The Impact of Socioeconomic Factors on the Spread of COVID-19 in California

Pioneer Open Summer Study

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Abstract

The COVID-19 pandemic is a serious concern for individuals worldwide; however, it seems to spread more rapidly within lower income communities. The purpose of this research, conducted as part of the Pioneer Open Summer Study program, is to investigate the connection between socioeconomic factors (particularly urbanization) and the spread of COVID-19. Examining data regarding all counties in the state of California, counties with similar infection or death rates were first clustered. This study then analyzed the values of socioeconomic factors within groups clustered by infection rates using boxplots, with the goal of finding correlations. Finally, through literature review, the socioeconomic factors that correlated with a higher infection rate were further researched. Urbanization, which impacts density and unemployment rate, was found to play a major role in the spread of COVID-19. Testing, treatment, and vaccination will be critical in stopping COVID-19, in both high and low income areas. This study found correlations between urbanization and COVID-19 within the counties of California; However, further studies are necessary to prove causal relationships.

Introduction

The Study

California is one of the states with the worst COVID-19 situations in America, with over 13,000 deaths and 700,000 cases by the beginning of September (New York Times). In addition, the variation between its counties — in terms of urbanization, median income, etc. — makes California a prime candidate to study the impact of socioeconomic factors. The focus on urbanization as a major factor in COVID-19 infection and death rates was prompted by the inherent qualities found in certain urban neighborhoods: overcrowding and unemployment. The original hypothesis was that more urbanization and an older average age would both correlate with a higher infection.

Background Information on COVID-19

Firstly, the spread and intensity of the virus can be further exacerbated by factors such as pre-existing conditions, prolonged exposure to other individuals in close proximity, and lack of proper hygiene. Since COVID-19 attacks the respiratory system, pre-existing conditions such as high blood pressure, asthma, and type 1 diabetes might increase the risk of severe illness from COVID-19. Furthermore, since the virus spreads through respiratory droplets, physical distancing is needed in order to reduce the risk of transmission. Finally, individuals can come in contact with the virus by touching infected surfaces and then touching their face (mouth, nose, eyes) so it's important for people to wash their hands frequently and to maintain proper hygiene.

Background Information of California - Policies and Cases

The first case of COVID-19 in California was reported on January 26, 2020. Throughout March, Governor Newsom began initiating a series of closures on public events, gatherings, public school districts, bars and wineries, and beaches. Although Newsom announced the order for all California residents to stay at home, many ignored the severity of the virus, contributing to a spike in cases in April. Meanwhile, smaller businesses began suffering as the order resulted in permanent discontinuation of their establishments and thus many laid off workers. With the resulting economic downturn, the U.S. government began providing monetary support through stimulus packages to aid unemployed and low-income families. California also implemented additional funds for workers unemployed due to COVID-19. Though Newsom began easing criteria of reopening requirements to allow some counties to reopen faster, the sudden reopenings likely contributed to the rapid increase of cases in subsequent months, forcing most businesses to close once again. As of late August, California's cases have begun rapidly decreasing, and this sharp decline might prompt more reopenings and hopefully a recovering economy (see Appendix A, Johns Hopkins Coronavirus Resource Center).

Today, the current testing positivity rate in California is 6.12%, which means about 6 people out of every 100 tested are positive. (Please note that this data may be skewed as only about 30% of the state's total population has been tested as of the end of August). According to Dr. Michael Ryan, Executive director of the WHO Health Emergencies Program, a percentage below 10% positivity rate indicates effective testing and hope for containing the virus and thus a faster reopening. Behind these statistics, however, there are many more social factors to be considered, possibly affecting the spread of COVID-19.

