Answering Unique Questions Pertaining to the COVID-19 Pandemic

Major Qualifying Project

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Executive Summary

The COVID-19 pandemic has forced most Americans to adapt the way they go about their daily lives. This project seeks to answer unique questions about the COVID-19 pandemic from a data-centric perspective. For this research project, we took on the challenge of answering various unique questions about the COVID-19 disease, using datasets provided by the Center for Disease Control and Prevention (CDC). For uniqueness, we focused on certain states, regions, and demographics to point to specific areas where scientists, doctors, and researchers can direct their attention towards mitigating the adverse effects of COVID-19.

Project Goals

The goal of the project was to conduct research and analysis on unexplored topics on the COVID-19 disease. The team aimed to analyze current findings and either expand on those findings or answer a unique question that has not been answered previously. The project also aimed to explore datasets from the CDC to provide insights on the impact COVID-19 has had on society.

Methods

Our team took various steps to develop visualizations to answer questions. We started by exploring datasets regarding COVID-19 on the CDC website and created an Excel Spreadsheet to list all current datasets publicly available. This allowed for efficient sorting and categorization of datasets based on questions we were interested in answering. To clean and refactor the datasets, we primarily used the PANDAS library in Python. It helped in storing the data into

PANDAS dataframes, which have various methods for manipulating data. We focused on incomplete and unnecessary data when we cleaned to ensure accurate results. Initially, our visualizations were created using the Matplotlib library in Python, but we found Tableau to be a more powerful tool, which provided aesthetically pleasing visualizations, and used it as our primary platform for creating visualizations.

Questions and Findings

1. Is there a discrepancy in COVID-19 deaths per state when comparing urban and rural regions?
2. Is there a connection between COVID-19 Deaths and county income?
    a. California
    b. Texas
    c. Kentucky
3. Is there a relationship between vaccinations and type of region (rural or urban)?
    a. California county vaccinations vs. county income
4. Do payments to rural and non-rural areas have an impact on the number of deaths in those regions?
5. Do states where there is a higher percentage of people who have difficulty paying for household expenses have a higher number of hospital deaths?
6. Is there a connection between household telehealth and place of death?
7. How have the age groups affected by COVID-19 changed over the course of the pandemic?

8. What is the connection between state populations, population densities, and COVID-19 deaths?
9. Does the percent of adults fully vaccinated in a state affect the excess deaths from COVID-19?
10. How has food scarcity changed in the United States throughout the course of the pandemic?
11. How does food scarcity in America relate to COVID-19 deaths in each state?
12. Which states have the highest percentage of onsite workers?
13. How has the number of people working onsite changed throughout the pandemic?
14. How has each state changed in terms of percentage of people working onsite throughout the pandemic?
15. How much of the older population receives an additional booster vaccine after the first?
16. On average, what date did each state close their schools?
17. What is the relation between deaths involving COVID-19 and average income in each county from 2019, 2020, and 2021?
18. What is the effect on state mandated restaurant action on food scarcity during the COVID-19 pandemic?
19. How does unemployment during the COVID-19 pandemic relate to food scarcity in each state?
20. How does state income impact food scarcity during COVID-19?
21. How does the Social Vulnerability Index per county relate to the income per county during COVID-19?

22. How has the average length of stays changed throughout the COVID-19 pandemic between age groups?
23. How has the average length of stays changed throughout the COVID-19 pandemic changed depending on whether a person was discharged alive or dead?
24. How did unemployment during the COVID-19 pandemic affect mental health help?

Recommendations and Conclusions

Through the research our team conducted on the COVID-19 disease, we have gained a better understanding of the social, economic, and wellbeing of the United States population. Some of our research gave more insight into COVID-19's impact on rural and urban regions and the workforce in the US. We hope that our work will help researchers choose unique paths of research to learn more about COVID-19. As COVID-19 is still a relatively new disease, a pressing area of research is the long-term effects of the disease. It is a complex disease that will require continuous research to fully understand its effects and develop effective interventions. Other areas of research consist of employment, tourism, education, and mental health.

Chapter 1: Introduction

The Coronavirus disease (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus. COVID-19 is a relatively new virus, with the first United States cases occurring in early 2020 (Holshue et al., 2020). As such, there is much to be learned about its connections and impacts on various aspects of society. Since its discovery, COVID-19 has caused over a million deaths in the United States alone.

COVID-19 has many symptoms including fever, cough, shortness of breath, fatigue, muscle aches, headache, loss of taste or smell, sore throat, congestion, nausea or vomiting, and diarrhea (Centers for Disease Control and Prevention, 2021). It is especially deadly for people in older age groups and people that have preexisting conditions such as lung problems, hard disease, diabetes or obesity, brain and nervous system conditions, cancer, kidney or liver disease.

There are a number of things that people can do to prevent the spread of COVID-19. According to the World Health Organization, the best ways to prevent the spread of the virus are getting vaccinated, keeping at least one meter away from others, wearing a mask, washing your hands thoroughly, and staying away from others when you are sick (World Health Organization, 2021). However, this is not an exhaustive list and there are many more safety measures people can take to protect themselves and others.

We started by exploring connections that had been made by previous researchers regarding COVID-19. This assisted our team in gaining a basic understanding of COVID-19, and learning about the current work being done to understand the virus. The team then compiled the information found into a document and used the theories in those papers as starting points for our

own questions. Next, we transcribed the datasets pertaining to COVID-19 from the CDC website into a spreadsheet to make it simpler to sort through them. At this point, we were able to find datasets that had clean data and cross reference them with other data sets containing similar attributes and themes. This allowed us to take a closer look at the similarities in the data and formulate questions that would grant useful insights about COVID-19.

While there is an extensive body of literature on COVID-19 research, there are some areas of research that we feel should receive more attention. In particular, our project aims to answer questions regarding demographics, relation to other diseases, and mental health. These categories encompass vaccination, telehealth, income, unemployment, school closures, food scarcity, onsite work, etc.

Our goal is to answer 24 unique questions related to COVID-19 by analyzing datasets provided by the Centers for Disease Control and Prevention (CDC) and other organizations. We create data visualizations for these questions in order to give the reader a clear understanding of the story that the data tells. We then make recommendations to researchers for future areas of study.

Our investigation reveals major changes that have occurred over the course of the pandemic, different types of people that are more at risk for COVID-19, effectiveness of vaccinations and other preventative measures, the approaches that each state has taken to combat the virus, and more. We hope that healthcare professionals and future researchers will be able to use the conclusions from our project to help mitigate the adverse effects that COVID-19 has had on our nation and the world. While we may never live life the same way we did before the COVID-19 pandemic, research and science has provided us a path to securing health and safety in a way that resembles our way of life before the pandemic.

Chapter 2: Background

The team explored research papers and conducted an interview with a state health department employee to gain a better understanding of current findings regarding COVID-19. We utilized the research papers as an aid for creating our own unique questions. Our team also analyzed the CDC's COVID-19 datasets before answering questions and found that a significant amount of data from the beginning of the pandemic may be unreliable as many COVID-19 deaths went unreported. Based on this research, we decided to focus primarily on questions comparing different states.

2.1 Interview

Our team reached out to a former state health department employee, Dr. Eleanor Adams, to learn more about the CDC and how they handle their datasets. During her employment, Dr. Adams worked on collecting data for the CDC. She informed us that the death statistics for COVID-19 are skewed because death certificates did not accurately cite the virus as the cause. She also noted that there were many unreported COVID-19 cases discovered by at home tests, meaning the data regarding the number of cases may be misrepresented. Additionally, Dr. Adams suggested that we investigate state datasets for supporting data. Finally, she gave us advice on working with incomplete, inaccurate, or hard to work with datasets.

2.2 Research Papers

Before beginning our own work, we examined research papers regarding current topics relating to COVID-19. Our team analyzed 18 papers and found interest in 10. We grouped them by specific categories: demographic, relation to other diseases, and mental health. We then moved on to doing our own unique research in related categories.

2.2.1 Demographic

In researching a disease, demographics are one of the most important topics to explore. The impact of a disease on an individual depends on many factors, which could be related to one or more demographics. Researchers found that people of minority ethnic descent have lower lung function on average compared with those of Caucasian descent (Abuelgasim et al., 2020). Minority communities are also more likely to suffer from higher rates of cardiovascular diseases and diabetes.

2.2.2 Relation to other diseases

Oftentimes, mixing COVID-19 with other diseases causes worse health outcomes for patients. Wadman found that people with obesity are much more likely to be hospitalized by COVID-19, "people with obesity who contracted SARS-CoV-2 were 113% more likely than people of healthy weight to land in the hospital, 74% more likely to be admitted to an ICU, and 48% more likely to die. (Wadman, 2020)" Immunocompromised people have an increased mortality rate from COVID-19 (Baek et al., 2021). In addition, COVID-19 patients have a higher chance of having a stroke than others (García-Lamberechts et al., 2021).

2.2.3 Mental Health

COVID-19 has had a significant impact on the mental health of individuals. Researchers found an escalation in the use of alcohol and increased mental health concerns (Rodriguez et al., 2020). Studies concerning stress resilience during the pandemic found that children and young people had increased distress because of their need for stronger social relationships (Manchia et al., 2022). Lastly, researchers looked at the purchasing pattern of individuals during the pandemic and concluded that purchasing behaviors were more unusual when compared to non-pandemic behaviors (Laato et al., 2020).

Chapter 3: Overview of Datasets

Our team primarily used the CDC's datasets for our research. To easily organize our data, the team created a spreadsheet of the CDC datasets. Consolidating the datasets into one document allowed our team to efficiently look for datasets relating to questions we had in mind.

Before beginning to answer questions, we looked through the datasets to see what information we had available to us. We discovered that some of the datasets were poorly designed and had difficult to use or completely unusable data. Because of this, and the interview conducted with Dr. Adams, our team decided to use state datasets for additional information that could not be gained from the CDC datasets.

Our team was able to find the Household Pulse Survey, a survey sent out by the U.S. Census Bureau to measure household experiences during the pandemic and the stages after. The data was arranged by weeks and had unique information that could not be found on the CDC's website. The datasets our team used from the survey were food scarcity, telehealth, difficulty paying household expenses, and changes in work location. The data was organized by the week of the survey and was easy to manipulate and clean. The Household Pulse Survey organizes "weeks" by blocks of five to twelve days that vary between datasets.

To allow for future replication of our work, we have compiled the specific datasets we used from the CDC website, the Household Pulse Survey, and from other state websites. Appendix A contains the table with the information about the datasets we used, including the date it was accessed and where it was found. We will go over how the datasets were manipulated to answer the questions so our work can be replicated for future research.

Dataset 1, Provisional COVID-19 Death Counts in the United States by County, was used to answer question 1. To clean the data, we dropped rows with no COVID-19 deaths. Then we dropped the county name and FIPS county code columns as those were not needed. Next, we grouped by state and urban rural code and summed up the deaths involving COVID-19. Finally, we separated the combined data into two different ones based on the urban rural code (large central metro and noncore) and normalized it. The final data was brought into Tableau to create the visualization.

Dataset 1, 2, and 3 (Provisional COVID-19 Death Counts in the United States by County, COVID-19 Vaccinations in the United States County, Personal Income by County, Metro, and Other Areas) were used to answer question 2. First, we renamed the columns in Dataset 1 to match Dataset 2: FIPS County Code to FIPS and County Name to County. We then dropped the rows with no COVID-19 deaths and unneeded columns (Footnote and Deaths from All Causes). We grouped Dataset 1 by State, County, FIPS, and Urban Rural Code and summed the deaths involving COVID-19. Dataset 2 was then read in, and we dropped the rows with no vaccinations and grouped by County, State, FIPS and summed the total vaccinations. Datasets 1 and 2 were merged, and then merged with Dataset 3 on county name. Finally, the resulting dataset was imported into Tableau and filtered to produce the graphs for California, Texas, and Kentucky. It was also used to answer question 4, California county vaccinations vs. county income.

Datasets 1 and 2 were used to answer question 3. Dataset 2 was grouped on state and the vaccines administered were summed. In Tableau, we were able to take the noncore and large central metro deaths from Dataset 1 and plot them against the vaccines administered from Dataset 2.

Datasets 1 and 4 were used to answer question 4. Instead of separating the data from Dataset 1 by urban rural code, the data was put into one table grouped by state and urban rural code, and the COVID-19 deaths were summed and normalized. Dataset 4 was first cleaned by removing the $, spaces, and punctuation from the values. The data was then grouped by state and the payments were summed up. Both datasets were imported into Tableau, and we were then able to make the graphs we needed to answer the question.

Datasets 5 and 6 were used to answer question 5. Dataset 5 was downloaded from the Household Pulse Survey, with all the weeks with available data. The data was cleaned by deleting the first two characters of the Week column. Unnecessary columns were dropped in Dataset 6, leaving the State, Place of Death, and Age Group. The data was grouped on the remaining columns and summed by all deaths involving COVID-19, and finally normalized. Dataset 7 was used in combination with 5 and 6 to answer question 6. The data was cleaned the same as Dataset 5, as they were both from the Household Pulse Survey.

Dataset 8 was used to answer question 7. First, we extracted the data from the "By Year" group with "United States" as its State value. Then we eliminated all columns that did not include age, COVID-19 deaths, and year. There were many extraneous age ranges that overlapped, so we only used the age ranges that are shown in Figure 4.13.

Dataset 9 was used to answer question 8. We used only the information about each state's population and population density from the dataset. We then merged this data with data from Dataset 8 containing the number of COVID-19 deaths in each state to create Figures 4.14 and 4.15.

Datasets 10 and 2 were used to answer question 9. From Dataset 10, we took the column data for State and Excess Estimate, and from Dataset 2, we took the column data for recip_state

and series_complete_yes. We then merged the two resulting datasets into a new dataset with one excess estimate value and one percentage fully vaccinated value for each state.

Dataset 11 was used to answer questions 10, 11 and 20. For question 10, we extracted the food scarcity percent for each state during the first week of data and the most recent week of data at the time the report was written. We compared the data from these two ranges in figure 4.17. To answer question 11, we took the quotient after dividing each state's population by their number of COVID-19 deaths. We took this ratio for each state and compared it with the food scarcity percentage in each state to determine if there is a correlation between food scarcity and COVID-19 deaths in a state. For question 20, we combined Dataset 11 with Dataset 3 to see how state income impacted food scarcity.

Dataset 12 was used to answer questions 12, 13, and 14. Like how we worked with Dataset 11, we extracted the percentage of onsite workers in each state from both the first and last weeks recorded in the dataset. We then created a new variable which is the difference between the end value and the beginning value to find a change over time. All three values are represented by graphs in Figure 4.19.

Dataset 14 was used to answer question 15. This dataset consists of COVID-19 vaccination demographics within the United States. We targeted the older demographic by using age and filtering out the older age group. Then we computed the percentage of those who received the first booster, but not a second.

Dataset 13 was used to answer question 16. This dataset listed school closures within the United States. We extracted the dates which each school closed and their states and computed the average date for each state. The counts of each date were then taken and a histogram was created, as shown in Figure 4.21.

Datasets 2 and 3 were combined to see if there is a relation between deaths involving COVID-19 and average income per county, answering question 17.

Dataset 15 was used to answer question 18. This dataset consisted of the mandated action on restaurants from the United States. This question consisted of three main restaurant responses to COVID-19, which was available in dataset 15. Those values were extracted for each state.

Dataset 16 was used to answer question 21. The dataset compared the COVID-19 deaths by a county's Social Vulnerability Index for each county. This question involves using the Social Vulnerability Index to compare incomes per county.

Dataset 17 was used to answer questions 22 and 23. This dataset had hospital data related to COVID-19. Questions 22 and 23 both answered the question of average length of hospital stays, which was available in the dataset.

Dataset 18 was used to answer question 24. This dataset consisted of mental health care in response to COVID-19. This question consisted of comparing three mental health indicators to unemployment rate, which was available in this dataset.

