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Impact of "Stay at Home" Policy on Covid-19 in the United States

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Abstract

In the past few months, Coronavirus Disease 2019 (COVID-19) has spread around the world. Among all the countries, the United States seems to be the one facing severe problems. This project begins with some graphical displays of basic explorations on confirmed and death cases in each state, followed by the application of the "lowess" smoother model on the recent trends of the daily new confirmed cases. Additionally, this project utilizes mathematical models and further graphical tools to investigate the impacts of the "Stay at Home" policy on the daily increment of confirmed cases. "Stay at Home" policy is practical to some extent since most state-level administrative divisions are seeing a decline in the number of new daily diagnoses. However, the condition for several states is still so severe that they need to reconsider the work resumption or adopt other useful approaches.

Keywords

COVID-19, "Stay at Home" Policy, increase trend, Rstudio.

1. INTRODUCTION

In December 2019, the Coronavirus Disease (COVID-19) started to spread in China. It spread rapidly all around the world and starting in January 2020, infected people started to appear in the United States. The United States has gradually become the country with the most confirmed cases. The fast-spreading speed and great possible harm of new coronavirus have threatened public health to a great extent. In the course of its spread, COVID-19 became a grave crisis for all mankind and has aroused great attention. Thus, the government started to implement the "Stay at Home" policy of varying degrees to mitigate the rapid increase.

It has been about four months since the "Stay at Home" policy became effective. Currently, several states have announced to reopen due to economical consideration. Both citizens and medical experts are worried about the reopening process since the effectiveness of this policy is obscure. This paper mainly focuses on the trend of daily new confirmed cases before and after reopening days of each state. By analyzing the trend, this paper can answer the question of whether it is a proper time to reopen and how efficient the "Stay at Home" policy is.

After reopening, we expect a change in the trend of daily confirmed cases. This paper studies how long it takes for trends to alter and make a table for each state. Then, based on the result, this paper will do some basic analysis and prediction of future circumstances.

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The COVID-19 pandemic has sparked an unprecedented wave of data-sharing research, with many people trying to understand the sources and implications of the problems associated with it. Based on all the sources this project has access to, Johns Hopkins Coronavirus Resource Center (CRC) has a complete and up-to-date source of ongoing COVID-19 data, including confirmed cases, deaths, countries, incidence rate, etc. This project uses CRC's open-source data on GitHub and collates it. A lot of people have already done integrated studies on the trends in different countries, and this project will focus on the new trends on state level and understand the impact of "Stay at Home" policy on the overall trend. This project starts with general exploration and then narrows it down to United States data. This project applies the "lowess" model and other calculations to evaluate the trend and come to some conclusions.

2. ABOUT THE DATA

Most of our data are from "Covid-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University" on the GitHub[1].

We clean up the raw data as followings:

Firstly, we find that there are four different types of data inputs. Therefore, we make several changes to sort these inputs.

1) For files from January 22nd to February 29th, we add the `Latitude` and `Longitude` columns.

2) For files from January 22nd to March 22nd, we add the `County` and `FIPS` columns.

3) For files from January 22nd to May 29th, the fatality ratios are calculated for each row.

4) For all the data, we unify the format of column names, reorder the columns and fix the country problem for China. We also add a column called `day` to indicate the number of days since January 22nd. We then put all the data back into a whole big data frame and export it to a .csv file for later analysis.

Secondly, we would like to find all the cases from the United States and fix some flaws.

1) We substitute all the abbreviations of states into their full names and add the "District of Columbia" for the cases from Washington, D.C.

2) For some rows, we fix the `county` and `Province_State` columns to make the format congruent.

3) We export all the cases of United States into a .csv file for later use.

Finally, we collect the data from New York Times about the instruction and termination day of "Stay at Home" policy for each state in the United States and put them into a file called "Home_Policy" [2, 3].

1) We read in the data and add `Effective.Day` and `Reopen.Day` columns to indicate the important date of the policy.

2) We calculate the duration of the policy in each state and add to the "Home_Policy" file.

3) We calculate the aggregate confirmed and death cases for each state and export them into two separate files for later usage.

4) We combine and select to new files we need and read those files in analysis.

Note: While scrutinizing the raw data sets, we found some problems. There are several inconsistencies in the `Country_Region` and `Province_State`. There exists the situation that a single country is presented in different names.

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3. INITIAL EXPLORATION

3.1. Basic Exploration

Four plots for each state about the count of cases for total confirmed, total deaths, increase in confirmed and deaths on Aug 15th.