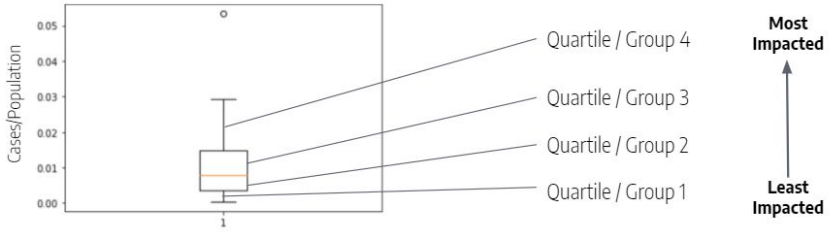
Methods

Data Collection

In order to create the following observations, data on multiple demographic and socioeconomic factors was collected for the counties in the state of California, organized by their state or level of urbanization. Out of the many factors that could have impacted the spread of the pandemic in California, the factors that were initially considered in this open study were the population, land area in square miles, population density, and reported SARS-CoV2 cases and deaths for each county. To compare the spread of COVID-19 in each of the 58 different counties, the infection (cases per population), death (deaths per population), and recovery (deaths per cases) rates were generated from this data, as taken from Johns Hopkins Coronavirus Research Center. Additional data pertaining to social factors and demographics were taken into consideration, such as the amount of hospitals, the unemployment rate, percent of people below the poverty line, and the median household incomes in each county. This was to better understand and to compare each county's response to COVID-19. All of the data was compiled into one spreadsheet to easily compare and export it.

Research Approach

For efficiency, Python was used to compare the compiled data. To quantify the impact of COVID-19 on different counties, two measures were used: primarily the infection rate (the ratio of cases per population) and secondly the death rate (the ratio of deaths to cases).



First, the infection rates of all the counties were graphed in the box plot shown above, with added markings indicating the quartiles. The quartiles consist of approximately the same number of counties, with similar COVID-19 infection rates in each quartile. For convenience, quartiles 1-4 were renamed as groups 1-4 respectively, with increasingly worse COVID-19 situations.

Then, for each of the groups, median values of different measures including average age, unemployment rate, and more, were listed in a table. Box plots of different factors were also created for analysis. The values in the table and the boxplot were used to identify correlations between economic/demographic variables and the infection rate or death rate of COVID-19.

It is important to note that in this data analysis approach, the correlations found do not necessarily imply causation, or prove that any one factor definitively does or does not influence the spread of COVID-19. For correlations that were found, they were further researched through literature review and secondary statistics in the "Economic Implications" section of the report.

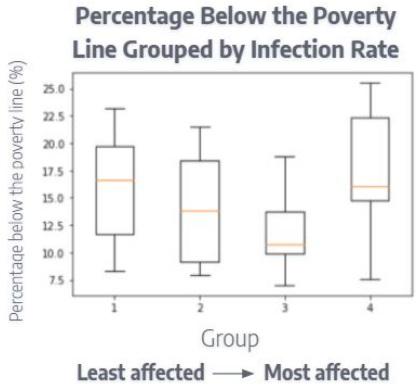
By only analyzing counties within California, the impact of varying statewide policies and perspectives on the data was minimized. However, one limitation of this research is that certain variables like anti-mask sentiment and protests were not considered. In addition, please note that counties were viewed as a whole, and thus certain high or low income communities within them were not isolated and analyzed alone.

Data Research Conclusions

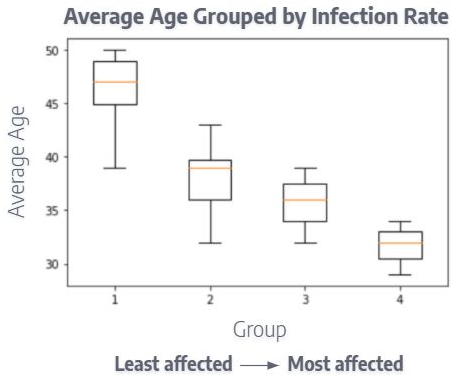
The table below was produced during the research, with quartiles grouped by the infection rate. Using the median values of different factors in the table and boxplots, correlations were determined.

	Cases/Pop. (%)	Death/Cases (%)	Median Age	Density (pop./sq mi)	Unemployment Rate (%)	Hospital Density (hos./sq mi)	Median Income	% Below Poverty Line*
group1	0.002322	0.003106	47.0	12.0	12.50	0.000780	47192.0	16.60
group2	0.005796	0.009355	39.0	165.0	12.20	0.002489	64861.0	13.80
group3	0.009700	0.010427	36.0	504.5	13.55	0.005568	76887.0	10.75
group4	0.018241	0.014830	32.0	142.0	15.00	0.001847	53253.0	16.10

For certain factors (specifically hospital density, median income, and percentage below the poverty line) there were not any significant correlations, as there was no clear trend in the values in the table and in the box plot. For example, the boxplot below displays the percentage below the poverty line, and there is significant overlap in the boxplots without a clear trend.