Datasets 19 and 20 were unemployment rates for the years 2020 and 2021 respectively. They were used to answer questions 19 and 24. These two questions used unemployment rate to compare to another underlying potential cause for COVID-19, to see if there are any patterns or trends.

The table below shows the datasets used to answer each question. Appendix A contains more information about the datasets.

Question	Datasets Used
Is there a discrepancy in COVID-19 deaths per state when comparing urban and rural regions?	Dataset 1

Is there a connection between COVID-19 Deaths and county income?	Dataset 1, 2, and 3
Is there a relationship between vaccinations and type of region (rural or urban)?	Dataset 1 and 2
Do payments to rural and non-rural areas have an impact on the number of deaths in those regions?	Dataset 1 and 4
Do states where there is a higher percentage of people who have difficulty paying for household expenses have a higher number of hospital deaths?	Dataset 5 and 6
Is there a connection between household telehealth and place of death?	Dataset 5, 6, and 7
How have the age groups affected by COVID-19 changed over the course of the pandemic?	Dataset 8
What is the connection between state populations, population densities, and COVID-19 deaths?	Dataset 9
Does the percent of adults fully vaccinated in a state affect the excess deaths from COVID-19?	Dataset 10 and 2
How has food scarcity changed in the United States throughout the course of the pandemic?	Dataset 11
How does food scarcity in America relate to COVID-19 deaths in each state?	Dataset 11
Which states have the highest percentage of onsite workers?	Dataset 12
How has the number of people working onsite changed throughout the pandemic?	Dataset 12
How has each state changed in terms of percentage of people working onsite throughout the pandemic?	Dataset 12
How much of the older population receives an additional booster vaccine after the first?	Dataset 14
On average, what date did each state close their schools?	Dataset 13
What is the relation between deaths involving COVID-19 and average income in each county from 2019, 2020, and 2021?	Dataset 2 and 3
What is the effect on state mandated restaurant action on food scarcity during the COVID-19 pandemic?	Dataset 11 and 15

How does unemployment during the COVID-19 pandemic relate to food scarcity in each state?	Dataset 11, 19, and 20
How does state income impact food scarcity during COVID-19?	Dataset 3 and 11
How does the Social Vulnerability Index per county relate to the income per county during COVID-19?	Dataset 3 and 16
How has the average length of hospital stays changed throughout the COVID-19 pandemic between age groups?	Dataset 17
How has the average length of hospital stays changed throughout the COVID-19 pandemic changed depending on whether a person was discharged alive or dead?	Dataset 17
How did unemployment during the COVID-19 pandemic affect mental health help?	Dataset 18, 19, and 20

Chapter 4: Questions and Answers

1. **Is there a discrepancy in COVID-19 deaths per state when comparing urban and rural regions?**

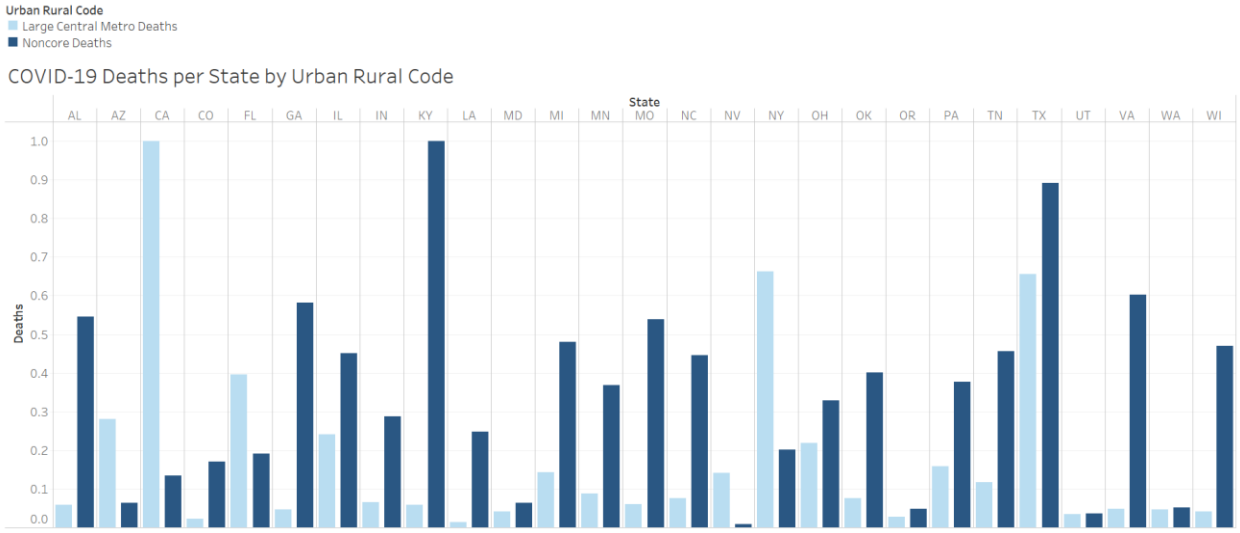


Figure 4.1: COVID-19 Deaths per State by Urban Rural Code.

Figure 4.1 shows the COVID-19 deaths per state by urban rural code from 2020-2023. Urban regions are classified as large central metropolitan areas, and rural regions are classified as noncore areas. Not every state is included in the visualization as some didn't have large central metro or noncore regions. Three states stand out in the graph: California, Kentucky, and Texas. California has the greatest number of large central metro deaths, while Kentucky has the highest number of noncore deaths. Texas has a considerable number of deaths for both regions. These three states can be explored further with deaths by county versus income and vaccinations.

Overall, it appears that most states have a larger number of deaths in noncore regions. Exploring rural regions and why they have more deaths than urban regions could be an interesting area of research for scientists. Knowing more about why these specific regions have more deaths can assist in tailoring the support they get from the government and other organizations.

2. Is there a connection between COVID-19 deaths and county income?

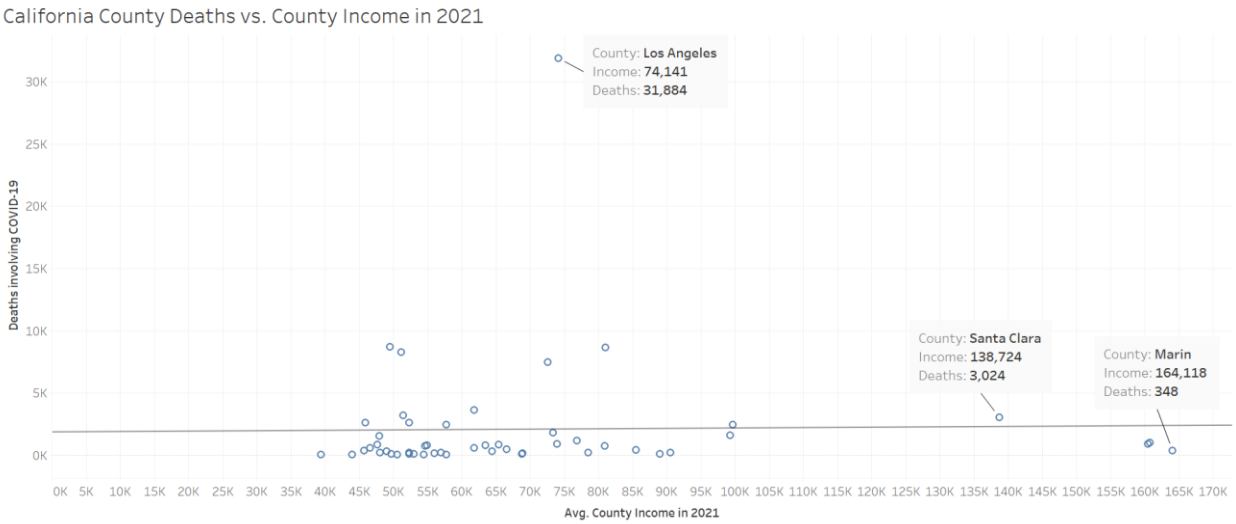


Figure 4.2: California County Deaths vs. County Income in 2021. The counties Los Angeles, Santa Clara and Marin are pointed out because they are outliers.

California

Figure 4.2 displays the deaths and income from 2021 for each county in California. The trendline has a small, positive slope meaning that as the income for the county increased, the deaths for the county increased slightly. There are three counties of interest pointed to on the graph, these being (from left to right): Los Angeles County, Santa Clara County, and Marin County. In 2021, these counties had a population of (respectively): 9.83 million, 1.886 million, and 260,206. Looking at these three counties alone, the number of COVID-19 deaths decreases as the population decreases. However, Marin County has a relatively small population compared to the other two, and yet received the most money from the state. One explanation for this is the number of landmarks in Marin County. Marin County contains many popular tourist destinations, so they would require more money from the state to manage these attractions.

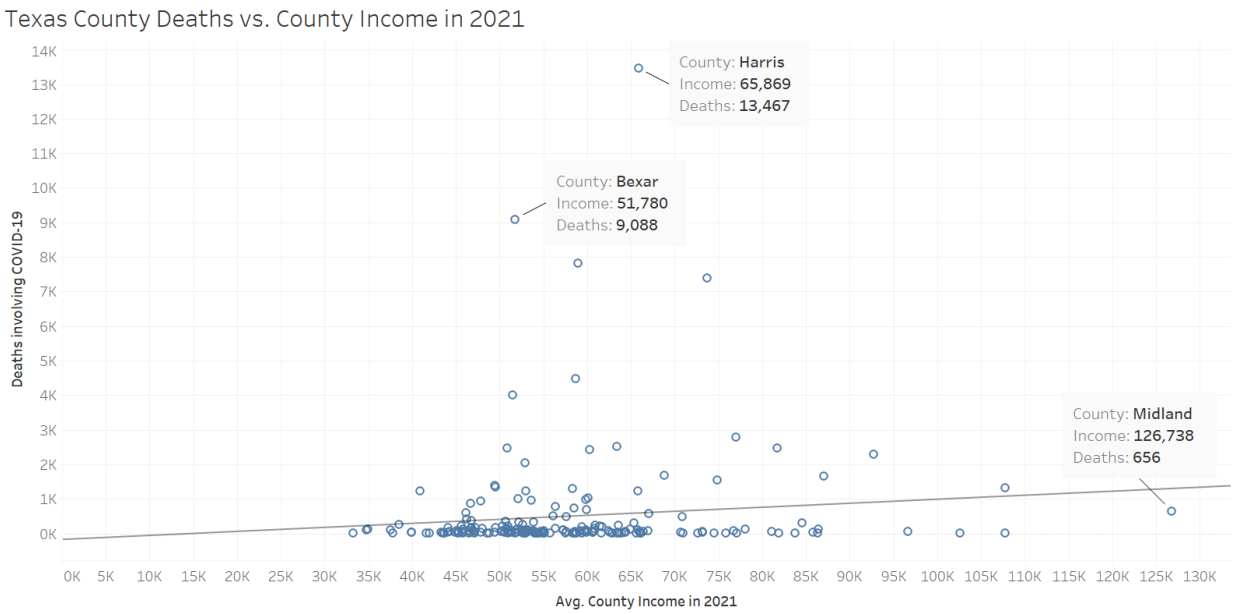


Figure 4.3: Texas County Deaths vs. County Income in 2021. The counties Harris, Bexar, and Midland are pointed out because they are outliers.

Texas

Figure 4.3 displays the deaths and income from 2021 for each county in Texas. The trendline shows a more considerable increase as income per county increased, meaning that as the number of COVID-19 deaths went up, the county income also went up. There are an increased number of counties in Texas, however many of them are rural. Figure 1 shows this clearly, as Texas is shown to have a high number of large central metro and noncore deaths. There are four counties of interest pointed to on the graph which are (from left to right): Bexar County, Harris County, and Midland County. The population for these counties in 2021 respectively was: 2.028 million, 4.728 million, and 167,969. Midland County is an interesting data point as the county has a very small population but received the largest income compared to the other counties. The small population could explain why the deaths are so low in this county.

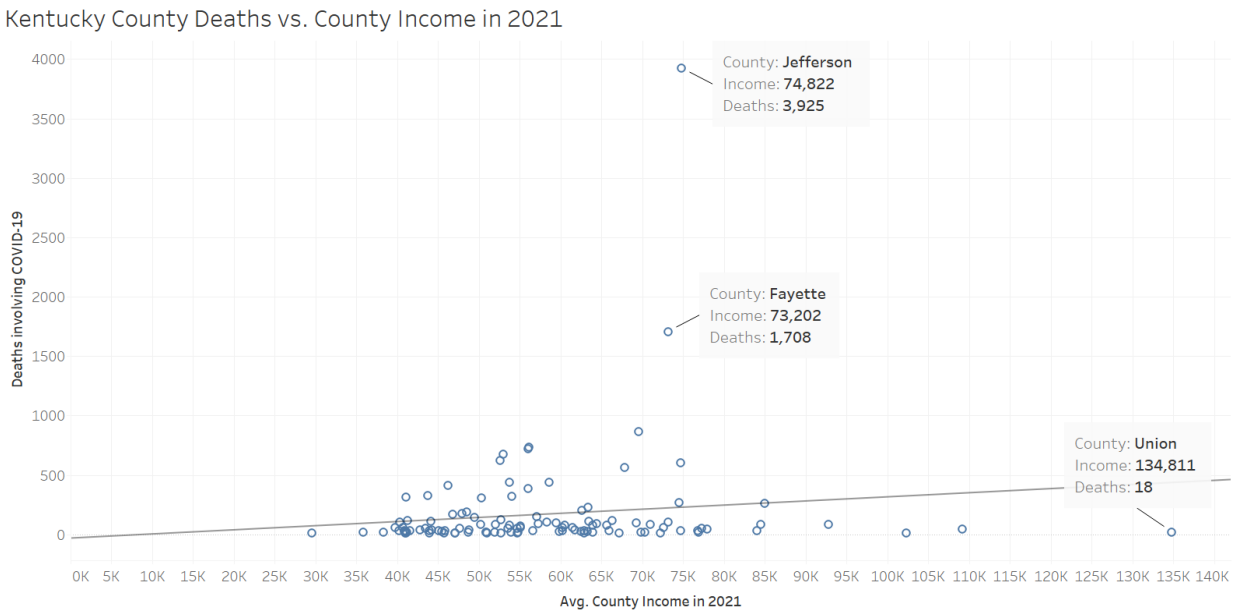


Figure 4.4: Kentucky County Deaths vs. County Income in 2021. The counties Jefferson, Fayette and Union are pointed out because they are the outliers on the graph.

Kentucky

Figure 4.4 displays the deaths and income from 2021 for each county in Kentucky. The trendline shows an increase as income per county increased, meaning that as the number of COVID-19 deaths went up, the county income also went up. Kentucky has many more rural counties than urban, and this is seen in Figure 1 as the deaths for noncore areas is very high. There are three counties of interest pointed to on the graph which are (from left to right): Jefferson County, Fayette County, and Union County. The population for these counties in 2021 respectively was: 777,874, 321,793, and 13,544. The difference in population between Jefferson and Fayette County explains why the difference in deaths between the two is so large despite both having a similar income. Union County is an interesting data point as the county has a very small population but received the largest income compared to the other counties. More exploration can be done into why this specific county received such a high income.

