712.519      8426.812       -0.245    -1.983    0.
047    -33235.447     -189.591
##     precipitation        -0.036         0.018       -0.029    -1.975    0.
048        -0.071        0.000
## ------------------------------------------------------------------------
------------------------------

model_B5_step <- lm(formula = confirmed ~
                  + deaths
+ total_population
+ daily_state_test
+ percent_diabetes
+ virus_pressure
+ houses_density
+ deaths_per_100000
+ ventilator
```

```
+ hosp_beds
+ percent_smokers
+ gdp_per_capita
+ social_dist
+ female_percent
+ meat_plants
+ icu_beds_ratio
+ precipitation  ,
data = ConfirmedB5)

summary(model_B5_step)

##
## Call:
## lm(formula = confirmed ~ +deaths + total_population + daily_state_test +
##     percent_diabetes + virus_pressure + houses_density + deaths_per_100000
+
##     ventilator + hosp_beds + percent_smokers + gdp_per_capita +
##     social_dist + female_percent + meat_plants + icu_beds_ratio +
##     precipitation, data = ConfirmedB5)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -124.19   -7.93   -0.70    5.89  384.36
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)        4.590e+01  1.537e+01   2.987  0.00284 **
## deaths             1.442e+01  6.197e-01  23.268  < 2e-16 ***
## total_population   2.578e-04  2.058e-05  12.530  < 2e-16 ***
## daily_state_test   4.280e-03  2.961e-04  14.455  < 2e-16 ***
## percent_diabetes  -2.563e-01  1.869e-01  -1.371  0.17048
## virus_pressure     1.233e+00  2.464e-01   5.003 5.97e-07 ***
## houses_density    -3.269e-02  1.650e-02  -1.981  0.04769 *
## deaths_per_100000 -8.595e-03  2.205e-03  -3.897 9.94e-05 ***
## ventilator         2.432e+04  7.632e+03   3.186  0.00146 **
## hosp_beds         -6.560e+02  1.789e+02  -3.666  0.00025 ***
## percent_smokers   -4.684e-01  1.354e-01  -3.459  0.00055 ***
## gdp_per_capita    -4.508e-02  1.381e-02  -3.265  0.00111 **
## social_dist        5.764e-01  1.836e-01   3.139  0.00171 **
## female_percent    -7.166e+01  3.183e+01  -2.251  0.02445 *
## meat_plants        1.450e+00  5.557e-01   2.610  0.00910 **
## icu_beds_ratio    -1.612e+04  8.437e+03  -1.910  0.05618 .
## precipitation     -3.439e-02  1.800e-02  -1.911  0.05614 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 24.1 on 2993 degrees of freedom
## Multiple R-squared:  0.4544, Adjusted R-squared:  0.4514
## F-statistic: 155.8 on 16 and 2993 DF,  p-value: < 2.2e-16
```

```
ols_vif_tol(model_B5_step)
```

```
##            Variables  Tolerance       VIF
## 1             deaths 0.84008276  1.190359
## 2   total_population 0.37569305  2.661747
## 3   daily_state_test 0.72605812  1.377300
## 4   percent_diabetes 0.36674611  2.726682
## 5     virus_pressure 0.76501964  1.307156
## 6     houses_density 0.46150265  2.166835
## 7  deaths_per_100000 0.34410876  2.906058
## 8         ventilator 0.01226400 81.539491
## 9          hosp_beds 0.29359137  3.406095
## 10   percent_smokers 0.53441698  1.871198
## 11    gdp_per_capita 0.64567162  1.548775
## 12       social_dist 0.67292874  1.486041
## 13    female_percent 0.56918340  1.756903
## 14       meat_plants 0.74069429  1.350085
## 15    icu_beds_ratio 0.01191432 83.932639
## 16     precipitation 0.86247240  1.159457
```

will remove icu_beds with assumption that it has ventilators