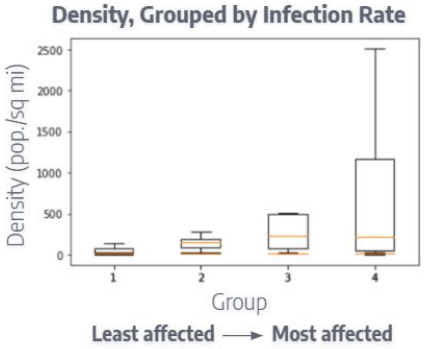


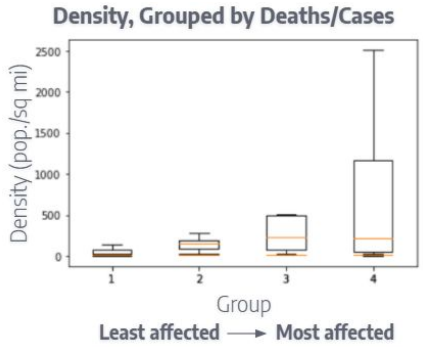
However, with median age and population density, the data did reveal correlations. Contrary to the expected outcome, the table showed that the average age in more infected counties had younger individuals, rather than older. The boxplot below also revealed the same. This indicates that age may not be as impactful on the infection rate in comparison with other factors.



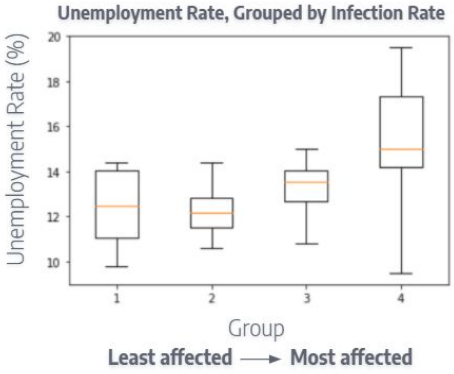
As for density, the data shows that it is positively correlated with both the infection rate and death/cases ratio (as density increases, infection rates and death/cases rates increase). Although there was overlap in the density of the counties between the groups least to most affected by COVID-19 as seen in the boxplots below, the range of population density

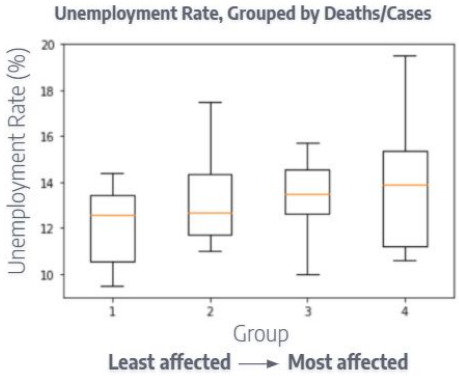
significantly increased as groups became more infected; the more highly dense counties were in groups 3 and 4, with worse COVID-19 situations. This correlation is reasonable since COVID-19 spreads in close proximity.





The unemployment rate was a unique situation because there was a possible correlation. In both boxplots (grouped by infection and death per cases) shown below, higher unemployment rates correlated with a worse COVID-19. However, there was significant overlap in the box plots, preventing it from being very statistically significant.





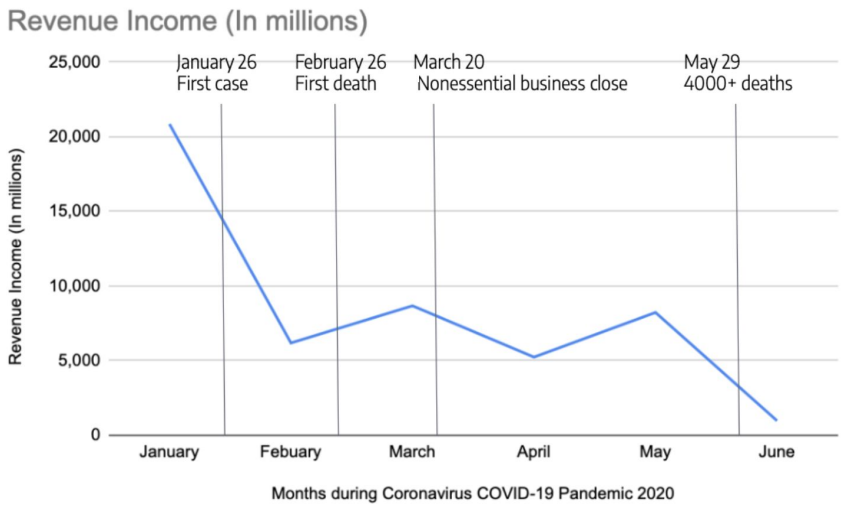
Since there were significant or possible correlations with density and certain socioeconomic factors, urbanization was also considered due to its impact on those factors. For each level of urbanization, the percentage of its counties in each group was recorded (for example, the percentage of rural counties in group 1). The data was recorded in the table below. For each level of urbanization, the group with the highest percentage of its counties was bolded. Through this research, it was found that increased urbanization correlated with higher infection rates for counties in California.