3. Is there a relationship between vaccinations and type of region (rural or urban)?

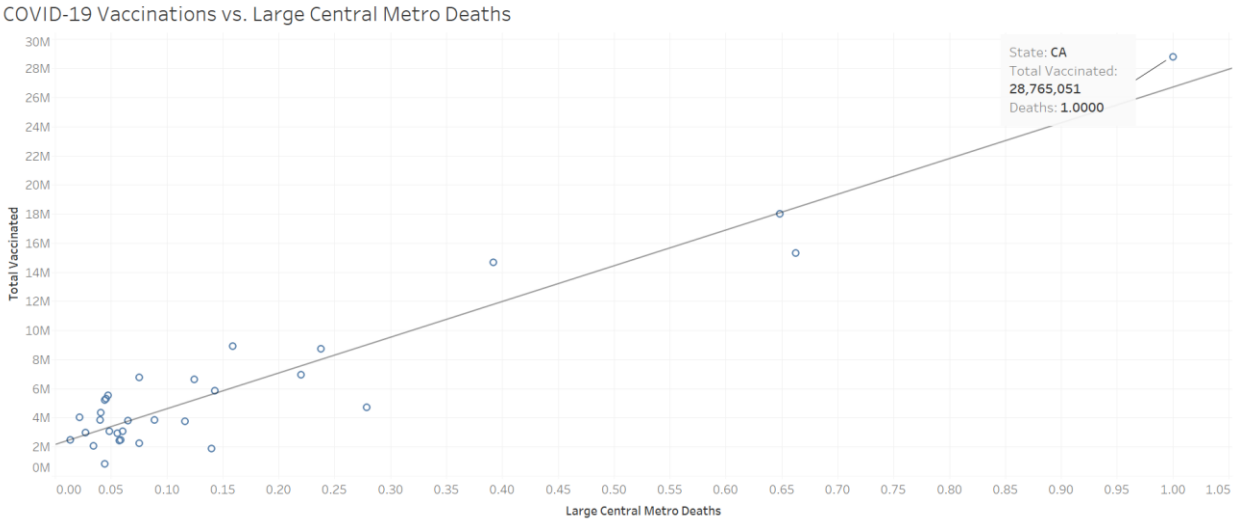


Figure 4.5: COVID-19 Vaccinations vs. Large Central Metro Deaths. The data point with the largest average number of total vaccinations and deaths is California.

Figure 4.5 illustrates the number of large central metro deaths compared to vaccines administered. The x-axis represents the percentage of large central metro deaths, and the y-axis is the total vaccinations. Each dot represents a state. As the number of deaths increases, the number of vaccinations increases. This could be due to the large population in these regions. California is the state with the largest number of deaths and vaccines administered, which could be a result of California having large, concentrated urban areas, such as Los Angeles.

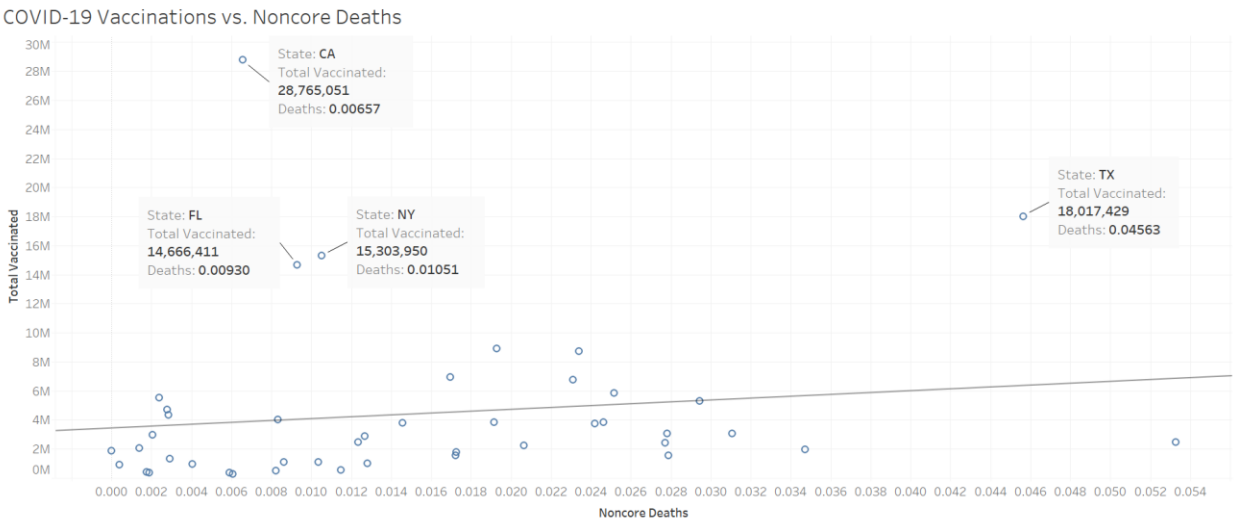


Figure 4.6: COVID-19 Vaccinations vs. Noncore Deaths. There are four states pointed out on the visualization: California, Florida, New York, and Texas. These states are outliers on the graph.

Figure 4.6 shows the vaccines administered per state versus to the noncore deaths. The x-axis represents the percentage of noncore deaths, and the y-axis is the number of total vaccinations. Each dot represents a state. There appears to be a slight relationship between the two, with the vaccines administered increasing as noncore deaths increase. However, there is more variation in this graph than in Figure 4.5. This could be because of the variation in population in noncore regions. The states with the largest number of vaccines are California, Texas, New York, and Florida. These are the states with the largest populations so there are going to be a higher number of vaccines in these areas, regardless of if the region is noncore or large central metro.

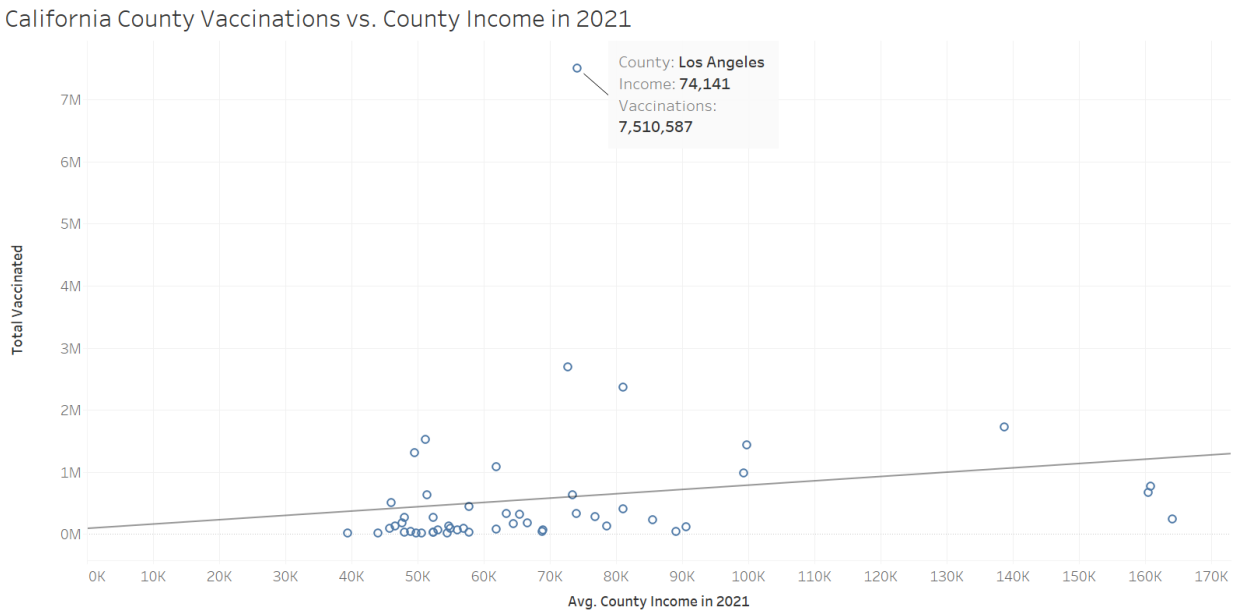


Figure 4.7: California County Vaccinations vs. County Income in 2021. Los Angeles County has the highest number of vaccinations.

California county vaccinations vs. county income

Looking a bit further into the vaccinations in California, there is one county that stands out from the rest. The x-axis represents the average county income in 2021, and the y-axis is the number of total vaccinations. Each dot represents a county in California. There seems to be a relationship between the number of vaccinations and county income, which could be attributed to the population of the counties (larger population means more vaccines and more money). Los Angeles County has the highest number of vaccinations, which is most likely due to the population in the county.

Overall, it appears that population has a significant impact on the number of vaccines administered. Further research could be done into the rural areas in these states to see if they were suffering due to their smaller population, as the states and regions with a larger population may garner more attention from the state and federal governments.

4. **Do payments to rural and non-rural areas have an impact on the number of deaths in those regions?**

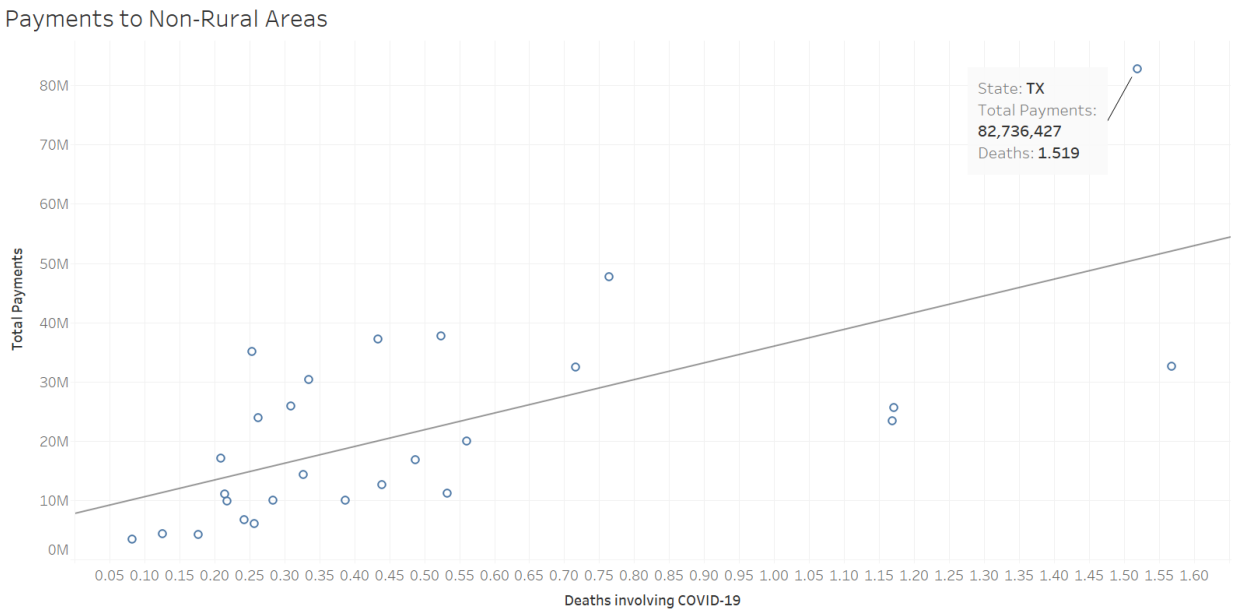


Figure 4.6: ARP Payments to Non-Rural Areas. Texas has the largest number of total payments and deaths involving COVID-19.

Payments to non-rural areas

Figure 4.8 shows the total payments made to non-rural areas through the American Rescue Plan (ARP). The x-axis represents the percentage of deaths involving COVID-19 per state, and the y-axis is the total payments made to each state. These payments were released to providers and suppliers "who have served rural Medicaid, Children's Health Insurance Program (CHIP), and Medicare beneficiaries" (*American Rescue Plan (ARP) Rural Payments | HRSA*, n.d.). The payments vary per state based on the number of providers and suppliers in those states. Texas has the largest number of total payments and COVID-19 deaths. This is interesting because Texas does have many rural regions, but the graph portrays payments to non-rural areas. Texas could have a larger number of providers and suppliers due to its large population, and how spread out the state is.

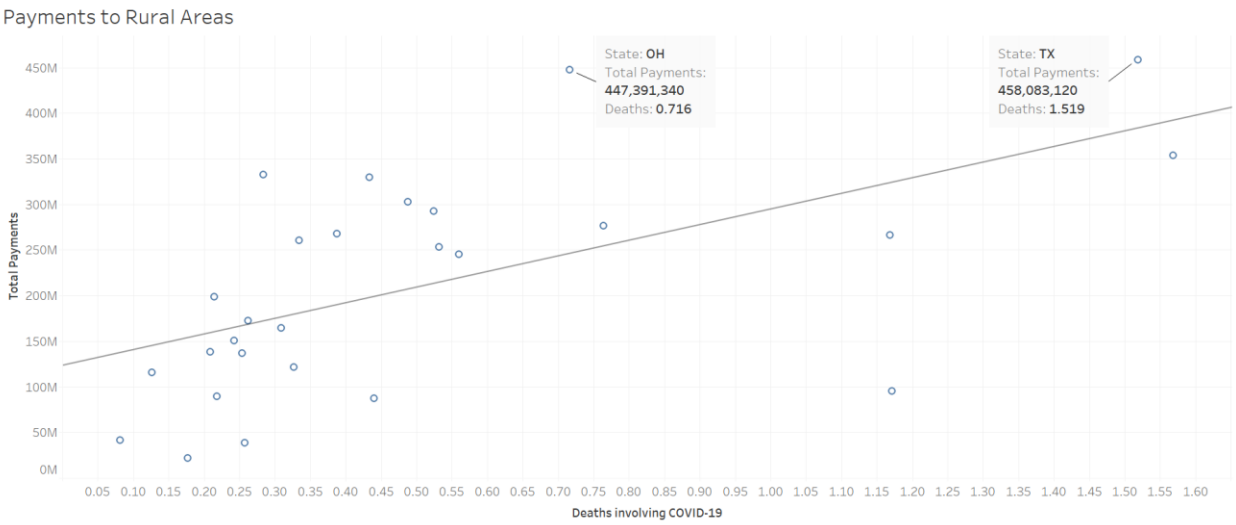


Figure 4.7: ARP Payments to Rural Areas. Ohio and Texas have the largest number of total payments and deaths involving COVID-19.

Payments to rural areas

Figure 4.9 shows the ARP payments made to rural areas. The x-axis represents the percentage of deaths involving COVID-19 per state, and the y-axis is the total payments made to each state. The states with the largest number of payments are Ohio and Texas. Ohio is an interesting data point as it has one of the highest total payments, but a lower number of deaths involving COVID-19. It could benefit providers in other states to look at what Ohio is doing differently to handle COVID-19.

5. **Do states where there is a higher percentage of people who have difficulty paying for household expenses have a higher number of hospital deaths?**

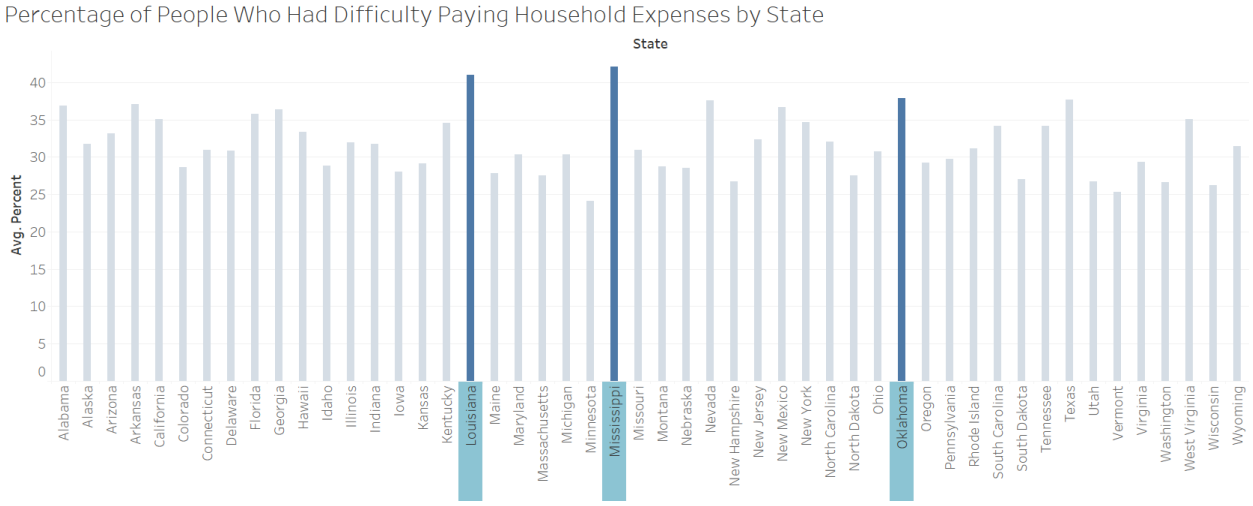


Figure 4.8: Percentage of People Who Had Difficulty Paying Household Expenses by State. Louisiana, Mississippi, and Oklahoma have the highest percentage of people who had difficulty paying for household expenses.