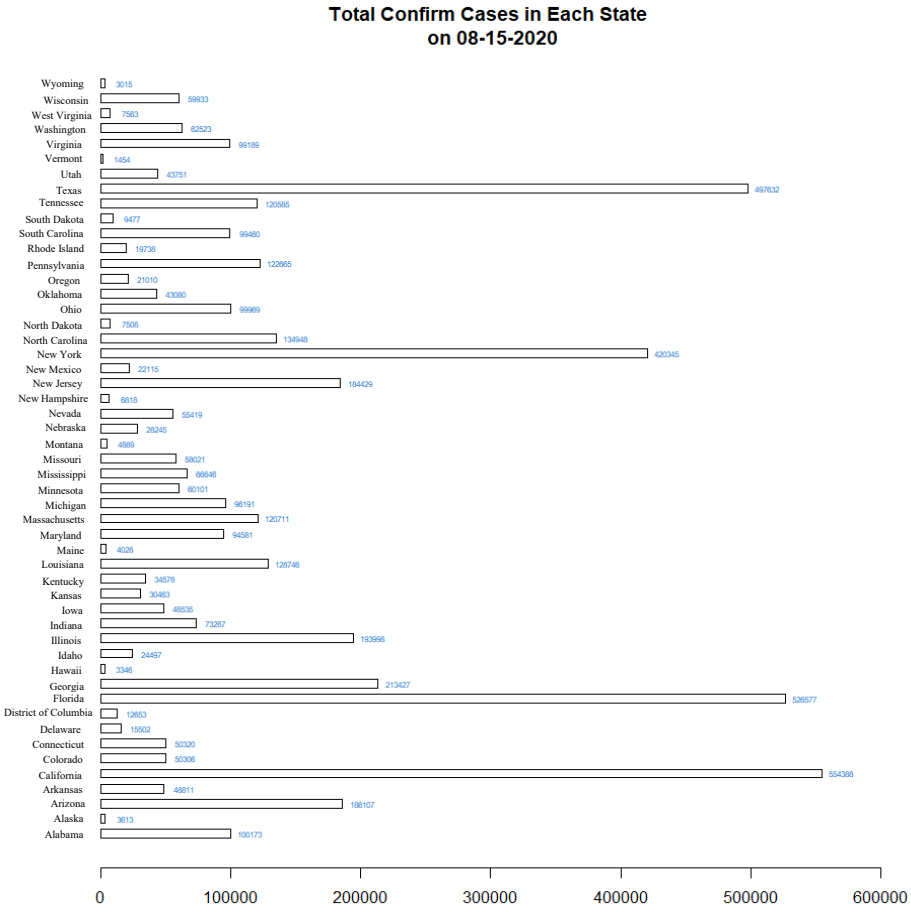

Figure 1. Total Confirmed Cases in Each State on Aug 15th

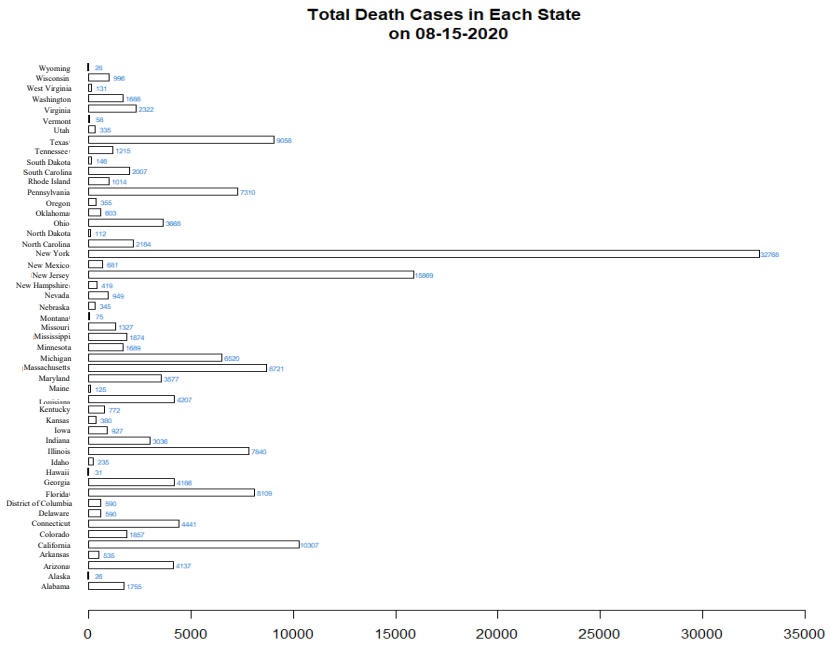

Figure 2. Total Death Cases in Each State on Aug 15th

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In Figure 1, by Aug 15th, only 10 states have fewer than 10,000 total confirmed cases and 14 states have reached more than 100,000 total confirmed cases so far. Among those states with more than 100,000 total cases, four states show more total cases than others, including Texas, New York, Florida and California. They have 497,632, 420,345, 526,577 and 554,388 cases respectively.

In Figure 2, New York has got the highest total death cases until Aug 15th. This may result from the fact that New York was the most crowded place for infected people back in March and April. It is quite difficult to cure numerous patients with limited medical resources in only a month and that is why New York has such a high fatality ratio and total death cases. Similarly, New Jersey has the second-highest total death cases, which is 15,869 by Aug 15th.