	Low Infection Rate →			High Infection Rate
	Group 1	Group 2	Group 3	Group 4
Rural	**54%**	21%	12%	13%
Suburban	0%	26%	**40%**	34%
Urban	4%	30%	24%	**42%**

Socioeconomic Implications

State of California's Economy

Due to California legislation mandates on the closing of businesses and community spaces, and the requirement to wear masks in public, the state economy has been drastically affected as a result of combating the state outbreak and, in turn, has seen higher rates of unemployment across the entire state. California's revenue income consistently decreased across all counties (see graph below). This decline is largely credited to the statewide lockdown starting from March 2020, requiring California residents to stay in their homes and refrain from going out unless they are purchasing food, healthcare items, or working at a job considered to be essential. The lockdown ordered nonessential businesses to be closed during this time, causing many of them to go in the red, having a detrimental effect on the state's economy as a whole. However, revenue income varies greatly between each county in California resulting in disparities in the virus' impact across regions (see Appendix B). In the midst of this statewide economic decline, high-risk and low-income communities have been most impacted as they have been historically disadvantaged with their low access to resources and higher exposure to unhealthy living conditions.

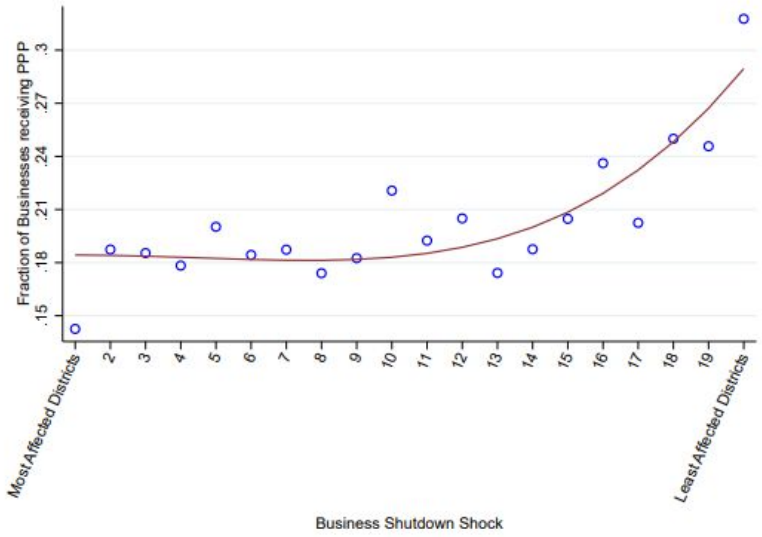


In the graph above the overall economic status of California ever since the first Coronavirus case on January 26, 2020 was depicted to show how the revenue income dropped from 20,000 million to less than 5,000 million in the span of six months. A socioeconomic implication happened on March 20 - nonessential business close which is a factor in decline of revenue income.

Distribution of PPP and Stimulus Packages

Recognizing economic issues on a national level, the federal government distributed stimulus packages in an attempt to help support individuals and Payment Protection Program (PPP) loans to help small businesses. However, these support systems failed to help communities at highest risk. For example, on May 31st, 2020, Internal Revenue Service Commissioner Charles Rettig answered Senate inquiries about the effectiveness of the stimulus payment system enacted in the Coronavirus Aid Relief and Economic Security (CARES) Act. Here he relayed that the IRS reported that 365,000 low income Americans did not receive the stimulus checks

they were due for dependent children. A graph from the working paper "Did the Paycheck Protection Program Hit the Target?" from the National Bureau of Economic Research shows how PPP loans were not being distributed to the higher risk areas that have higher rates of business shutdown.