Figure 4.10 shows the percentage of people who had difficulty paying for household expenses by state. The three states with the highest percentages were Louisiana, Mississippi, and Oklahoma.

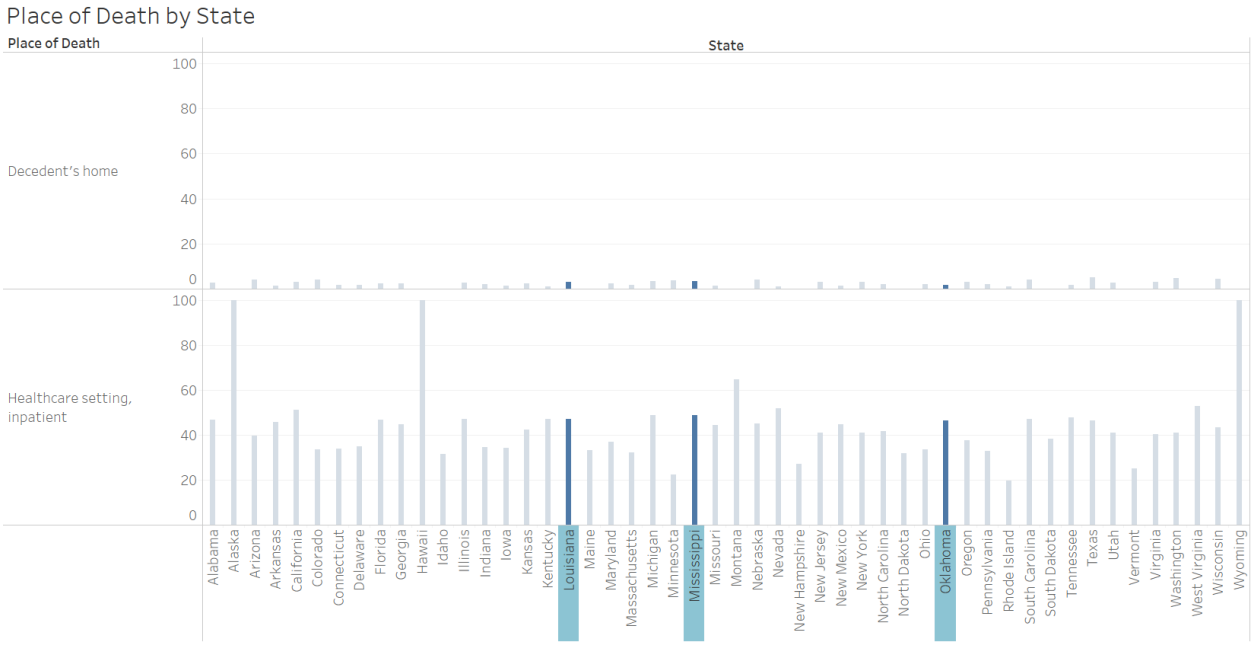


Figure 4.9: Place of Death by State. Louisiana, Mississippi, and Oklahoma are highlighted to compare their values to the other states.

Figure 4.11 shows the place of death per state. The three states from Figure 4.10 above are highlighted to compare their percentage with others. It looks like these three states do not have a

number out of the ordinary and are in line with the other states. There seems to be no connection between difficulty with paying for household expenses and place of death. However, more people in these states died in the descendant's home than others.

6. Is there a connection between household telehealth and place of death?

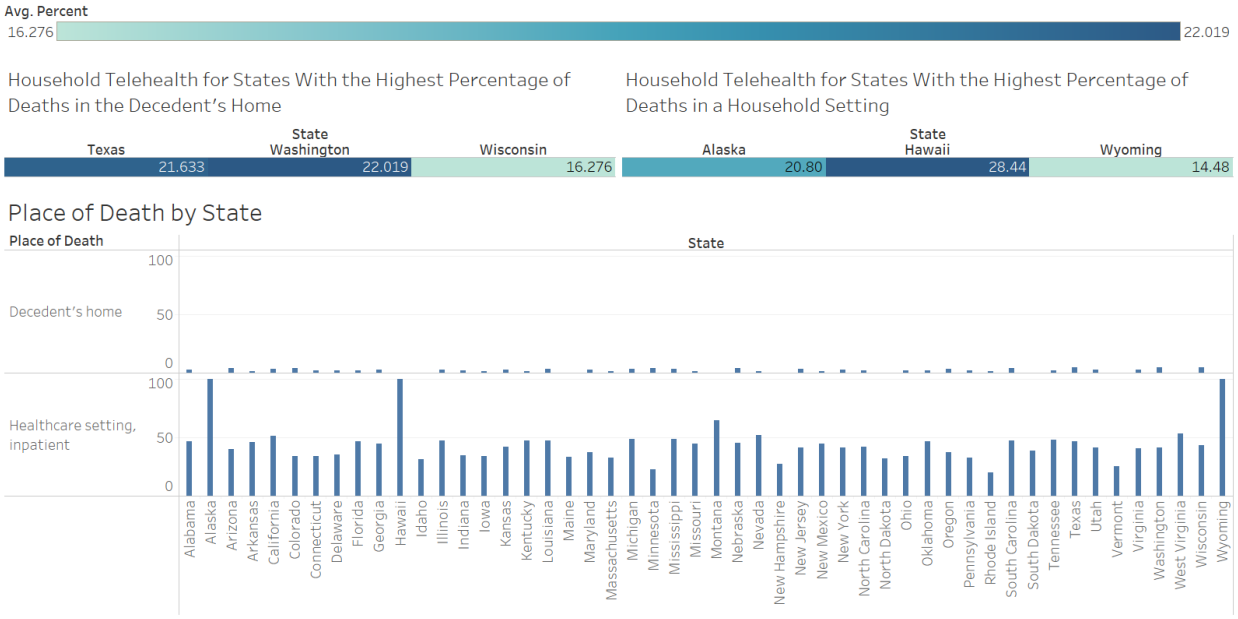


Figure 4.10: Household Telehealth and Place of Death by State. Alaska, Hawaii, and Wyoming have the highest percentage of inpatient deaths. Texas, Washington, and Wisconsin have the highest percentage of deaths at home. The percentage of household telehealth for these states is displayed above.

Figure 4.12 displays the percentage of people who used household telehealth in the three states with the highest percentage of inpatients and the three states with the highest percentage of at home deaths. Alaska, Hawaii, and Wyoming have the highest percentage of inpatient deaths, and Hawaii has the largest percentage of household telehealth. Household telehealth may be popular in Hawaii due to the isolated location of the state. The same reasoning can go for Alaska. In turn, Texas, Washington and Wisconsin had the highest percentage of deaths at home. Texas and Washington have a high percentage of telehealth users. This could be because more people stay home when they're feeling unwell and decide to reach out through online telehealth.

7. **How have the age groups affected by COVID-19 changed over the course of the pandemic?**

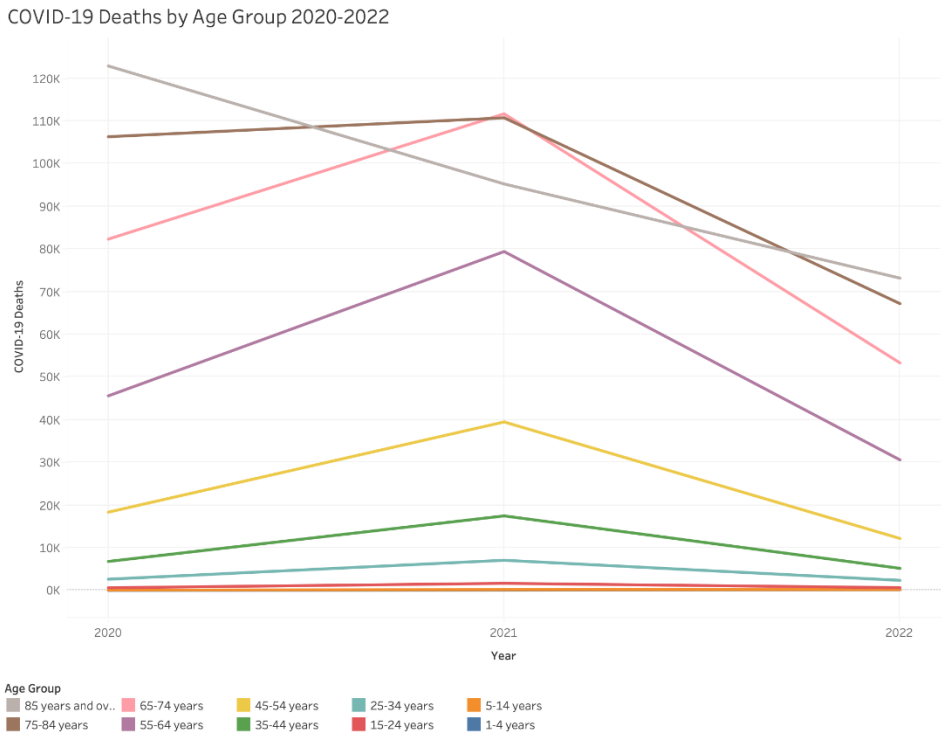


Figure 4.11: COVID-19 Deaths by Age Group Over 2020, 2021, and 2022. COVID-19 deaths increased from 2020 to 2021 and then decreased from 2021 to 2022.

Figure 4.13 shows the COVID-19 deaths for each age group from the years 2020, 2021, and 2022. From the figure, there are two major takeaways. The first is that the older age groups have significantly more deaths from COVID-19 than younger age groups. One anomaly presented in the data is that the age group of 85 years and older had a decrease in COVID-19 deaths from 2020 to 2021 while all other age groups showed increases. This may be a combination of the fact that there is a lesser number of adults 85 or older compared with adults in the 75 to 85 range (Duffin, 2022) and adults 85 or older had the most COVID-19 deaths in 2020.

The second important takeaway is that COVID-19 deaths increased from 2020 to 2021 but decreased from 2021 to 2022. This may be a sign that interventions put in place over the course of 2021 and 2022 have worked to lessen the death caused by COVID-19. While there was an overall decrease in COVID-19 deaths from 2021 to 2022, people of the 1-4 and 5-14 age groups had an increase in the number of COVID-19 deaths during this period. One suspicion we have is that this increase is due to the return of in-person schooling in America, however this increase is not reflected in the 15-24 age group who were also affected by a return to in-person school.

8. What is the connection between state populations, population densities, and COVID-19 deaths?

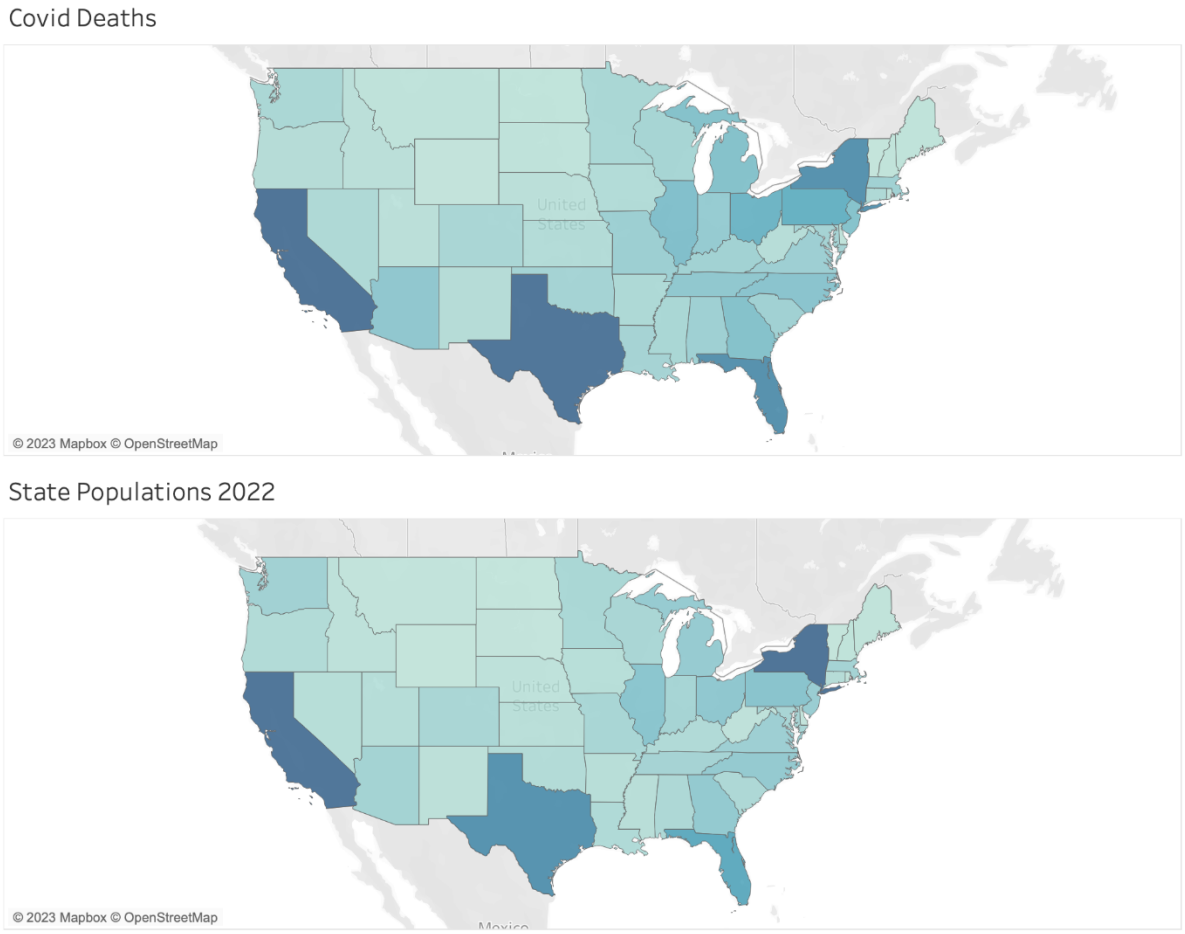


Figure 4.12: COVID-19 Deaths and State Populations by State. The states with the highest number of COVID-19 deaths are closely linked to the states with the highest populations.