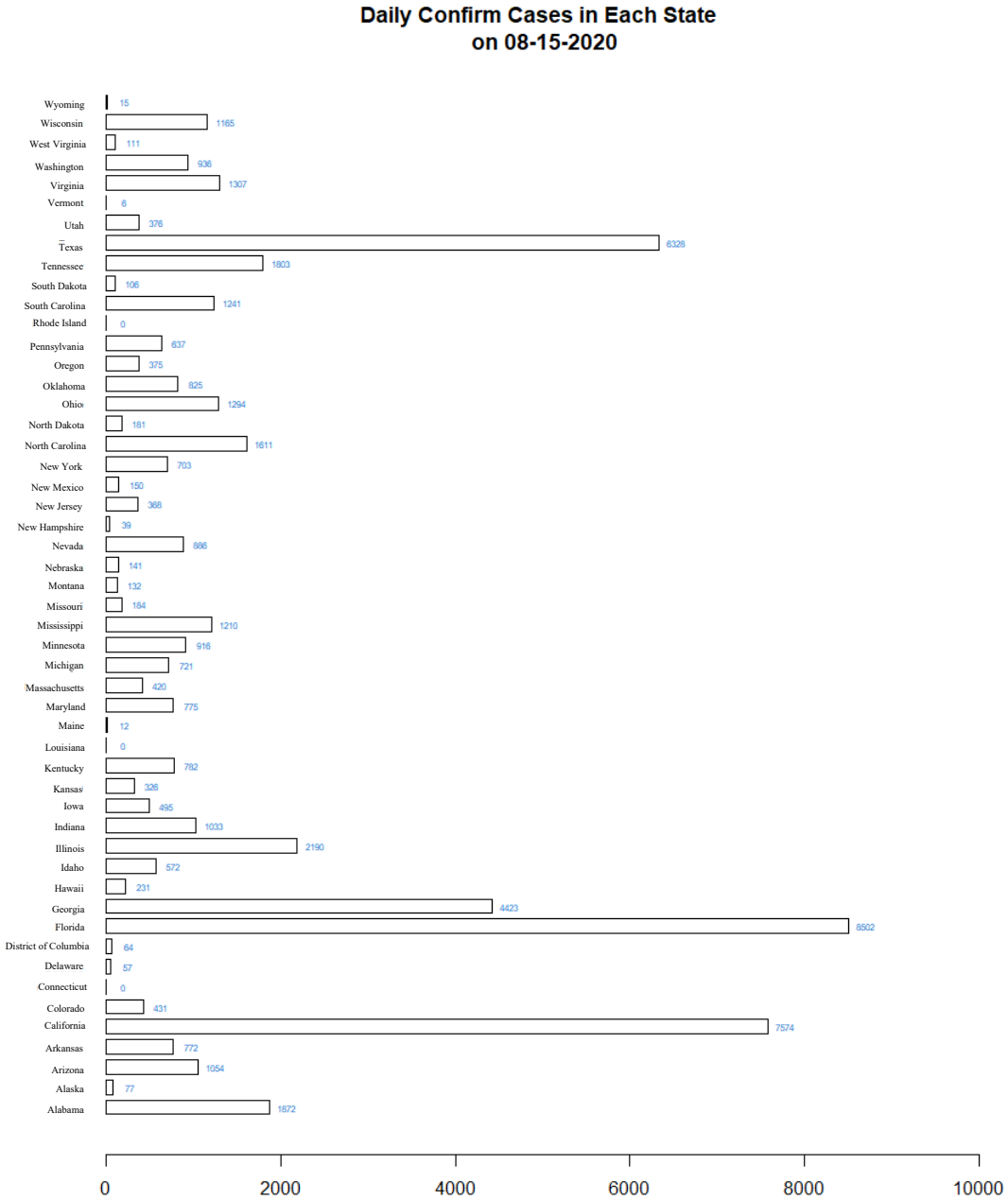

Figure 3. Daily Confirmed Cases in Each State on Aug 15th

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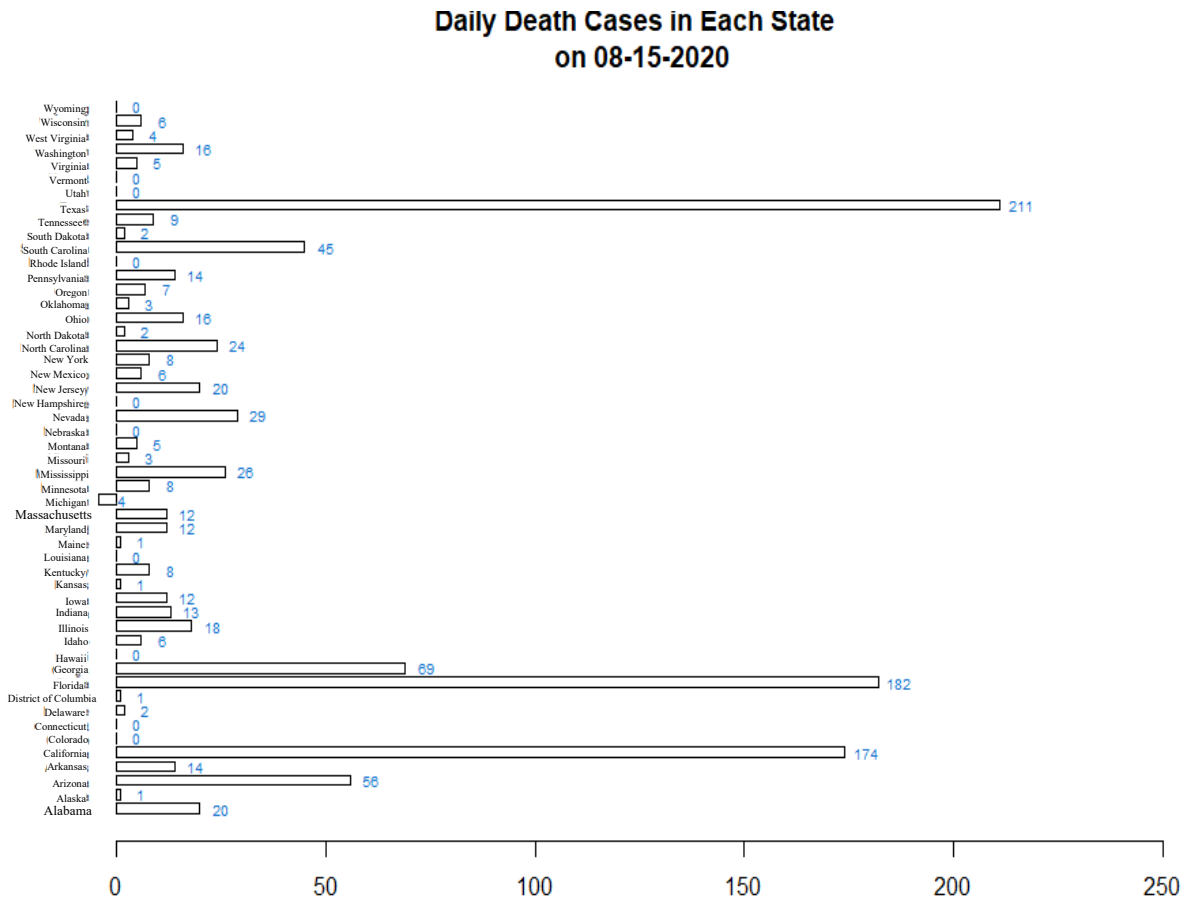

Figure 4. Daily Death Cases in Each State on Aug 15th

Figure 3 and 4 are the daily confirmed and death cases in each state on August 15th. We could see that Florida, California, Texas and Georgia are the 4 states with most new confirmed and death cases on this day. As is shown in Figure 1, Florida, California and Texas are the states with most total cases. While Georgia is not among these states, the great number of daily new cases might be an indication of a rapid future increase. Besides, New York was among the states with the most severe cases. Nevertheless, the most recent daily increase in both confirmed and death cases are not as severe as the other states mentioned above. This situation may signify that New York is in better condition and is getting steady recovery.

3.2. Negative Values

When calculating the daily increase for confirmed and death cases, some negative values are found. The following two tables (Table 1 and Table 2) show the negative values we find in the increase in the number of confirmed cases and the deaths. The second columns “Con_Day” and “Dea_Day” are the day number from January 22nd and the third columns “Con_Data” and “Dea_Data” are for the actual difference value between that day and the day before. We have reasonably speculated and found evidence that some states or lower-level districts may periodically revise their reported data. For instance, “on July 27, Texas