The graph shows that the fraction of businesses receiving PPP was lower in the districts most affected by the business shutdown shock and higher in districts least affected by the shock. Granja, João. "Did the Paycheck Protection Program Hit the Target?" *National Bureau of Economic Research*, 2020.

Density and Urbanized Neighborhoods

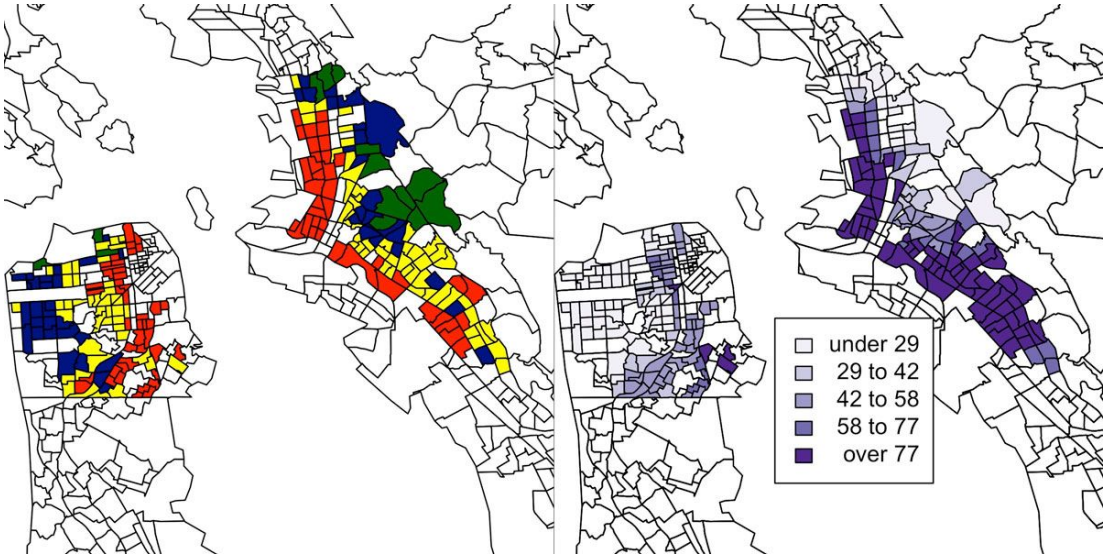
Additionally, within more urbanized counties, there are certain pockets with higher density and poverty rates. These have been more impacted by COVID-19 due to a variety of factors. For example, in the urban county of Los Angeles, the LA times found that"those who live in lower-income communities … are three times more likely to die of COVID-19 than those in wealthier communities" Furthermore, "neighborhoods where 30% to 100% of the residents live in poverty have seen about 16.5 deaths per 100,000 people, compared with 5.3 deaths per 100,000 in communities, where less than 10% of residents live in poverty" (Wigglesworth). There are a multitude of factors that contribute to this imbalance. According to Jim Mangia, chief executive of St. John's Well Child and Family Center, which operates 18 clinics in predominantly low-income communities of color, "health disparities ... the lack of access to social distancing and the fact that many of our residents have to continue to work in high-risk situations" (Barboza), are among the reasons why poverty-stricken neighborhoods exhibit higher death rates from COVID-19.

Furthermore, lower income neighborhoods tend to be more densely populated. In LA County alone, neighborhoods like Pico Union and Westlake are so dense, that in more than a third of housing units — there is more than one person living in a room, excluding bathrooms. The lack of space leads to difficulty in maintaining social distancing guidelines, 6 feet apart, in

the case that one family member becomes ill. Additionally, since bathrooms and living spaces are often shared in cramped quarters, these conditions accelerate the spread of the virus at an alarming rate.

Pre-existing Health Conditions In Low-Income Areas

Individuals in low-income communities have been found to be more likely to have underlying medical conditions such as asthma and diabetes, increasing rates of severe illness and death from COVID-19. According to the National Institute of Health, "Diabetes may be up to two times more prevalent in low income populations compared to the wealthy population". The disparities in low income communities have contributed to minorities having the highest COVID-19 case rates in the U.S. as reported by the Centers for Disease Control and Prevention (CDC). Many urbanized communities have historically experienced redlining on the basis of social class and race; although racial segregation practices have been outlawed in the U.S., the effect of historical underservice in these communities are still present in its symptoms of overcrowding, low community funding, and poorer living conditions. A study led by UC Berkeley student Anthoney Nardone found that historically redlined communities in California have higher rates of asthma, likely due to increased air pollution and psychological stresses. The graphic below reveals the correlation between Home Owners' Loan Corporation ratings, historical ratings based on the density of minorities and low-income people, of communities in the urbanized cities of San Francisco and Oakland and the rates of asthma in these communities.