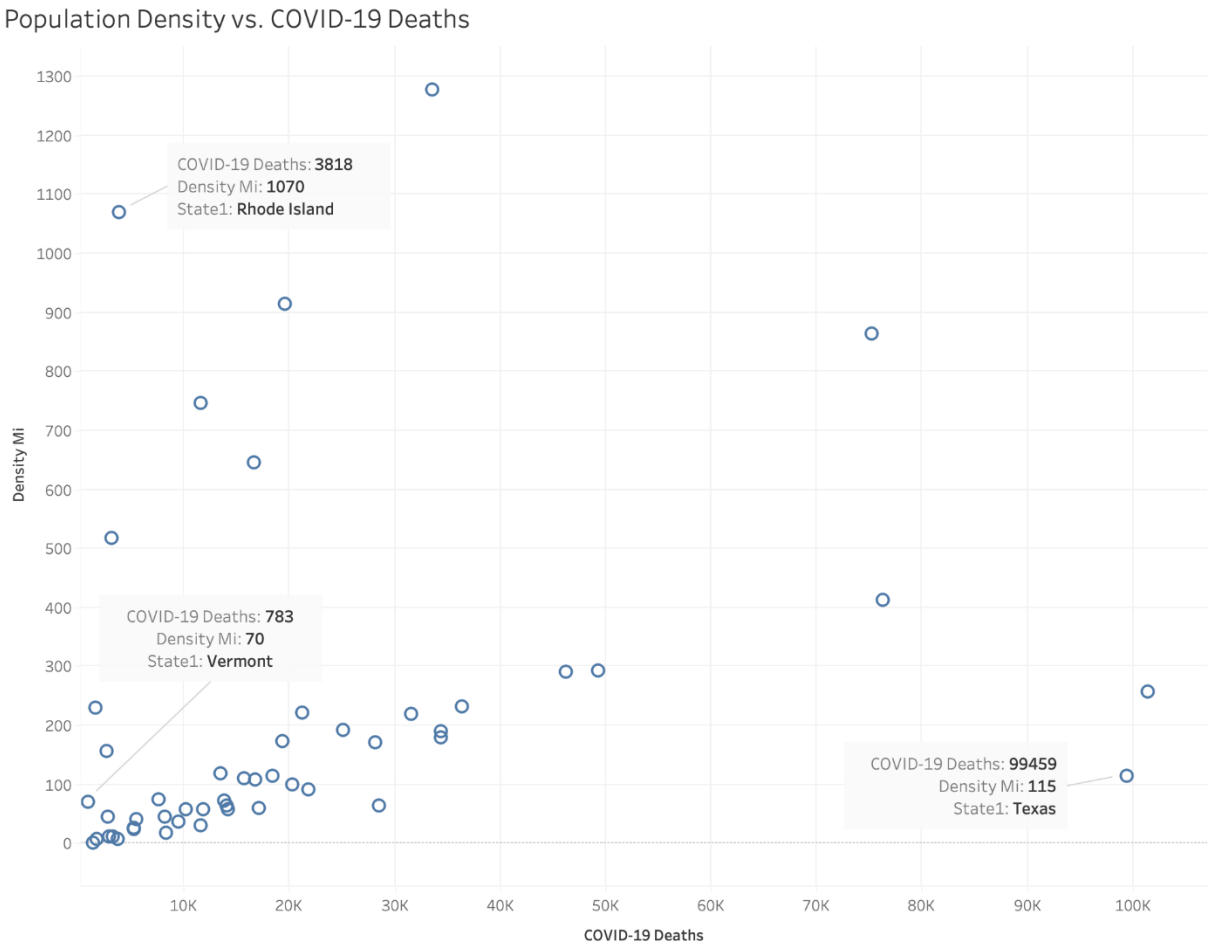


Figure 4.13: COVID-19 Deaths and State Population Densities by State. There is a positive correlation between COVID-19 deaths and population density, but there are a few outliers.

Figures 4.14 and 4.15 show how state populations and population densities relate to the number of COVID-19 deaths in a state. We can see in figure 4.14 that COVID-19 deaths in a state are strongly correlated with population. At the time data was recorded, Mississippi was doing the worst overall having the most COVID-19 deaths proportional to its population, while Hawaii had the least COVID-19 deaths for its population.

When looking at population density, one might intuitively think that states with higher population densities would have more COVID-19 deaths. While there is a positive correlation between the two, there was a wide range across the states. Vermont has the lowest number of COVID-19 deaths proportional to its population density. Journalists suggest that Vermont's success at preventing COVID-19 during the pandemic comes from early action, a statewide emphasis on health, and a centralized public health system (Deliso, 2020). Rhode Island is a significant outlier because it has the second highest population density but a relatively low number of COVID-19 deaths. This may be because it has a small population size. Finally, Texas is a significant outlier because it has a much lower population density than other states with

similar amounts of COVID-19 deaths, but it still has the second most COVID-19 deaths. This means that many people died from COVID-19 even while spread out across the state more.

9. **Does the percentage of adults fully vaccinated in a state affect the excess deaths from COVID-19?**

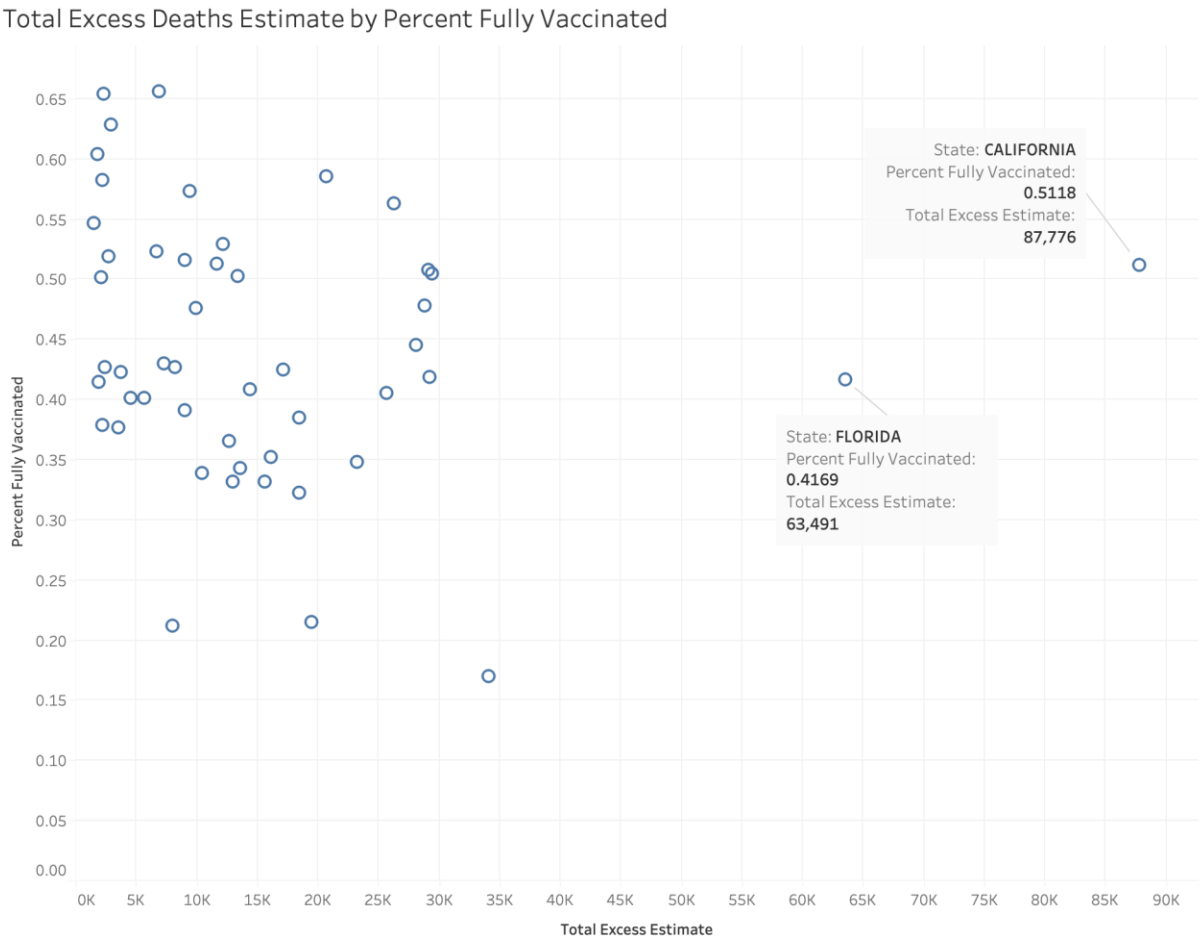


Figure 4.14: Total Excess Deaths Estimated by Percent Fully Vaccinated. Florida and California are outliers with the largest total excess deaths.

Figure 4.16 shows a scatterplot of the percentage of adult residents fully vaccinated, and the total excess deaths estimate in each state. Excess deaths refer to the number of deaths that occur more than what is predicted from historical trends. As seen in the plot, there is a clump where most of the states rest. From analyzing the data, we conclude that the excess deaths in a state are not influenced significantly by the percent of residents fully vaccinated in that state. Even states with lower vaccination rates have a comparable number of COVID-19 deaths. Florida and California are outliers on the other end as they have more than double the number of excess deaths that most other states have but have similar vaccination rates to other states. The large number of

excess deaths makes sense because they are two of the states with both the highest population and highest COVID-19 deaths.

10. How has food scarcity changed in the United States throughout the course of the pandemic?

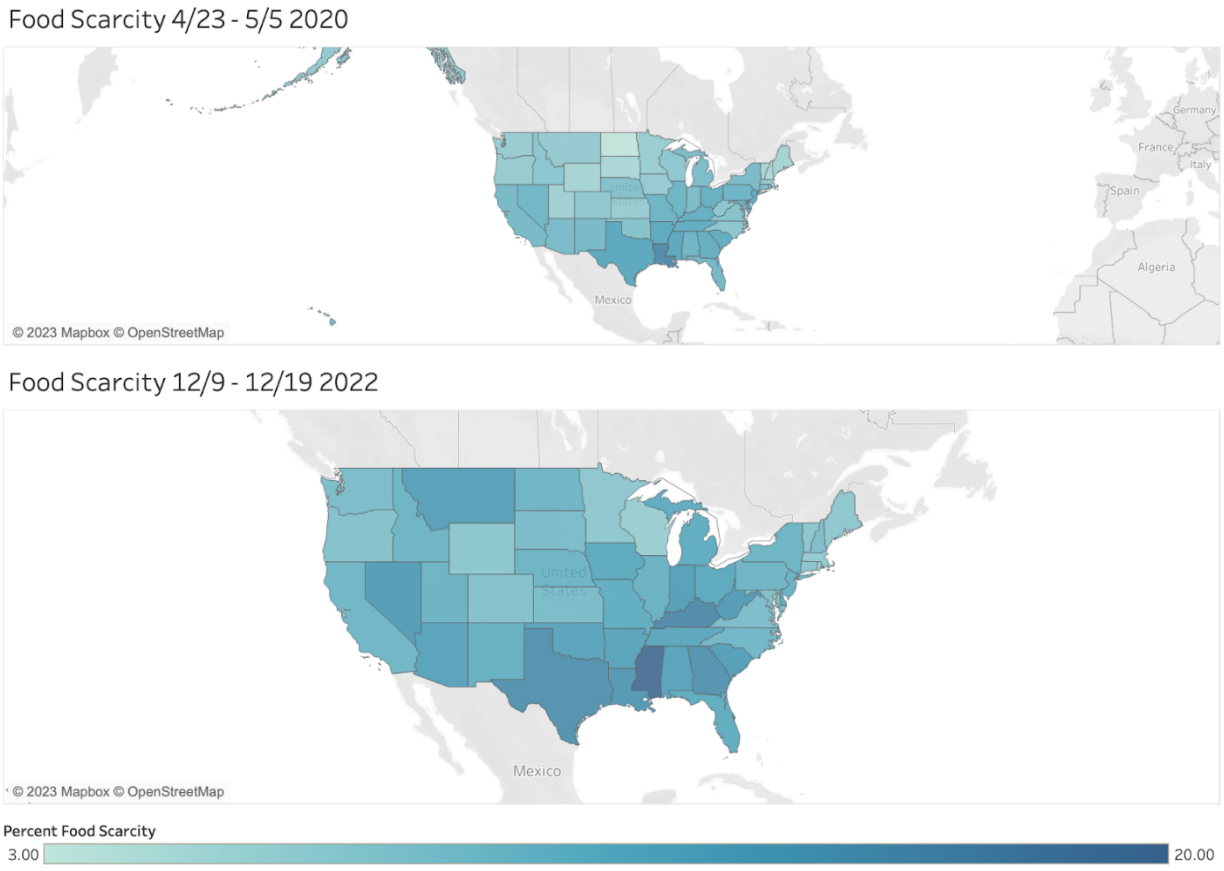


Figure 4.15: Food Scarcity from 4/23/2020-5/5/2020 and 12/9/2022-12/19/2022. States of interest include Mississippi, Louisiana, and Michigan.

The top graph of Figure 4.17 shows food scarcity across America during April of 2020 and the bottom graph shows food scarcity in December of 2022. In 2020, the lowest food scarcity in a state was around 3% and the highest was around 20%. Overall, food scarcity has gotten worse in America since the beginning of the pandemic. At the end of 2022, the worst state in terms of food scarcity was Mississippi, where food scarcity had increased by around 60% from mid 2020. However, there are a few notable states that are doing better now than they were previously. Louisiana, the state with the highest food scarcity at the beginning of the pandemic, has reduced its food scarcity by 12%. Michigan's food scarcity has improved by more than 16%. There also seems to be a downward trend in food scarcity among some northeastern states like Rhode Island, Connecticut, and New Jersey.

11. How does food scarcity in America relate to the COVID-19 deaths in each state?

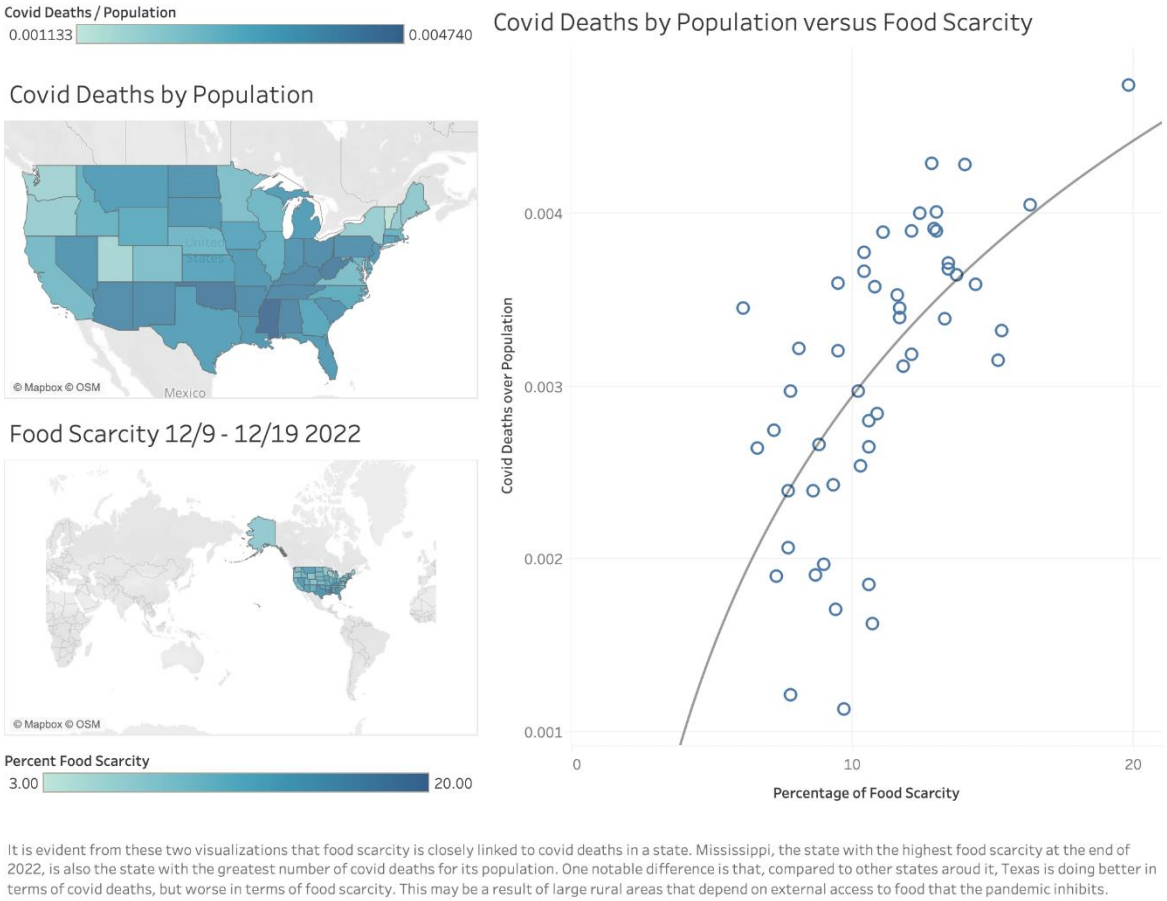


Figure 4.16: COVID-19 Deaths by Population vs. Food Scarcity during 12/9/2022-12/19/2022. Graph on the right shows COVID-19 deaths vs. food scarcity with a trendline to illustrate their positive correlation.