```
model_B5_step1 <- lm(formula = confirmed ~
                  + deaths
+ total_population
+ daily_state_test
+ percent_diabetes
+ virus_pressure
+ houses_density
+ deaths_per_100000
+ ventilator
+ hosp_beds
+ percent_smokers
+ gdp_per_capita
+ social_dist
+ female_percent
+ meat_plants
+ precipitation  ,
data = ConfirmedB5)

summary(model_B5_step1)
```

```
##
## Call:
## lm(formula = confirmed ~ +deaths + total_population + daily_state_test +
##     percent_diabetes + virus_pressure + houses_density + deaths_per_100000
+
##     ventilator + hosp_beds + percent_smokers + gdp_per_capita +
##     social_dist + female_percent + meat_plants + precipitation,
##     data = ConfirmedB5)
##
```

```
## Residuals:
##     Min      1Q  Median      3Q     Max
## -124.94   -8.02   -0.73    5.81  383.97
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)         5.171e+01  1.507e+01   3.432 0.000608 ***
## deaths              1.450e+01  6.185e-01  23.445  < 2e-16 ***
## total_population    2.600e-04  2.055e-05  12.652  < 2e-16 ***
## daily_state_test    4.321e-03  2.954e-04  14.629  < 2e-16 ***
## percent_diabetes   -2.746e-01  1.867e-01  -1.471 0.141513
## virus_pressure      1.193e+00  2.456e-01   4.857 1.26e-06 ***
## houses_density     -4.215e-02  1.575e-02  -2.677 0.007477 **
## deaths_per_100000 -8.548e-03  2.206e-03  -3.875 0.000109 ***
## ventilator          1.005e+04  1.578e+03   6.371 2.17e-10 ***
## hosp_beds          -7.041e+02  1.773e+02  -3.972 7.29e-05 ***
## percent_smokers    -4.758e-01  1.354e-01  -3.513 0.000449 ***
## gdp_per_capita     -4.689e-02  1.378e-02  -3.402 0.000677 ***
## social_dist         5.979e-01  1.834e-01   3.261 0.001122 **
## female_percent     -8.366e+01  3.122e+01  -2.680 0.007411 **
## meat_plants         1.343e+00  5.531e-01   2.428 0.015235 *
## precipitation      -3.491e-02  1.800e-02  -1.939 0.052602 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 24.11 on 2994 degrees of freedom
## Multiple R-squared:  0.4537, Adjusted R-squared:  0.451
## F-statistic: 165.8 on 15 and 2994 DF,  p-value: < 2.2e-16

ols_vif_tol(model_B5_step1)

##            Variables Tolerance      VIF
## 1             deaths 0.8440999 1.184694
## 2   total_population 0.3768880 2.653308
## 3   daily_state_test 0.7300036 1.369856
## 4   percent_diabetes 0.3677190 2.719468
## 5     virus_pressure 0.7705426 1.297787
## 6     houses_density 0.5071971 1.971620
## 7  deaths_per_100000 0.3441507 2.905704
## 8         ventilator 0.2872108 3.481764
## 9          hosp_beds 0.2994974 3.338927
## 10   percent_smokers 0.5348546 1.869667
## 11    gdp_per_capita 0.6487221 1.541492
## 12       social_dist 0.6754738 1.480442
## 13    female_percent 0.5922417 1.688500
## 14       meat_plants 0.7483470 1.336278
## 15     precipitation 0.8626694 1.159193