added 675 additional deaths through death certificate reviews”, but “only 44 deaths were truly new deaths on July 27” (Our Data). Thus, the revisions are reasonable and it will not impact our further research. Some possible reasons why they revise the data reported can be found in the website [4].

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Table 1. Negative Values and Day Found in Confirmed Cases

state	Con_Day	Con_Data
Arizona	92	-18
California	28	-400
California	59	-5
Connecticut	88	-1
Connecticut	168	-15
Delaware	34	-27
District of Columbia	117	-84
Georgia	116	-1
Hawaii	190	-1
Hawaii	198	-5
Kentucky	20	-3
Louisiana	75	-119
Maine	115	-1
Montana	86	-1
Montana	118	-1
Nebraska	105	-43
Nevada	52	-1
Nevada	76	-20
Nevada	92	-34
Nevada	105	-51
New Hampshire	50	-1
New Hampshire	51	-1
New Hampshire	74	-51
New Hampshire	86	-63
New Jersey	189	-31
New Mexico	95	-37
North Dakota	163	-35
South Carolina	170	-7
Tennessee	180	-112
Texas	132	-2
Texas	149	-1

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Utah	166	-2
Vermont	225	-1
Vermont	62	-1
Washington	185	-62
Washington	218	-141
West Virginia	241	-4
Wyoming	151	-8

Table 2. Negative Values and Day Found in Death Cases

state2	Dea_Day	Dea_Data
Alabama	101	-1
Arizona	201	-1
Colorado	201	-10
District of Columbia	132	-2
Hawaii	140	-1
Idaho	195	-1
Indiana	199	-60
Kansas	97	-1
Kentucky	202	-7
Louisiana	106	-81
Maine	128	-1
Maryland	40	-60
Massachusetts	107	-41
Michigan	153	-4
Michigan	154	-1
Mississippi	168	-34
Missouri	72	-13
Missouri	101	-4
Montana	54	-1
Nebraska	96	-1
Nebraska	155	-1
Nebraska	156	-1
Nebraska	160	-1
Nebraska	163	-2