The top left graph of figure 4.18 shows the number of COVID-19 deaths in each state in relation to its population. The graph on the bottom left shows the food scarcity in each state at the end of 2022. The scatterplot on the right shows the correlation between food scarcity and COVID-19 deaths within a state. Generally, as food scarcity increases, COVID-19 deaths in a state also increase. It is apparent from these two visualizations that food scarcity is closely correlated with COVID-19 deaths. Mississippi, the state with the highest food scarcity at the end of 2022, is also the state with the greatest number of COVID-19 deaths for its population. One notable outlier is Texas. Compared to other states around it, Texas is doing better in terms of COVID-19 deaths, but worse in terms of food scarcity.

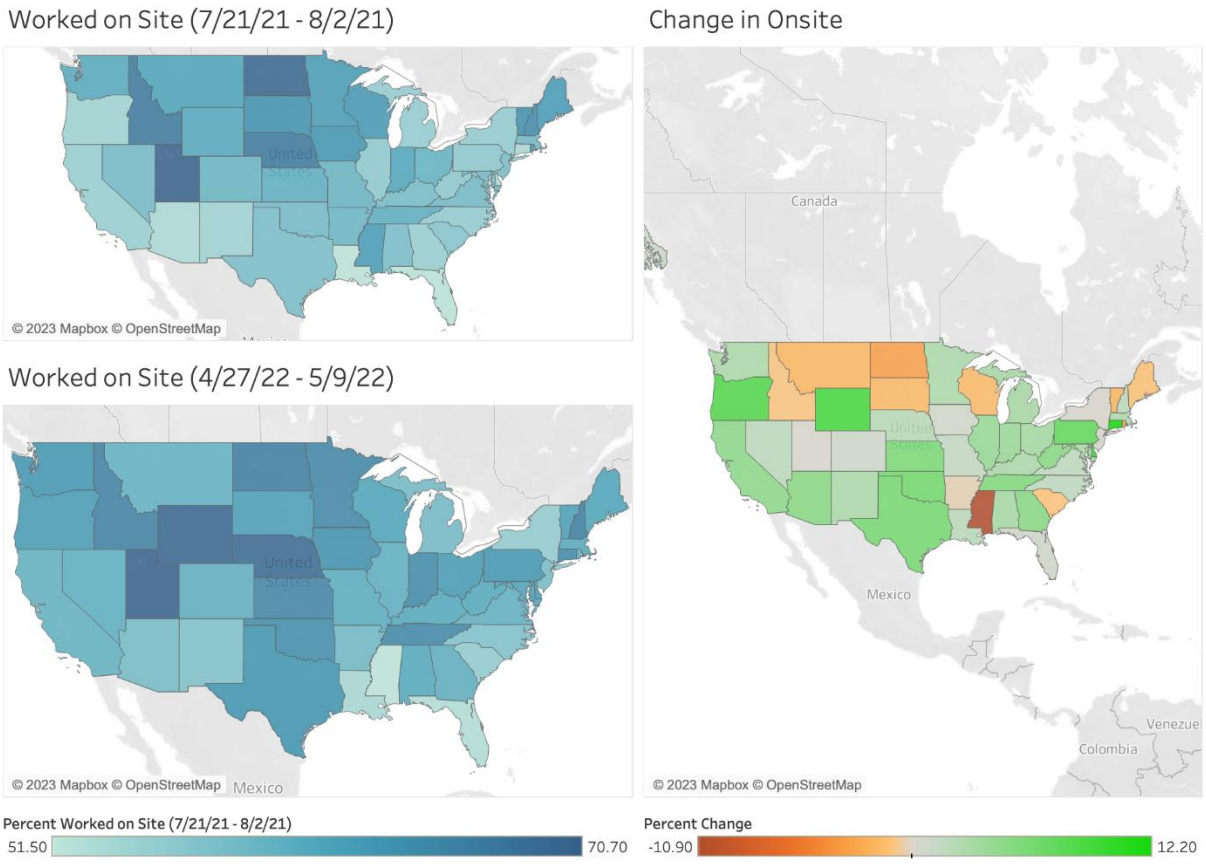


Figure 4.17: Percentage of Onsite Workers from 7/21/2021-8/2/2021 and 4/27/2022-5/9/2022, Changes in Onsite Workers. Most states increased their number of onsite workers, but Mississippi dropped onsite workers drastically.

12. Which states have the highest percentage of onsite workers?

Figure 4.19 shows the percentage of onsite workers at two different points in the pandemic. The snapshot on top shows the percentage of workers who worked onsite from 7/21/21 to 8/2/21. The snapshot below shows the percentage of workers who worked onsite from 4/27/22 to 5/9/22. Throughout America, all states had between 51 and 71 percent of workers working partially or fully onsite. States in the mid and northwest had the largest percentage of onsite workers.

13. How has the number of people working onsite changed throughout the pandemic?

The graph on the right of the dashboard shows the change in the percentage of onsite workers from the first week measured and 9 months later. Over 8 million additional workers moved to onsite work in the United States. This came out to an average of 2.35% of workers moving to onsite work in each state. 78% of states did better than the previous year or stayed the same. This trend shows that the pandemic was steadily moving toward a better direction during this period.

14. How has each state changed in terms of percentage of people working onsite throughout the pandemic?

Out of the 11 states that had less onsite workers than the previous year, only 1 state was less by more than 4%. Mississippi dramatically decreased the number of onsite workers by 10.9% of their total workers. Although Mississippi had the greatest decrease, most of the states with a decrease in onsite workers are scattered across the North of the US. The West and Midwest are an interesting case because they contain most of the states that decreased working onsite but also contain the second and third states with the largest increase in onsite workers: Oregon and Wyoming.

15. How much of the older population receives an additional booster vaccine after the first?

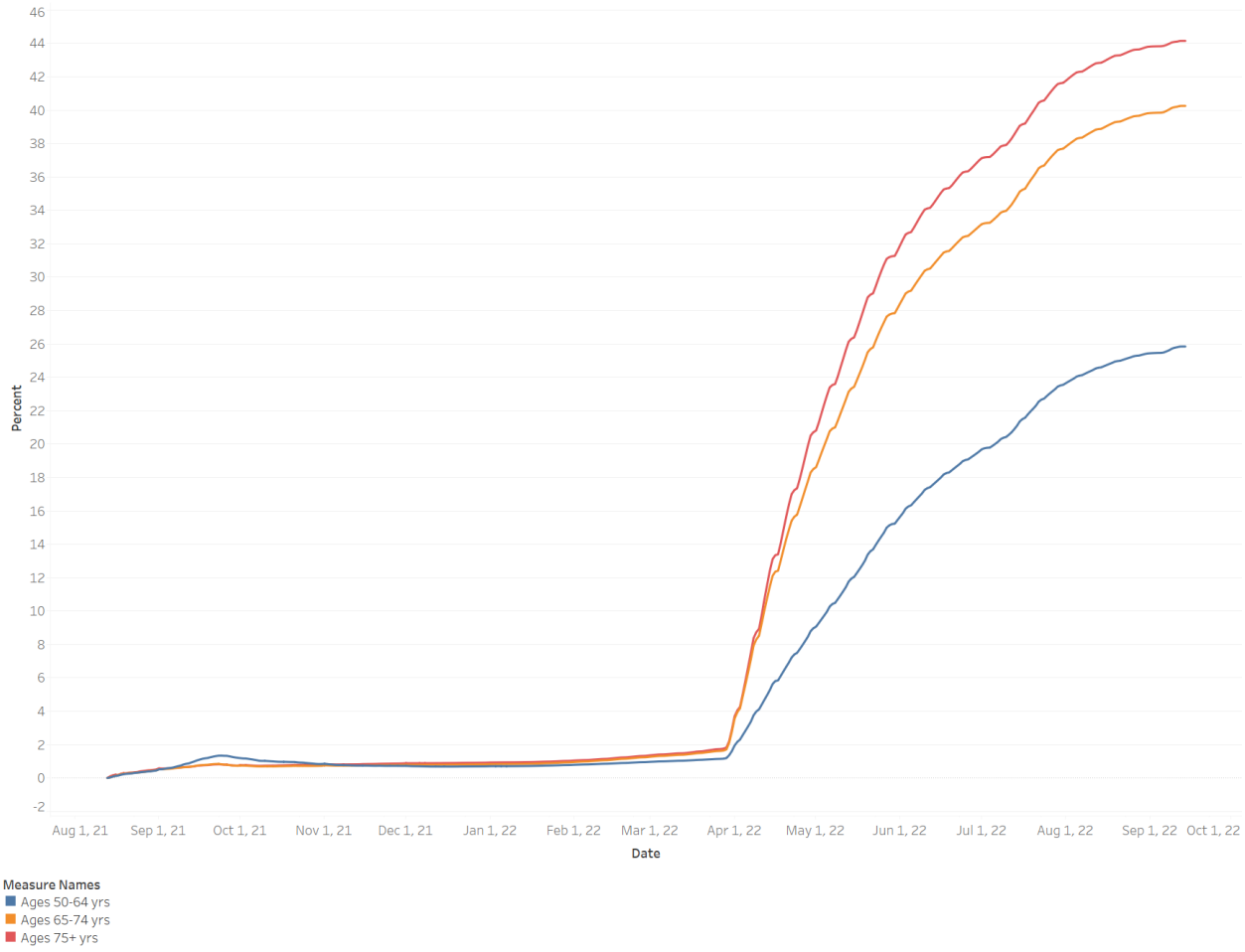


Figure 4.18: Percentage of Older Individuals who Receive Both Booster Shots After Receiving the First Booster.

Figure 4.20 represents the relationship between the older population and the percentage of which that specific age group receives an additional COVID-19 booster vaccine after the initial booster vaccine. The age groups represented are ages 50 – 64, ages 65 – 74, and ages 75 and above.

From August 2021 to April 2022, the percentage of people who receive an additional booster shot remained low and showed a slight increase. Starting April 2022, the number of people who receive the COVID-19 second booster shot seems to spike in percentage, with those who are older being more likely to have received the additional booster. After around June or July 2022, the rate of which people receive the COVID-19 second booster shot seems to decrease. From these findings, the older people are, the more likely they are to have received the second booster dose. This trend might be due to the higher risk that COVID-19 poses on older adults, prompting them to seek additional safety measures. Other reasons may be due to public health officials prioritizing older adults due to their vulnerability.

16. On average, what date did each state close their schools?

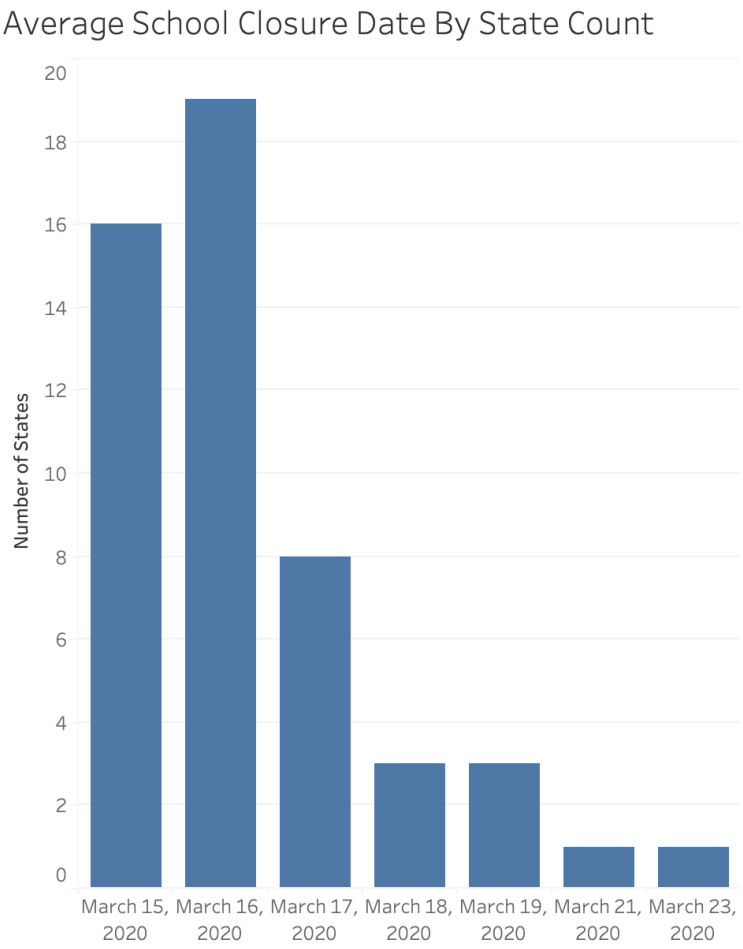


Figure 4.19: Average School Closure by Date Count.

Figure 4.21 represents all 50 US states and the average date of which the schools within their state closed in response to the COVID-19 pandemic. The graph indicates that most schools closed their doors between March 15, 2020, and March 17, 2020. These three days marked the beginning of widespread recognition of the severity of the COVID-19 pandemic and the need for

action became apparent. Of the 50 states, only 8 states on average closed their schools after March 17, 2020, with the latest closing on March 23, 2020. This is due to some states' differences in their perception of the severity of the pandemic, the prevalence of COVID-19 cases within the state, or the state government's action on the pandemic, but proves that most states took quick action in mitigating the spread of COVID-19 by closing schools.