This map shows the Home Owners' Loan Corporation ratings of communities in the urbanized cities of San Francisco and Oakland historically based on the density of minorities and low-income people on the left correlating to the rate of asthma related emergency room visits per 10,000 residents on the right side. Manke, Kara. "Historically Redlined Communities Face Higher Asthma Rates." *Berkeley News*, 22 May 2019.

Impact of Unemployment

Another factor that further exacerbates the spread of the virus is the inability for most low-income workers to work remotely. Higher-wage earners tend to have more opportunities to work from home remotely and order food and other essentials online and have them delivered, thus lowering their exposure to conditions where they could potentially catch the virus. Contrastingly, most lower-income individuals, when faced with company lay-offs, are forced to take up in-person jobs without proper protection in order to pay the bills. Lopez, the daughter of a minimum wage worker said,"I ask myself a lot why there is more sickness where [they] are," Lopez said. "Sometimes I tell my brother: This virus was created to eliminate us" (Barboza). Furthermore, there is no guaranteed paid sick leave in the United States. According to the Economic policy Institute, "though 90% of America's top quartile of wage-earners have access to paid sick leave, only 47% of the bottom quarter" do. Combined with inadequate stimulus packages, these conditions force individuals who are closer to the poverty line to work longer hours in possibly unsafe conditions, leading to prolonged exposure to the virus.

Barriers to Testing and Treatment

Finally, this economic disparity also impacts testing and treatment, with those in richer neighborhoods getting access far earlier and more efficiently. According to Dr. Coco Auerswald, an associate professor at the UC Berkeley School of Public Health, "L.A. County's early numbers reflected a nationwide trend of wealthier people being first in line for testing...The rich and famous were getting tested first because they had the means to get tested in an environment where testing was scarce," she said (Barboza). Due to testing delays, low-income individuals are diagnosed later and could have spread the virus unknowingly while being asymptomatic.

Another factor which further compounds the impact of the virus is the scarcity of healthcare access. According to Time Magazine, "about 28.6 million people across the U.S. are not covered by any form of insurance." Private insurance companies, such as Medicare and Medicaid are now offering to test symptomatic patients free of charge, but 28.6 million people across the U.S. are still not covered by any form of insurance. If they come down with symptoms of the virus, such as fever, dry cough or shortness of breath, low-income individuals are less likely to have access to a general practitioner who can offer a formal diagnosis. Without insurance, many low income families lack the money needed to pay the medical expenses for treatment plans (medication, etc.). In conclusion, the higher number of essential workers, crowded housing, higher rates of preexisting conditions, along with barriers to testing/treatment, cause lower-income communities to be more heavily impacted by COVID-19.

Vaccines

In order to treat patients as soon as possible and prevent the pandemic from infecting more people, a vaccine must be developed. Normally, vaccines take up to 10 to 15 years to be put into use. They go through a multi-step process, with multiple trials and required approvals. The general stages include the exploratory, pre-clinical, clinical development, regulatory review and approval, manufacturing, and quality control stages. The most important state is clinical development, a three-phase process that includes the clinical trials and sometimes phase IV ongoing studies after the approval and licensing of a vaccine.

Amidst the COVID-19 pandemic, vaccines are being created in a quicker, expedited manner. The process for developing these vaccines include pre-clinical testing, clinical development, and approval. Under clinical development, there are the phase I safety trials, phase II expanded trials, and the phase III efficacy trials and phases could also be combined for faster testing. There are over 200 vaccines that have been tested worldwide within the past 6 months. However, approximately 24 are in phase I, 14 are in phase II, nine are in phase III, three are under limited approval, and no vaccines have been approved for full use yet.