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Nebraska	170	-3
Nebraska	183	-4
Nevada	103	-3
Nevada	105	-3
Nevada	119	-7
Nevada	130	-1
New Jersey	192	-30
New Jersey	199	-27
New Jersey	206	-15
New Jersey	213	-5
North Carolina	189	-1
Oklahoma	195	-1
Tennessee	187	-2
Tennessee	200	-1
Texas	103	-8
Utah	190	-5
Vermont	218	-1
Virginia	190	-5
Washington	76	-5
Washington	102	-39
Washington	114	-1
Wisconsin	81	-1
Wisconsin	115	-1
Wyoming	130	-1

3.3. Data Analysis

In order to further analyze the increasing speed of the confirmed cases, we create the line plots for each state showing their daily confirmed cases in the period shown in the data set. We also indicate the effective day of the "Stay at Home" Policy and the reopening day on the plots. Furthermore, we do some data smoothing and fit them into linear models to better illustrate the trend. We use the "lowess" function in R to do the data smoothing.

Besides, we compute the maximum second derivative value for each model to find the day with the greatest rate of change in daily confirmed cases. This is shown as the blue point in each plot in this section. Figure 5 is for Alabama. We then calculate the slope of each line in the most recent week to see the actual recent increasing rate. Then, by simply subtracting the reopen day, we can get the duration between reopening day and the day when situations deteriorate.

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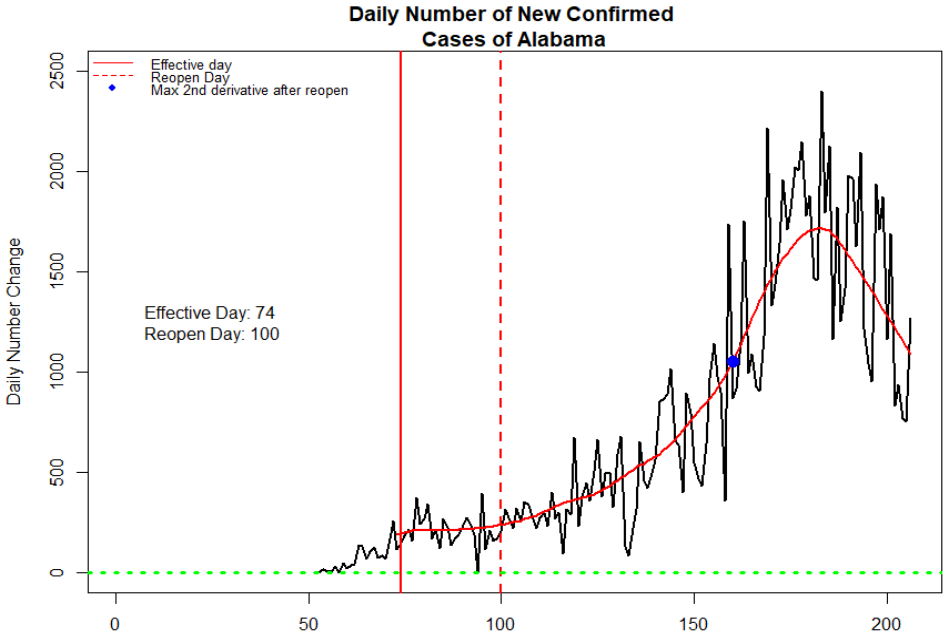