MAE(predict(model_B5, newdata = ConfirmedB5), ConfirmedB5$confirmed) # full m
odel
```

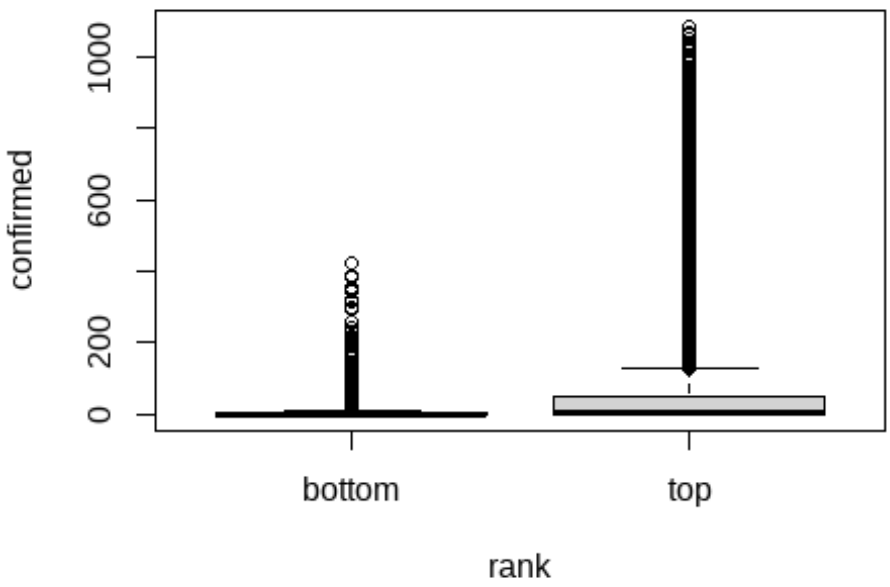
```
## Warning in stats::predict.lm(object, ...): prediction from a rank-deficien
t fit
## may be misleading

## [1] 11.34005

MAE(predict(model_B5_step1, newdata = ConfirmedB5), ConfirmedB5$confirmed) #
reduced model

## [1] 11.2955
```

ANOVA

```
# create another column "rank" for top and bottom 5 states
ConfirmedT5_rank <- ConfirmedT5 %>% add_column(rank = "top")
ConfirmedB5_rank <- ConfirmedB5 %>% add_column(rank = "bottom")

# merge 2 dataframe
Confirmed_rank <- rbind(ConfirmedT5_rank, ConfirmedB5_rank)

rm(ConfirmedT5_rank, ConfirmedB5_rank) # remove dataframes

# anova
summary(aov(confirmed~rank, data = Confirmed_rank))

##                Df    Sum Sq Mean Sq F value Pr(>F)
## rank            1   8519678 8519678   457.1 <2e-16 ***
## Residuals   10961 204317940   18640
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

p value is less than 0.05, so we reject null hypothesis that both groups are equal.

```
boxplot(confirmed~rank, data = Confirmed_rank) # checking for the boxplot
```