17. What is the relation between deaths involving COVID-19 and average income in each county from 2019, 2020, and 2021?

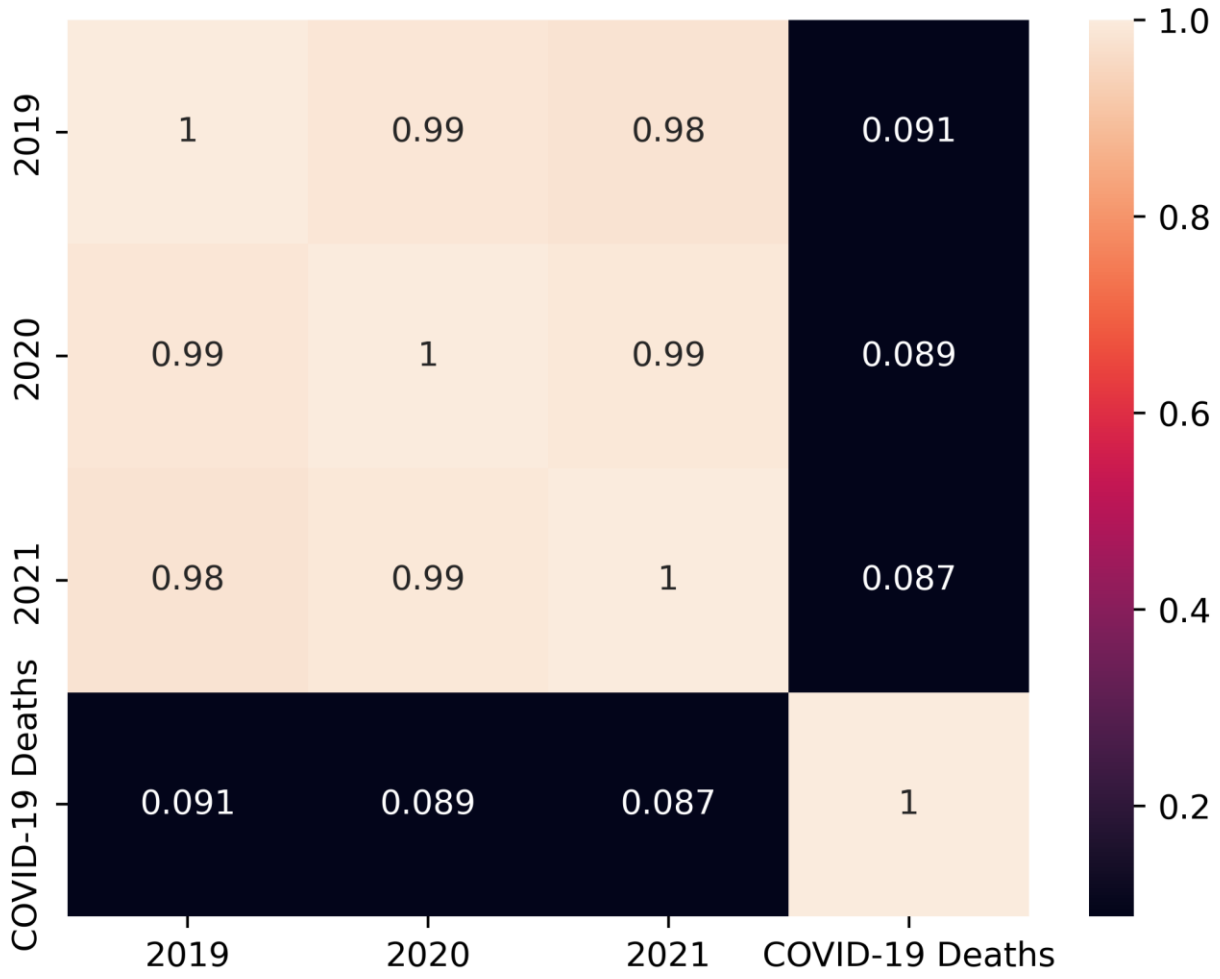
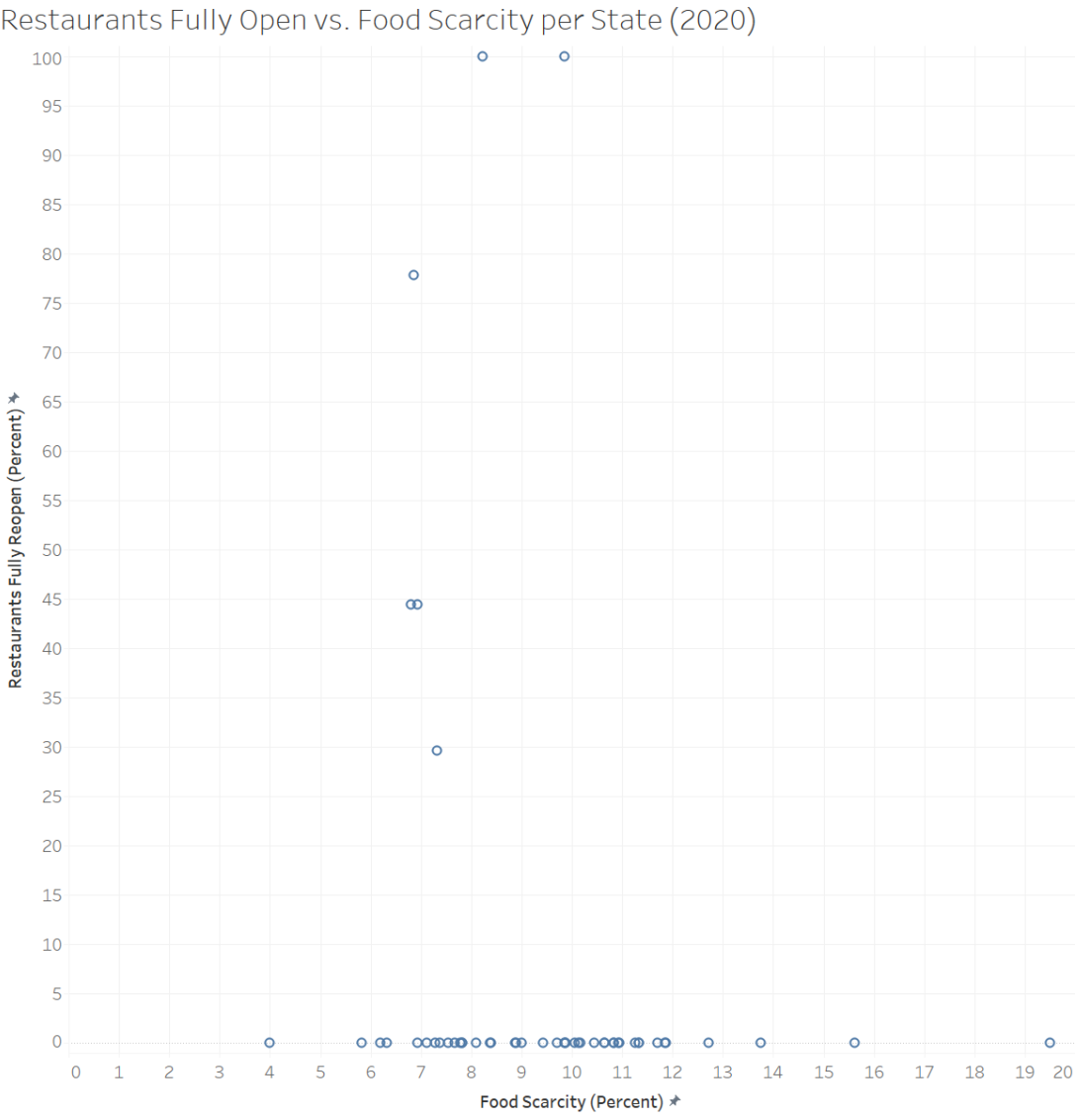


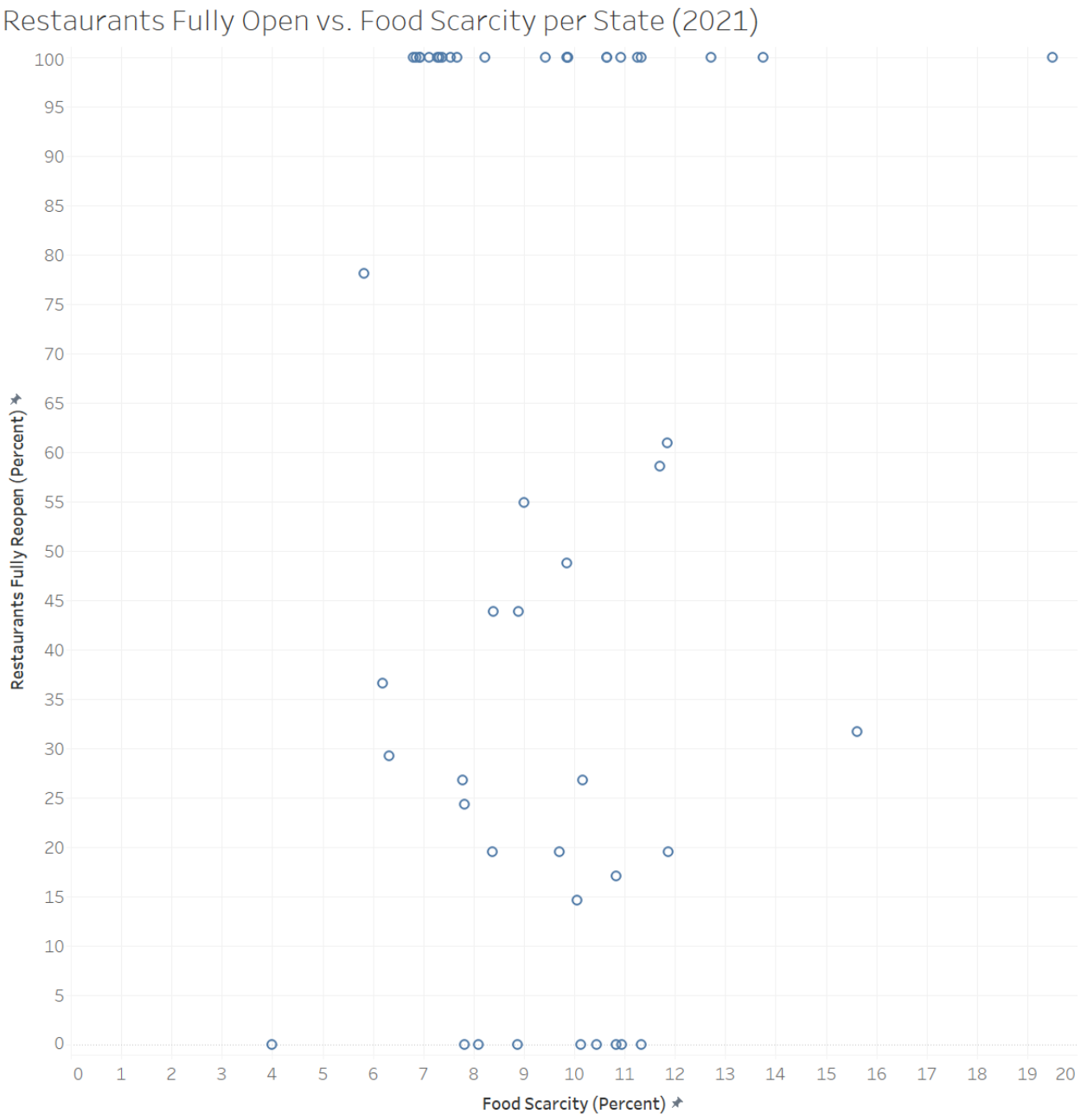
Figure 4.20: Correlation Matric Between Income per County and Deaths Involving COVID-19.

Figure 4.22 represents a correlation matrix of the relationship between income per county in the years 2019, 2020, and 2021 and Deaths involving COVID-19. The goal of this analysis was to find any significant connection between county's average income and the deaths stemming from COVID-19. From the findings, it seems like there is no correlation between income in those years and deaths involving COVID-19, as the correlation coefficient is less than 0.1 in those three years in relation to COVID-19 deaths. This may be due to many lower income jobs varying

in interaction with people, which would explain the low correlation in COVID-19 deaths and income levels. COVID-19 deaths largely involve the interaction with other individuals, and income level does not directly impact the amount of human interaction.

18. What is the effect on state mandated restaurant action on food scarcity during the COVID-19 pandemic?




Restaurants Fully Open vs. Food Scarcity per State (2021)
Restaurants Fully Reopen (Percent)
Food Scarcity (Percent)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
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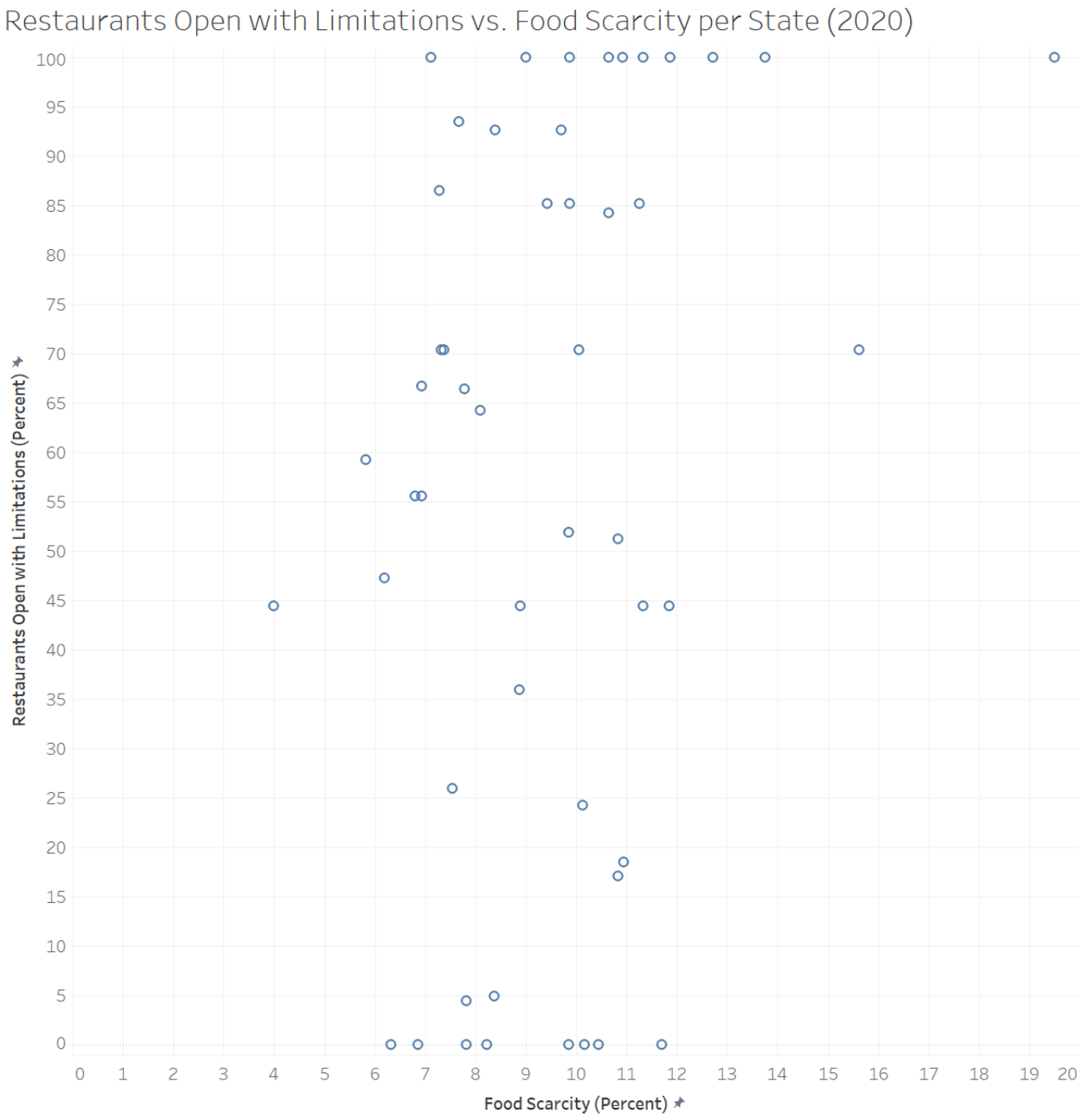
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20


Restaurants Open with Limitations vs. Food Scarcity per State (2020)
Restaurants Open with Limitations (Percent)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
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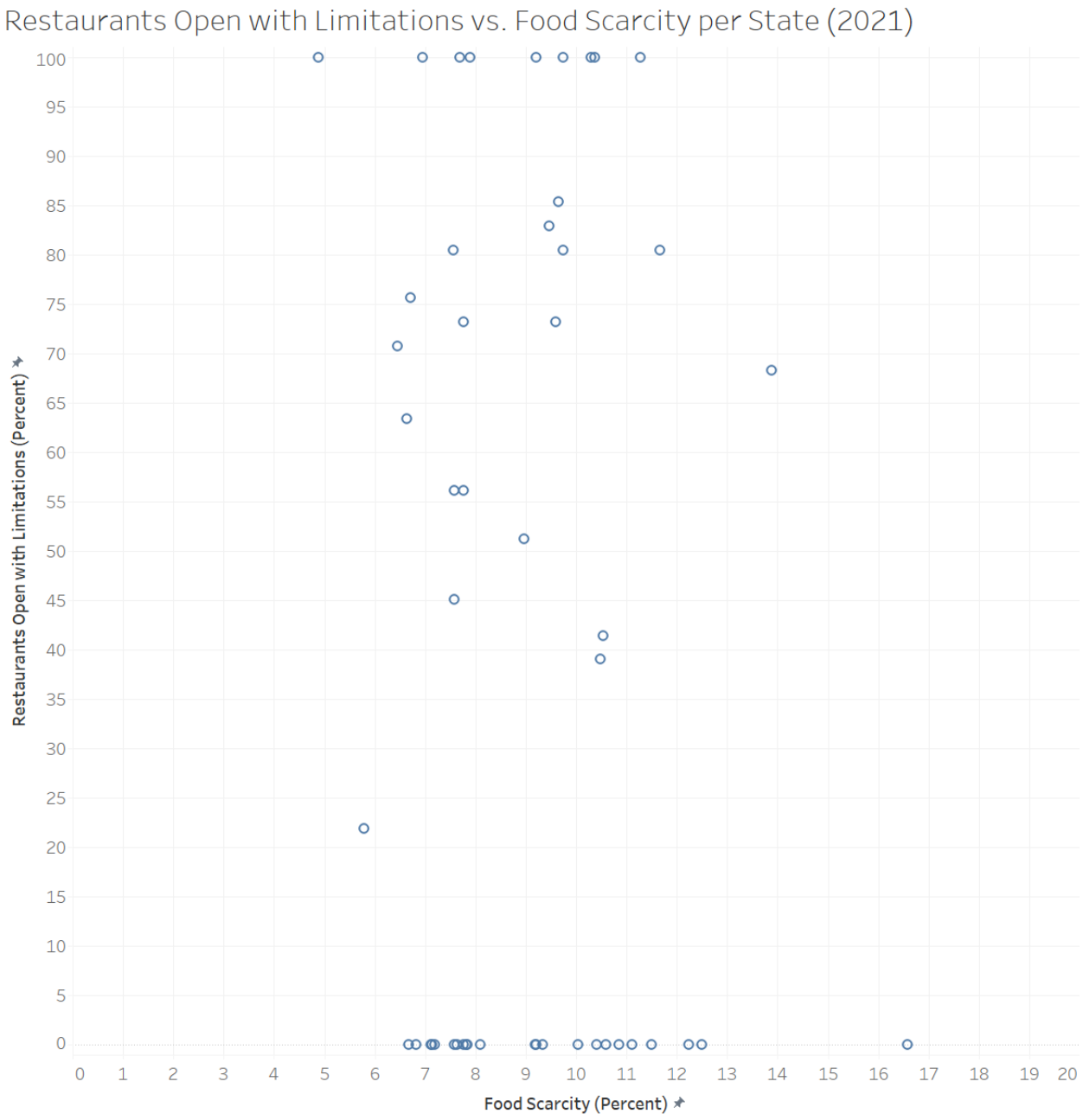
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Food Scarcity (Percent)