Figure 5. Daily Number of New Confirmed Cases of Alabama

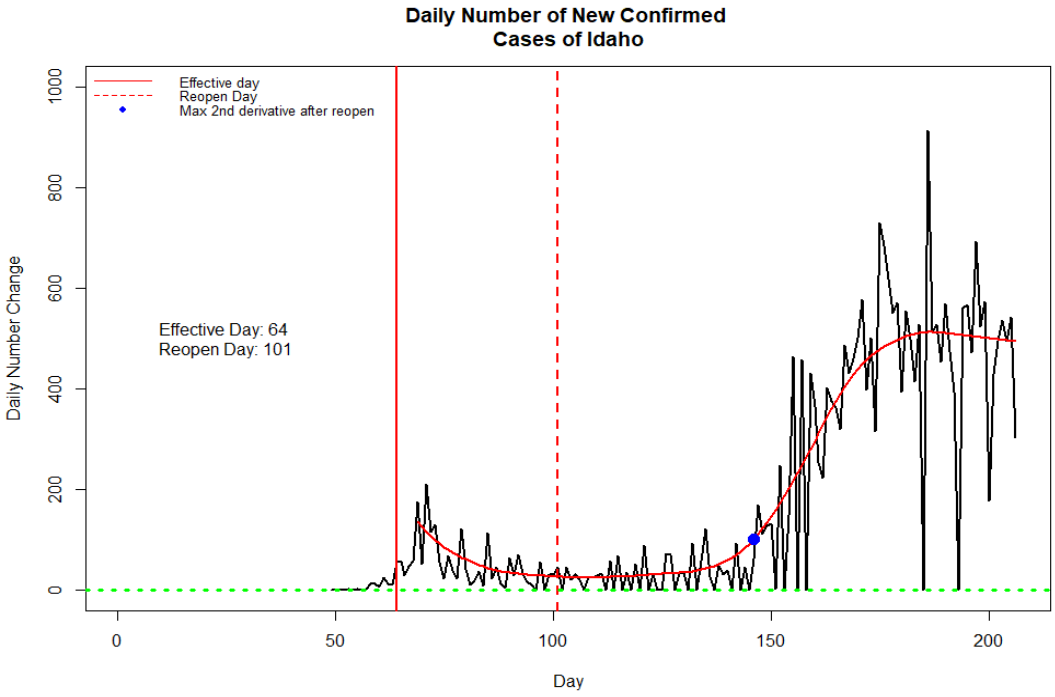

Figure 6. Daily Number of New Confirmed Cases of Idaho

Some states that have obvious weekly patterns in the plots. For example, the daily confirmed cases would bounce between zero and a positive number. Two typical instances would be Idaho and Rhode Island.

As we could see from Figure 6, between day 100 and day 150, there is an apparent pattern and there exist several zeros in this period. By searching the actual data, we find that from May 13th to the end of May, the state has a zero in daily new confirmed cases for every 2 days. And from June 1st to the end of June, the state has a zero for about every 3 or four days. Therefore, a

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possible reason might be that the state of Idaho reported the new cases for 2 or 3 days and then rested for one day.

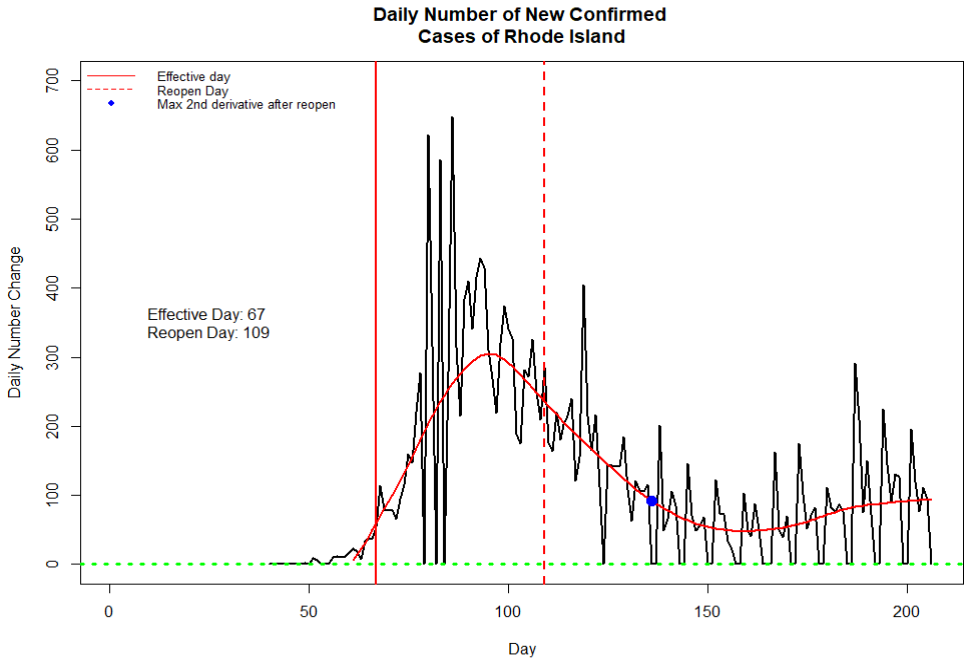

Figure 7. Daily Number of New Confirmed Cases of Rhode Island

Similar situations appear in Rhode Island as well. From Figure 7, we could see an even clearer pattern since about day 140. Then according to the real data, we know that from day 136 to the latest day, there exist 2 zeros at the end of seven days. Thus, it is safe to say that Rhode Island reports the daily new cases from Monday to Friday and then rest for the weekend.

Some other states have strange patterns like a sharp change in the daily cases.