Deaths Cases

Top 5 states: New York, New Jersey, California, Texas, Florida

```
DeathsT5 <- week_finalT %>% filter(state_fips == 36 | state_fips == 34 | stat
e_fips == 6 | state_fips == 48 | state_fips == 12)
unique(DeathsT5$state_fips) # checking

## [1] 12 34  6 36 48

# 7,953 observations

model_T5d <- lm(formula = deaths ~ .-date -county_fips -state_fips -mahal - b
admahal, data = DeathsT5)
summary(model_T5d)

##
## Call:
## lm(formula = deaths ~ . - date - county_fips - state_fips - mahal -
##     badmahal, data = DeathsT5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -16.2420  -0.8893  -0.3200   0.3339  29.9135
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)                  -3.509e+00  8.403e+00  -0.418 0.676205
## confirmed                     2.007e-02  2.582e-04  77.758  < 2e-16 ***
## social_dist                  -2.024e-02  1.394e-02  -1.452 0.146508
## daily_state_test             -2.865e-05  1.684e-06 -17.010  < 2e-16 ***
## precipitation                 2.433e-03  6.737e-04   3.611 0.000306 ***
## temperature                   9.194e-02  5.927e-03  15.511  < 2e-16 ***
## virus_pressure               -2.051e-03  5.888e-04  -3.483 0.000498 ***
## total_population              7.319e-07  1.359e-07   5.385 7.39e-08 ***
## female_percent                5.261e+00  1.762e+00   2.985 0.002838 **
## area                          1.959e-05  2.877e-05   0.681 0.495930
## population_density           -2.753e-04  9.495e-05  -2.899 0.003750 **
## hosp_beds                     6.847e+01  2.588e+01   2.645 0.008171 **
## ventilator                    1.683e+02  6.214e+02   0.271 0.786583
## icu_beds_ratio               -4.040e+02  7.327e+02  -0.551 0.581356
## houses_density                5.133e-04  1.781e-04   2.882 0.003957 **
## college_pop                  -3.656e-01  1.340e-01  -2.728 0.006380 **
## percent_smokers               5.332e-02  1.699e-02   3.138 0.001707 **
## percent_diabetes             -2.685e-03  8.740e-03  -0.307 0.758661
## Religious_congregation_ratio  6.973e-04  2.379e-03   0.293 0.769464
## political_party               2.236e+00  1.705e-01  13.113  < 2e-16 ***
## airport_distance             -2.793e-03  6.828e-04  -4.090 4.34e-05 ***
## pass_load                     3.137e-03  1.012e-02   0.310 0.756616
## meat_plants                  -1.109e-02  5.370e-03  -2.065 0.038953 *
## income                        3.519e-06  3.434e-06   1.025 0.305541
## percent_insured              -5.153e-02  1.131e-02  -4.558 5.22e-06 ***
## deaths_per_100000            -1.041e-05  2.341e-04  -0.044 0.964552
## gdp_per_capita                1.283e-04  2.159e-04   0.594 0.552425
## Age_0_19                      2.068e-02  8.434e-02   0.245 0.806339
## Age_20_59                     2.805e-02  8.433e-02   0.333 0.739420
## Age_60                        5.292e-02  8.360e-02   0.633 0.526705
## immig_student                 6.336e+00  2.580e+00   2.456 0.014066 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.201 on 12176 degrees of freedom
## Multiple R-squared:  0.4761, Adjusted R-squared:  0.4748
## F-statistic: 368.8 on 30 and 12176 DF,  p-value: < 2.2e-16

bothfit.T5d <- ols_step_both_p(model_T5d, pent = 0.05, prem = 0.05, progress
= TRUE, details = FALSE)

## Stepwise Selection Method
## -------------------------
##
## Candidate Terms:
##
## 1. confirmed
## 2. social_dist
## 3. daily_state_test
## 4. precipitation
```

```
## 5. temperature
## 6. virus_pressure
## 7. total_population
## 8. female_percent
## 9. area
## 10. population_density
## 11. hosp_beds
## 12. ventilator
## 13. icu_beds_ratio
## 14. houses_density
## 15. college_pop
## 16. percent_smokers
## 17. percent_diabetes
## 18. Religious_congregation_ratio
## 19. political_party
## 20. airport_distance
## 21. pass_load
## 22. meat_plants
## 23. income
## 24. percent_insured
## 25. deaths_per_100000
## 26. gdp_per_capita
## 27. Age_0_19
## 28. Age_20_59
## 29. Age_60
## 30. immig_student
##
## We are selecting variables based on p value...
##
## Variables Entered/Removed:
##
## - confirmed added
## - total_population added
## - daily_state_test added
## - temperature added
## - political_party added
## - Age_20_59 added
## - precipitation added
## - airport_distance added
## - virus_pressure added
## - hosp_beds added
## - percent_smokers added
## - percent_insured added
## - Age_60 added
## - meat_plants added
##
## No more variables to be added/removed.
##
##
## Final Model Output
```

```