One promising candidate for the COVID-19 vaccine is mRNA-1273, developed by Moderna and the NIH (National Institute of Health). It is currently in phase III clinical trials and on the path to approval. It is a lipid nanoparticle-encapsulated, nucleoside-modified mRNA-based vaccine that stabilizes the COVID-19 spike glycoprotein, required for viral cell entry, in its prefusion conformation. Since the vaccine attacks the virus, it can provide protection and immunity for infected and uninfected individuals. According to The New England Journal of Medicine, the vaccine was administered to healthy adults from ages 18 to 55 through dose-escalation clinical trials (Jackson et. al.). They were given the two doses of the vaccine, 28 days apart. Patients were asked to record them. After the trials, the results were favorable. No serious adverse events were noted, and no halting procedures were executed. Solicited systemic adverse events occurred after each of the vaccinations, but the events were less frequent, but moderate after the first vaccination. After the second vaccination, these events were seen more often and more severe. No patients had fevers after the first vaccination. However, after the second, a few reported fevers. The main takeaway was that the trials did not reveal any consistent and concerning issues with the vaccine. As of August, mRNA-1273 is the furthest along in the vaccine development process out of all the others, and it is expected to be available in early November.

Another potential vaccine is the antiviral medication, Remdesivir. According to The New England Journal of Medicine, a total of 1063 patients underwent randomization in the clinical trials for Remdesivir (Beigel et. al.). 114 of the 541 patients in the vaccine group who underwent randomization reported having serious adverse events. 49 patients had Remdesivir treatment discontinued before day 10 because of a moderate or serious adverse event. As of April 28, 2020, a total of 391 patients in the Remdesivir group had COVID-19, and the 340 patients in the placebo group that did not have COVID-19 completed the trial through day 29, and had either recovered or died. Patients in the Remdesivir group reported a faster recovery than those in the placebo group. During trials, Many sites did not have enough trial-related supplies and personal protective equipment. However, research teams are continuing to work on this potential vaccine and more testing is needed.

To be most effective, vaccines must be mass produced and distributed to as many people as possible. This includes distribution to low and high-income communities in order to

effectively stop the spread of COVID-19. Many medical insurance plans for low income families do not cover the full cost of vaccines, potentially endangering these families. Without containing the virus, it will lead to a greater number of preventable fatalities. In order to contain that spread and promote mass immunity, the vaccine needs to be mass produced and distributed to people of all economic backgrounds.

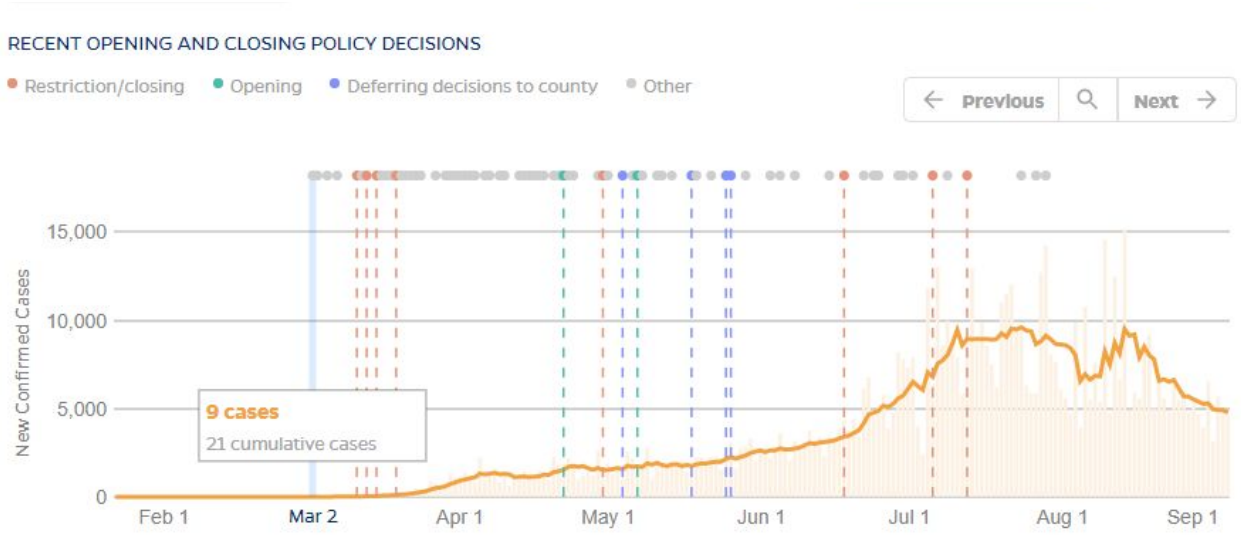
Conclusion

There are numerous socioeconomic disparities all over the state of California. This study drew relationships between the factors and the spread of COVID-19 within counties in California. It is important to note that COVID-19 is an evolving and rapidly changing situation, and the compiled data used to determine the infection, death, and recovery rates reflects the situation up until the beginning of August. The correlations found do not necessarily imply causation, or prove that any one factor definitively does or does not influence the spread of COVID-19. Further experiments and studies will be needed to prove causation.