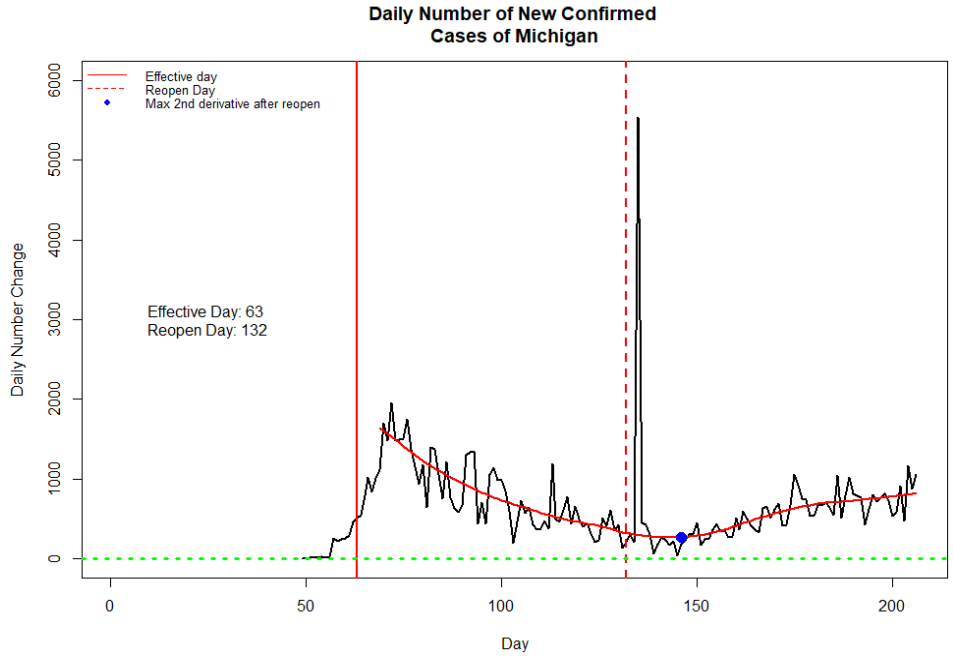

Figure 8. Daily Number of New Confirmed Cases of Michigan

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For example, there is an unusual sudden increase in the plot for Michigan. As is shown in Figure 8, the data on about day 130 is extremely higher than other days. By looking at the actual data, we find that on June 2nd, which is day 133 in this period, there is an increase of 5,536. This is abnormal compared to other days. Given that the data is collected on a county basis and the situation appeared in several other states, some counties might not report the cases timely and there are many accumulated cases from several days that are added to the data set in a single day.

4. RESULTS

4.1. Recent Trends

We print out the table with the trend and the percentage change in the trend. For the trend, we calculate the slope of the "lowess" smoother model for the most recent 7-day data which uses locally-weighted polynomial regression. Since the database of each state varies greatly, we believe that the percentage change in the trend will reflect our findings more intuitively.

Based on the "Trend" column, Florida has a relatively high decreasing rate in daily confirmed cases. Same situations occur in California and Texas. These states are among the states with the most severe circumstances and have a high total number of confirmed cases. However, the high decreasing rate in these states might be an indication of remission and well-controlled spreading speed. This is a sanguine sign of possible outbreak mitigation. On the contrary, Hawaii has a high increasing rate. It had very few confirmed cases in the early stage but gradually got worse. Another state that has an abnormally high increasing rate is Illinois. Compared to its relatively low percentage change in new cases, it has the highest increasing speed. The high total number of confirmed cases in Illinois might be the cause.

Table 3. Recent Trend Data for 50 States and District of Columbia

States	Trend	Percent Change
Hawaii	7.648641758	3.692923190
South Dakota	1.325296690	1.392480199
Illinois	21.846235669	1.209571696
Vermont	0.070270157	1.100534966
New Jersey	4.278143492	0.993328828
Montana	1.266678957	0.978740088
Indiana	8.651908357	0.912907079
North Dakota	1.175522923	0.845476164
Michigan	5.851926831	0.733814570
Massachusetts	2.658328228	0.683005976
West Virginia	0.851693116	0.645611688
Missouri	7.123118123	0.554991519
Kansas	2.245767841	0.505255821
Kentucky	2.272658946	0.381669083
Rhode Island	0.339103695	0.366526873
Nebraska	1.030931736	0.360849251
District of Columbia	0.230400103	0.356785924

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Iowa	1.307978741	0.262841341
Alaska	0.005547062	0.007653493
Minnesota	-0.477162716	-0.070801733
New York	-0.851722586	-0.129377122
Virginia	-1.491874305	-0.151772421
Wisconsin	-1.534640030	-0.177830059
Idaho	-1.030811866	-0.207439682
Pennsylvania	-3.141089942	-0.389366031
Oregon	-1.320419290	-0.439787918
New Hampshire	-0.121293339	-0.452671733
Georgia	-15.090668222	-0.461085947
Maryland	-3.740266407	-0.494183301
Arkansas	-4.026121082	-0.582088196
Ohio	-9.047727689	-0.811676303
Oklahoma	-6.426050669	-0.823848065
Maine	-0.139628000	-0.877135890
Delaware	-0.826337664	-0.982640179
Washington	-6.930213385	-1.099596112
Texas	-77.877058937	-1.134967673
California	-86.435210212	-1.255709965
Wyoming	-0.524962333	-1.497985634
Tennessee	-26.348109522	-1.546637171
Nevada	-14.224969027	-1.812037519
Colorado	-7.589489238	-1.970597011
Mississippi	-16.953208746	-1.972642593
Utah	-7.519282619	-2.037124493
North Carolina	-28.162466847	-2.133520663
Florida	-163.444088895	-2.461601320
Connecticut	-2.058210158	-2.643117029
Alabama	-31.591376283	-2.658289757
South Carolina	-33.020919472	-3.285897435
New Mexico	-5.885092740	-3.503501296
Louisiana	-54.146597101	-5.587655141
Arizona	-63.683465966	-6.309158401

From the ordered percentage change, more than half of all the administrative areas are in a decreasing trend of new confirmed cases, especially for states as Louisiana or Arizona. Their situation is more optimistic. However, for states like Hawaii, the percentage growth of new

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confirmed cases around 3.69 is not optimistic. While the highest number of new confirmed cases is not that high compared to New York or other states already in a more severe condition, the rate of rapid increase should be of more concern.