## ------------------
##
##                            Model Summary
## ----------------------------------------------------------------
## R                       0.689       RMSE                 3.203
## R-Squared               0.475       Coef. Var          200.698
## Adj. R-Squared          0.474       MSE                 10.259
## Pred R-Squared          0.473       MAE                  1.541
## ----------------------------------------------------------------
##  RMSE: Root Mean Square Error
##  MSE: Mean Square Error
##  MAE: Mean Absolute Error
##
##                                   ANOVA
## --------------------------------------------------------------------------
##                    Sum of
##                   Squares           DF    Mean Square       F         Sig.
## --------------------------------------------------------------------------
## Regression    113110.462           14       8079.319    787.564    0.0000
## Residual      125073.051        12192         10.259
## Total         238183.514        12206
## --------------------------------------------------------------------------
##
##                                     Parameter Estimates
## ------------------------------------------------------------------------
--------------------
##            model      Beta    Std. Error    Std. Beta       t        Sig
lower     upper
## ------------------------------------------------------------------------
--------------------
##      (Intercept)     2.464         0.792                  3.112    0.002
0.912     4.016
##        confirmed     0.020         0.000        0.664     78.494    0.000
0.019     0.020
## total_population     0.000         0.000        0.083      5.874    0.000
0.000     0.000
## daily_state_test     0.000         0.000       -0.191    -17.475    0.000
0.000     0.000
##      temperature     0.092         0.006        0.178     15.853    0.000
0.081     0.104
##  political_party     2.147         0.156        0.230     13.807    0.000
1.842     2.452
##        Age_20_59    -0.038         0.011       -0.037     -3.345    0.001
-0.060    -0.016
##    precipitation     0.003         0.001        0.026      3.778    0.000
0.001     0.004
## airport_distance    -0.003         0.001       -0.036     -4.790    0.000
-0.004    -0.002
##   virus_pressure    -0.002         0.001       -0.023     -2.989    0.003
-0.003    -0.001
```

```
##        hosp_beds    43.745        15.695        0.019       2.787    0.005
12.980    74.510
##  percent_smokers     0.038         0.013        0.023       3.025    0.002
0.014     0.063
##  percent_insured    -0.034         0.009       -0.055      -3.625    0.000
-0.052    -0.015
##           Age_60     0.019         0.008        0.025       2.492    0.013
0.004     0.034
##      meat_plants    -0.012         0.005       -0.030      -2.273    0.023
-0.022    -0.002
## ------------------------------------------------------------------------
--------------------
```

```
model_T5d_step <- lm(formula = deaths ~
                     + confirmed
+ total_population
+ daily_state_test
+ temperature
+ Age_20_59
+ precipitation
+ airport_distance
+ virus_pressure
+ hosp_beds
+ percent_smokers
+ percent_insured
+ Age_60
+ meat_plants ,
data = DeathsT5) # removed political party since it's categorical nominal

summary(model_T5d_step)
```

```
##
## Call:
## lm(formula = deaths ~ +confirmed + total_population + daily_state_test +
##     temperature + Age_20_59 + precipitation + airport_distance +
##     virus_pressure + hosp_beds + percent_smokers + percent_insured +
##     Age_60 + meat_plants, data = DeathsT5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -16.3600  -0.8093  -0.3268   0.2339  30.4127
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -2.209e+00  7.213e-01  -3.062  0.00220 **
## confirmed         1.975e-02  2.559e-04  77.168  < 2e-16 ***
## total_population  5.474e-07  1.236e-07   4.430 9.51e-06 ***
## daily_state_test -1.923e-05  1.508e-06 -12.746  < 2e-16 ***
## temperature       5.586e-02  5.234e-03  10.671  < 2e-16 ***
## Age_20_59        -6.321e-02  1.130e-02  -5.593 2.28e-08 ***
```

```
## precipitation     2.038e-03  6.758e-04   3.016  0.00257 **
## airport_distance -1.683e-03  5.513e-04  -3.052  0.00228 **
## virus_pressure   -1.621e-03  5.785e-04  -2.803  0.00508 **
## hosp_beds         4.539e+01  1.582e+01   2.870  0.00411 **
## percent_smokers  -9.267e-03  1.230e-02  -0.753  0.45125
## percent_insured   6.324e-02  6.113e-03  10.346  < 2e-16 ***
## Age_60            8.429e-04  7.643e-03   0.110  0.91218
## meat_plants       1.550e-03  5.120e-03   0.303  0.76206
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.228 on 12193 degrees of freedom
## Multiple R-squared:  0.4667, Adjusted R-squared:  0.4661
## F-statistic: 820.7 on 13 and 12193 DF,  p-value: < 2.2e-16

ols_vif_tol(model_T5d_step)

##           Variables Tolerance      VIF
## 1         confirmed 0.6035658 1.656820
## 2  total_population 0.2182577 4.581740
## 3  daily_state_test 0.4388161 2.278859
## 4       temperature 0.4303568 2.323653
## 5         Age_20_59 0.3684285 2.714231
## 6     precipitation 0.9342694 1.070355
## 7  airport_distance 0.7882525 1.268629
## 8    virus_pressure 0.7581458 1.319007
## 9         hosp_beds 0.9551414 1.046965
## 10  percent_smokers 0.7860575 1.272172
## 11  percent_insured 0.4354491 2.296480
## 12           Age_60 0.4374165 2.286151
## 13      meat_plants 0.2648353 3.775931

MAE(predict(model_T5d, newdata = DeathsT5), DeathsT5$deaths) # full model

## [1] 1.546916

MAE(predict(model_T5d_step, newdata = DeathsT5), DeathsT5$deaths) # reduced m
odel

## [1] 1.511238
```