This study found that urbanization, population density, and unemployment were found to significantly impact the spread of COVID-19, more so than age. As a result, lower-income communities seem to be impacted worse, with higher infection and death rates. In addition, historic redlining, barriers to testing and treatment, higher pre-existing condition rates, and more result in the disproportionate impact of COVID-19 on low-income communities and the highest rates of COVID-19 cases for minorities.

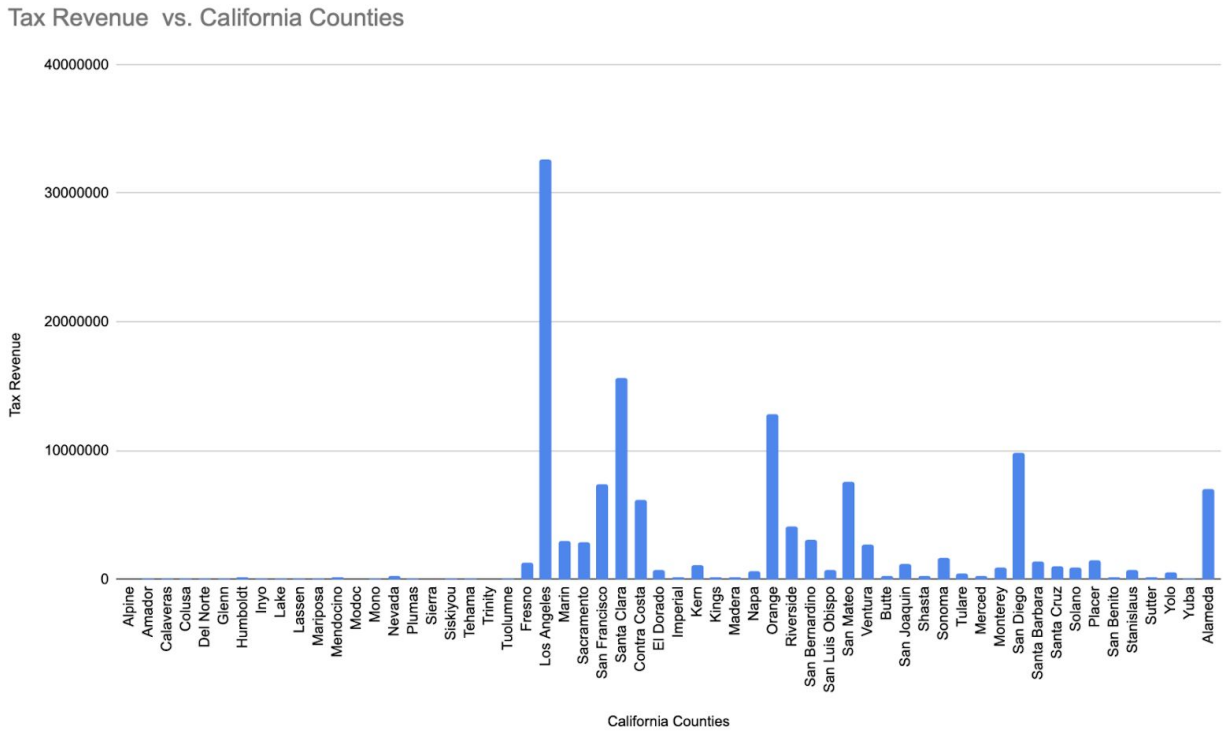
Healthcare is a basic necessity for day to day lives and vaccines along with other medications should be made much more accessible for people. With mass productions of vaccines, health needs for people in low to high-income communities need to be met. More equitable policies and healthcare among all communities will be critical in slowing the spread of COVID-19, and are also necessary for preventing future situations.

Appendix A



This graphic shows cumulative COVID-19 cases in California and significant policies, including closings and openings of public areas. (JHU Coronavirus Resource Center)
Please note the two-week incubation period between initial infection and reported case.

Appendix B



This graph was produced using data of tax revenues for different California counties as listed by the IRS for 2017. As seen above, the economic situations of different counties vary significantly..

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