4.2. Day from Reopen

To identify how effective the "Stay at Home" policy is, after smoothing the curve, we locate the maximum second derivative point after the reopening day on the curve for each state. The X value for each point is the day that the pandemic situation becomes worse. Then, by subtracting the X value of reopening day point from the X value of the maximum second derivative point, we get the duration of that time. Next, we make a table showing the result in decreasing order of all 50 states plus the District of Columbia.

From the Table 4, 9 states have no results since they do not have a "Stay at Home" policy. Except for states where "Stay at Home" policy does not exist, the range for the result is from 1 to 84, meaning that for some states, the situation deterioration happened immediately after state reopening but for some other states, it took nearly three months to observe the change in the trend after reopen day. Then, we calculate the mean and the median value of the result. The mean value is 34 and the median value is 33, showing that generally, it took around a month for the whole United States to observe a pandemic situation exacerbation.

Table 4. Day from Reopening Data for 50 States and District of Columbia

States	day	States	day	States	day
Kansas	84	Nevada	37	Michigan	14
Hawaii	79	New Mexico	36	North Carolina	10
Missouri	66	Kentucky	34	Illinois	9
Montana	64	Texas	33	Oregon	9
Alaska	62	Wisconsin	33	Vermont	7
Alabama	60	Louisiana	29	New Jersey	6
Indiana	58	Ohio	28	Washington	2
Colorado	55	Rhode Island	27	Maine	1
Georgia	52	District of Columbia	25	Arkansas	NA
West Virginia	50	Pennsylvania	25	Iowa	NA
Tennessee	49	Minnesota	24	Nebraska	NA
Mississippi	47	California	21	North Dakota	NA
Idaho	45	New York	17	Oklahoma	NA
Maryland	45	Arizona	16	South Carolina	NA
Florida	44	Delaware	16	South Dakota	NA
New Hampshire	41	Massachusetts	16	Utah	NA
Virginia	39	Connecticut	14	Wyoming	NA

In all, this paper finds that the "Stay at Home" policy does have some good effects on limiting the increasing trend of daily confirmed cases in each state and the influence of the policy could

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last for several weeks after reopening. However, there are some states showing a worrying result that their COVID-19 situation worsens only a few days after reopening. From this observation, it is important to think the reopen policy prudently for states like Maine and Washington than other states since their circumstances aggravate rapidly after reopening.

5. CONCLUSION

As with other emerging phenomena, diseases, and so on, it is not easy to analyze and predict trends in COVID-19. The project begins by collating the overall data and looking primarily at the number of diagnoses and deaths in the United States. A large number of overall diagnoses gives us a better understanding of the severity of the COVID-19 situation. We review all the data from the beginning to the most recent and decided to analyze the trend of the number of daily new confirmed cases in the last week with smoother data.

Concerning the effectiveness of the "Stay at Home" policy on limiting the spread COVID-19, this project identifies when the outbreak intensified after reopening. Since the increase in diagnoses for most states does not begin to deteriorate until four weeks after the reopening, we can argue that this policy has had a positive effect. Nonetheless, for those states whose "Stay at Home" policy's influence lasts less than a week, it is crucial to think carefully about the reopening policy.

As for the trend of the latest week, more than half of all states are on the decreasing trend in the number of new diagnoses per day, which may be partly helped by the "Stay at Home" policy. Moreover, this evidence might illustrate that most states are under gradually better condition. In contrast, there are several states with an increasing trend and this might be a sign of danger and should be taken conscientiously. They can reconsider the reopening or take other actions.

Due to the various conditions in different states, it is difficult to analyze the effectiveness of the "Stay at Home" policy and conclude it in a general pattern. Therefore, to study further impact on every single state, more detailed data in the states should be included. For example, climate change would also be a factor that causes a possible transformation in the virus. The series of events that happened in this period, such as the several holidays and weekends, would have contributed to the possible increase in the confirmed cases.

More importantly, the availability of medical facilities and tools as well as the professional doctors and nurses would be a critical aspect that helps patients get faster remedy or, on the contrary, lead to possible fatality. In addition, statistics on deaths may be less accurate. Many other diseases might be the cause of death during this time, and thus the count of death cases are easy to be misidentified in wrong categories. Different data sets from other research teams would be needed.

A further study on finding factors that efficiently limit the increasing trend other than the "Stay at Home" policy in the United States can be done. Although from the result, "Stay at Home" policy did have some good effect for some states, it is not enough for the United States to thoroughly control the pandemic situation. Looking ahead, COVID-19 vaccine can be a promising option. However, since the vaccine is still some way from becoming available, it is critical to identify factors limiting the spread of COVID-19 before a vaccine is available.

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This paper focused on the effect of stay-at-home policy on preventing the spread of the COVID-19 virus in the United States from January 2020 till August 2020. Every author has the same contribution to the group paper. The ranking is in original submission order.

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