Bottom 5 states: Alaska, Wyoming, Vermont, Hawaii, Maine

```
DeathsB5 <- week_finalT %>% filter(state_fips == 2 | state_fips == 56 | state
_fips == 50 | state_fips == 15 | state_fips == 23)
unique(DeathsB5$state_fips) # checking

## [1] 15  2 23 50 56

# 1,885 observations
```

```
model_B5d <- lm(formula = deaths ~ .-date -county_fips -state_fips -mahal - b
admahal, data = DeathsB5)
summary(model_B5d)

##
## Call:
## lm(formula = deaths ~ . - date - county_fips - state_fips - mahal -
##     badmahal, data = DeathsB5)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.5316 -0.1506 -0.0363  0.0671  7.1162
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   7.160e-02  5.488e+00   0.013   0.9896
## confirmed                     1.411e-02  5.678e-04  24.860  < 2e-16 ***
## social_dist                  -3.647e-02  5.602e-03  -6.510 9.63e-11 ***
## daily_state_test             -2.445e-05  1.858e-05  -1.316   0.1883
## precipitation                -1.200e-04  6.297e-04  -0.191   0.8489
## temperature                  -2.763e-03  1.939e-03  -1.425   0.1544
## virus_pressure               -1.536e-02  1.021e-02  -1.504   0.1328
## total_population              3.436e-07  5.195e-07   0.661   0.5085
## female_percent                2.027e+00  2.612e+00   0.776   0.4378
## area                          3.810e-06  8.836e-06   0.431   0.6664
## population_density           -5.183e-03  1.069e-03  -4.850 1.34e-06 ***
## hosp_beds                    -7.299e+00  1.183e+01  -0.617   0.5374
## ventilator                    5.520e+02  5.701e+02   0.968   0.3331
## icu_beds_ratio               -3.627e+02  6.455e+02  -0.562   0.5743
## houses_density                1.450e-02  2.520e-03   5.756 1.01e-08 ***
## college_pop                  -1.849e-01  1.669e-01  -1.108   0.2682
## percent_smokers              -2.572e-02  1.469e-02  -1.750   0.0802 .
## percent_diabetes              3.043e-02  1.212e-02   2.512   0.0121 *
## Religious_congregation_ratio -1.780e-03  2.457e-03  -0.724   0.4690
## political_party               9.845e-03  5.644e-02   0.174   0.8616
## airport_distance             -2.109e-04  4.677e-04  -0.451   0.6521
## pass_load                     2.907e-03  2.270e-02   0.128   0.8981
## meat_plants                  -1.096e-02  1.415e-02  -0.775   0.4386
## income                       -1.579e-06  3.385e-06  -0.466   0.6410
## percent_insured              -5.927e-03  8.702e-03  -0.681   0.4959
## deaths_per_100000            -2.872e-05  1.677e-04  -0.171   0.8641
## gdp_per_capita                7.760e-05  1.273e-03   0.061   0.9514
## Age_0_19                      4.421e-03  6.138e-02   0.072   0.9426
## Age_20_59                     4.401e-03  5.346e-02   0.082   0.9344
## Age_60                       -1.691e-02  5.740e-02  -0.295   0.7684
## immig_student                 5.249e+00  3.990e+00   1.316   0.1885
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.5975 on 1854 degrees of freedom
```

```
## Multiple R-squared:  0.3831, Adjusted R-squared:  0.3731
## F-statistic: 38.38 on 30 and 1854 DF,  p-value: < 2.2e-16

bothfit.B5d <- ols_step_both_p(model_B5d, pent = 0.05, prem = 0.05, progress
= TRUE, details = FALSE)

## Stepwise Selection Method
## ---------------------------
##
## Candidate Terms:
##
## 1. confirmed
## 2. social_dist
## 3. daily_state_test
## 4. precipitation
## 5. temperature
## 6. virus_pressure
## 7. total_population
## 8. female_percent
## 9. area
## 10. population_density
## 11. hosp_beds
## 12. ventilator
## 13. icu_beds_ratio
## 14. houses_density
## 15. college_pop
## 16. percent_smokers
## 17. percent_diabetes
## 18. Religious_congregation_ratio
## 19. political_party
## 20. airport_distance
## 21. pass_load
## 22. meat_plants
## 23. income
## 24. percent_insured
## 25. deaths_per_100000
## 26. gdp_per_capita
## 27. Age_0_19
## 28. Age_20_59
## 29. Age_60
## 30. immig_student
##
## We are selecting variables based on p value...
##
## Variables Entered/Removed:
##
## - confirmed added
## - female_percent added
## - social_dist added
## - Age_60 added
```

```
## - temperature added
## - airport_distance added
## - gdp_per_capita added
##
## No more variables to be added/removed.
##
##
## Final Model Output
## ------------------
##
##                          Model Summary
## ----------------------------------------------------------------
## R                       0.594       RMSE                 0.608
## R-Squared               0.353       Coef. Var          412.447
## Adj. R-Squared          0.350       MSE                  0.370
## Pred R-Squared          0.307       MAE                  0.229
## ----------------------------------------------------------------
##  RMSE: Root Mean Square Error
##  MSE: Mean Square Error
##  MAE: Mean Absolute Error
##
##                                 ANOVA
## --------------------------------------------------------------------
##                 Sum of
##                Squares          DF    Mean Square       F         Sig.
## --------------------------------------------------------------------
## Regression     378.508           7         54.073    146.141    0.0000
## Residual       694.493        1877          0.370
## Total         1073.001        1884
## --------------------------------------------------------------------
##
##                                    Parameter Estimates
## ------------------------------------------------------------------------
-------------------
##            model      Beta    Std. Error    Std. Beta      t        Sig
lower     upper
## ------------------------------------------------------------------------
-------------------
##      (Intercept)    -2.728         0.622                -4.388    0.000
-3.947    -1.509
##        confirmed     0.015         0.001        0.569    29.512    0.000
0.014     0.016
##   female_percent     6.474         1.276        0.135     5.075    0.000
3.972     8.975
##      social_dist    -0.029         0.005       -0.109    -5.390    0.000
-0.039    -0.018
##          Age_60    -0.008         0.004       -0.053    -2.097    0.036
-0.016    -0.001
##      temperature    -0.006         0.001       -0.075    -3.826    0.000
-0.008    -0.003
```

```
## airport_distance    -0.001         0.000       -0.076    -3.395    0.001
-0.001     0.000
##   gdp_per_capita     0.002         0.001        0.060     2.270    0.023
0.000     0.003
## ------------------------------------------------------------------------
------------------
```

```
model_B5d_step <- lm(formula = deaths ~
                     + confirmed
+ female_percent
+ social_dist
+ Age_60
+ temperature
+ airport_distance
+ gdp_per_capita  ,
data = DeathsB5)

summary(model_B5d_step)
```

```
##
## Call:
## lm(formula = deaths ~ +confirmed + female_percent + social_dist +
##     Age_60 + temperature + airport_distance + gdp_per_capita,
##     data = DeathsB5)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.0221 -0.1443 -0.0514  0.0289  7.2352
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -2.7280087  0.6216608  -4.388 1.21e-05 ***
## confirmed         0.0148675  0.0005038  29.512  < 2e-16 ***
## female_percent    6.4735686  1.2755469   5.075 4.26e-07 ***
## social_dist      -0.0285662  0.0052994  -5.390 7.92e-08 ***
## Age_60           -0.0082490  0.0039346  -2.097 0.036168 *
## temperature      -0.0055754  0.0014574  -3.826 0.000135 ***
## airport_distance -0.0007928  0.0002335  -3.395 0.000701 ***
## gdp_per_capita    0.0016603  0.0007314   2.270 0.023318 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6083 on 1877 degrees of freedom
## Multiple R-squared:  0.3528, Adjusted R-squared:  0.3503
## F-statistic: 146.1 on 7 and 1877 DF,  p-value: < 2.2e-16
```

```
ols_vif_tol(model_B5d_step)
```

```
##          Variables Tolerance      VIF
## 1        confirmed 0.9263912 1.079458
## 2   female_percent 0.4908379 2.037332
```

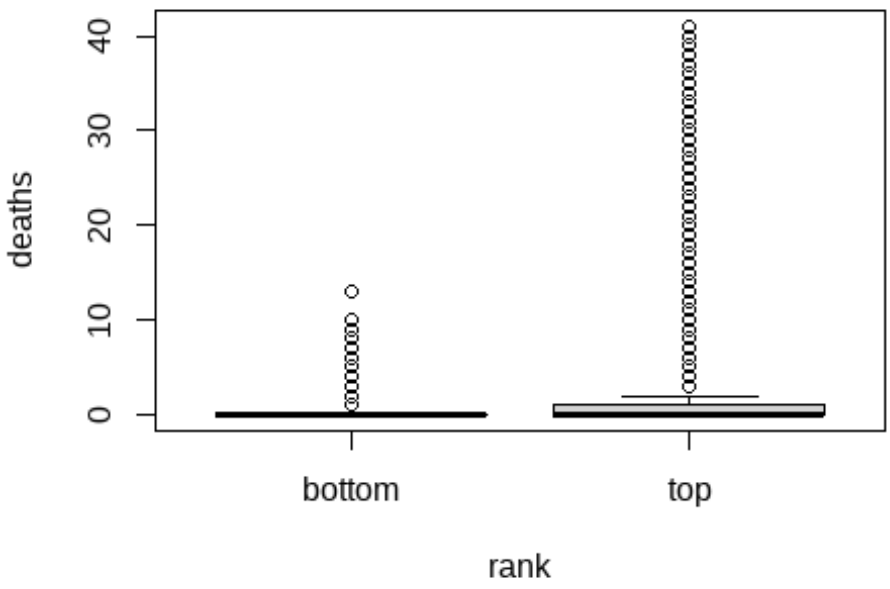
```
## 3      social_dist 0.8510990 1.174951
## 4           Age_60 0.5459178 1.831777
## 5      temperature 0.8912085 1.122072
## 6 airport_distance 0.6806707 1.469139
## 7   gdp_per_capita 0.4993489 2.002608

MAE(predict(model_B5d, newdata = DeathsB5), DeathsB5$deaths) # full model

## [1] 0.2395637

MAE(predict(model_B5d_step, newdata = DeathsB5), DeathsB5$deaths) # reduced m
odel

## [1] 0.2291375
```

Anova

```
# create another column "rank" for top and bottom 5 states
DeathsT5_rank <- DeathsT5 %>% add_column(rank = "top")
DeathsB5_rank <- DeathsB5 %>% add_column(rank = "bottom")

# merge 2 dataframe
Deaths_rank <- rbind(DeathsT5_rank, DeathsB5_rank)

rm(DeathsT5_rank, DeathsB5_rank) # remove dataframes

# anova
summary(aov(deaths~rank, data = Deaths_rank))

##               Df Sum Sq Mean Sq F value Pr(>F)
## rank           1   3426    3426   201.7 <2e-16 ***
## Residuals   14090 239257      17
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

p value is less than 0.05, so we reject null hypothesis that both groups are equal.

```
boxplot(deaths~rank, data = Deaths_rank) # checking for the boxplot
```


deaths
0
10
20
30
40
bottom
top
rank