Restaurants Open with Limitations vs. Food Scarcity per State (2021)
Restaurants Open with Limitations (Percent)
100
95
90
85
80
75
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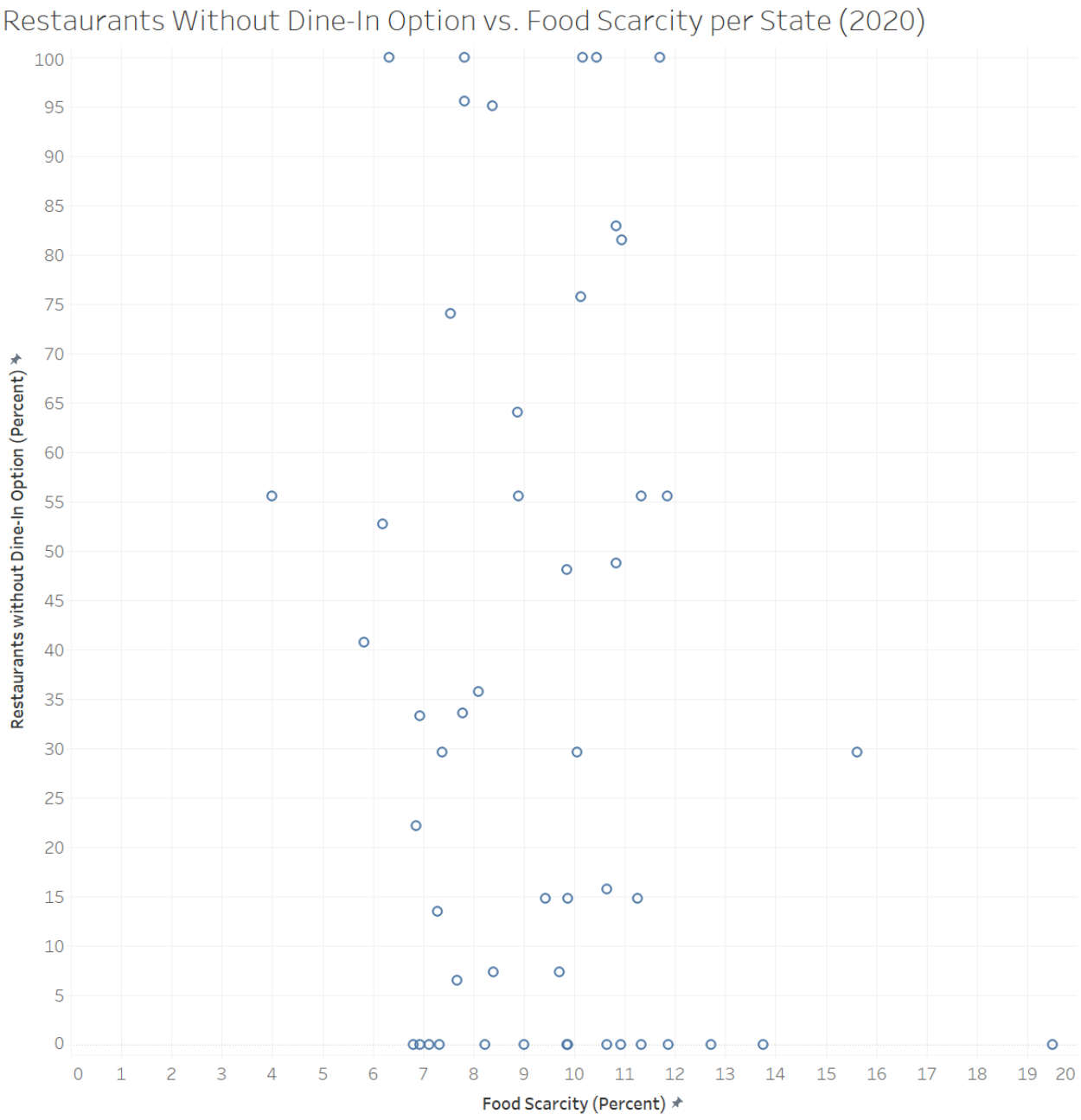
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Food Scarcity (Percent)


Restaurants Without Dine-In Option vs. Food Scarcity per State (2020)
Restaurants without Dine-In Option (Percent)
Food Scarcity (Percent)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
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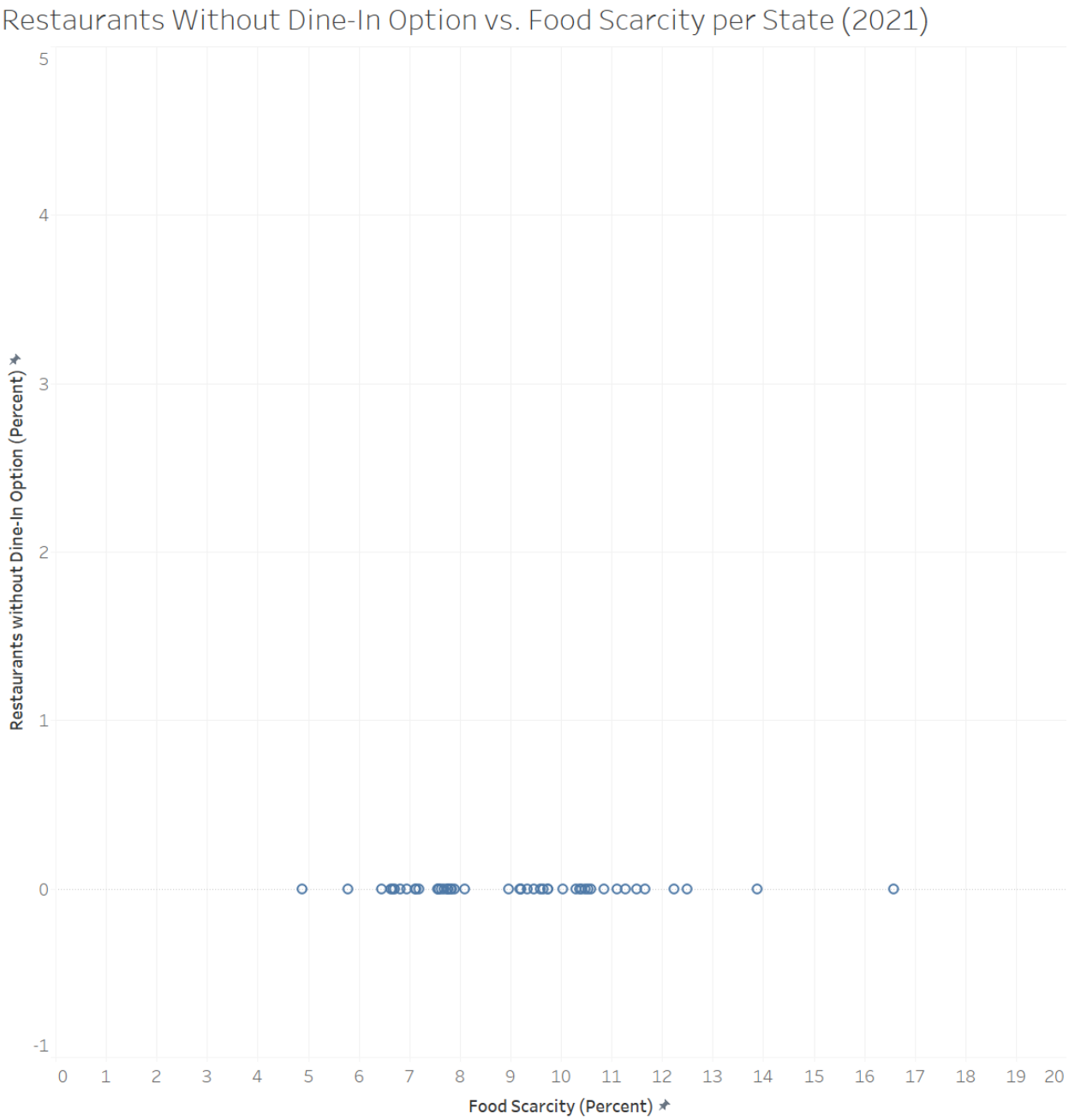

Figure 4.21: State Mandated Restaurant Actions in 2020 and 2021 and Restaurants Without Dine-In Options.

Figure 4.23 compares the actions restaurants in the United States took in response to COVID-19 in relation to restaurants and food scarcity per state. The actions taken are restaurants are fully open, restaurants are open with restrictions, meaning social distancing, and restaurants that do not have a dine-in option, which mostly consists of take out or curbside pickup. There seems to be very little correlation between food scarcity and the action taken on restaurants, but there is a significant change between 2020 and 2021. More restaurants were allowed to fully open in 2021, compared to 2020, and all restaurants were allowed to have a dine-in option in 2021, which

shows the progress made in mitigating the risk of COVID-19. This figure suggests there is minimal direct impact on food scarcity levels within a state due to the actions taken by restaurants in response to the pandemic. This may be largely related to supermarkets not being considered in this analysis, which is a major food source for households, apart from restaurants.

19. How does unemployment during the COVID-19 pandemic relate to food scarcity in each state?

Figure 4.22: Unemployment Rate vs. Food Scarcity in 2020 and 2021.

Figure 4.24 compares the unemployment rate and food scarcity in 2020 and 2021 per state. There seems to be a positive correlation between these in both years, meaning higher unemployment rates contributed to the increased food scarcity within each state. The reason for this correlation is that unemployment often leads to financial hardship, making it difficult for households to afford necessities such as food. When people lose their jobs, their income decreases, and they may not be able to afford food, resulting in food insecurity. Unemployment seems to go down between 2020 and 2021, as expected, as it was between the transition out of the COVID-19 pandemic. This is due to many businesses reopening, which meant people regained employment, resulting in the decrease in unemployment rate. This shows the progress in economic recovery the years leading out of the pandemic.

20. How does state income impact food scarcity during COVID-19?

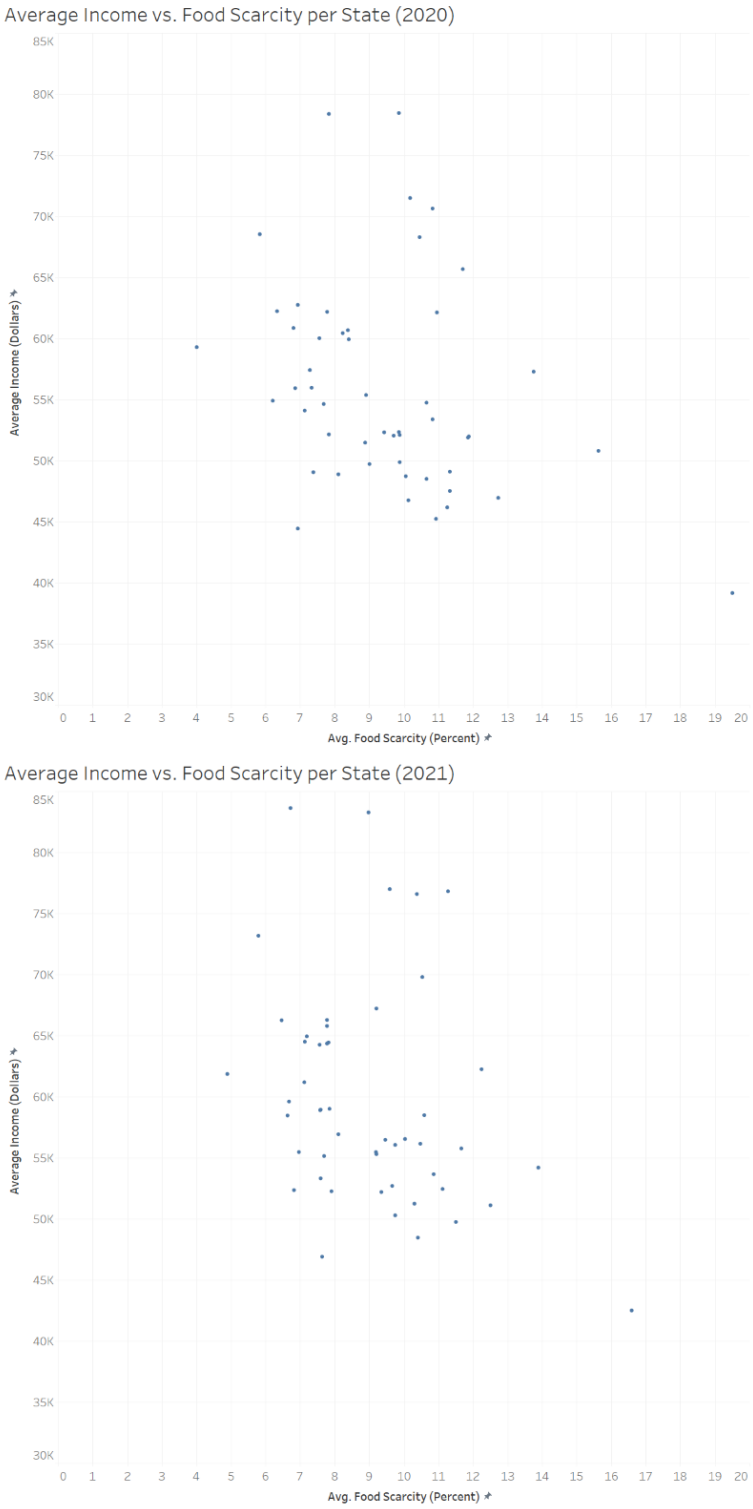

Figure 4.23: Average Income vs. Food Scarcity per State in 2020 and 2021.

Figure 4.25 compares the average income and food scarcity per state in 2020 and 2021. There seems to be no correlation in both years between income and food scarcity. The lack of correlation between income and food scarcity may be related to the income distribution within states, as higher income individuals may hide those who suffer from poverty and food scarcity. Government assistance programs such as Supplemental Nutrition Assistance Program (SNAP) also helps individuals put food on the table, even though they are a low-income household, which may relate to the minimal correlation.

21. How does the Social Vulnerability Index per county relate to the income per county during COVID-19?

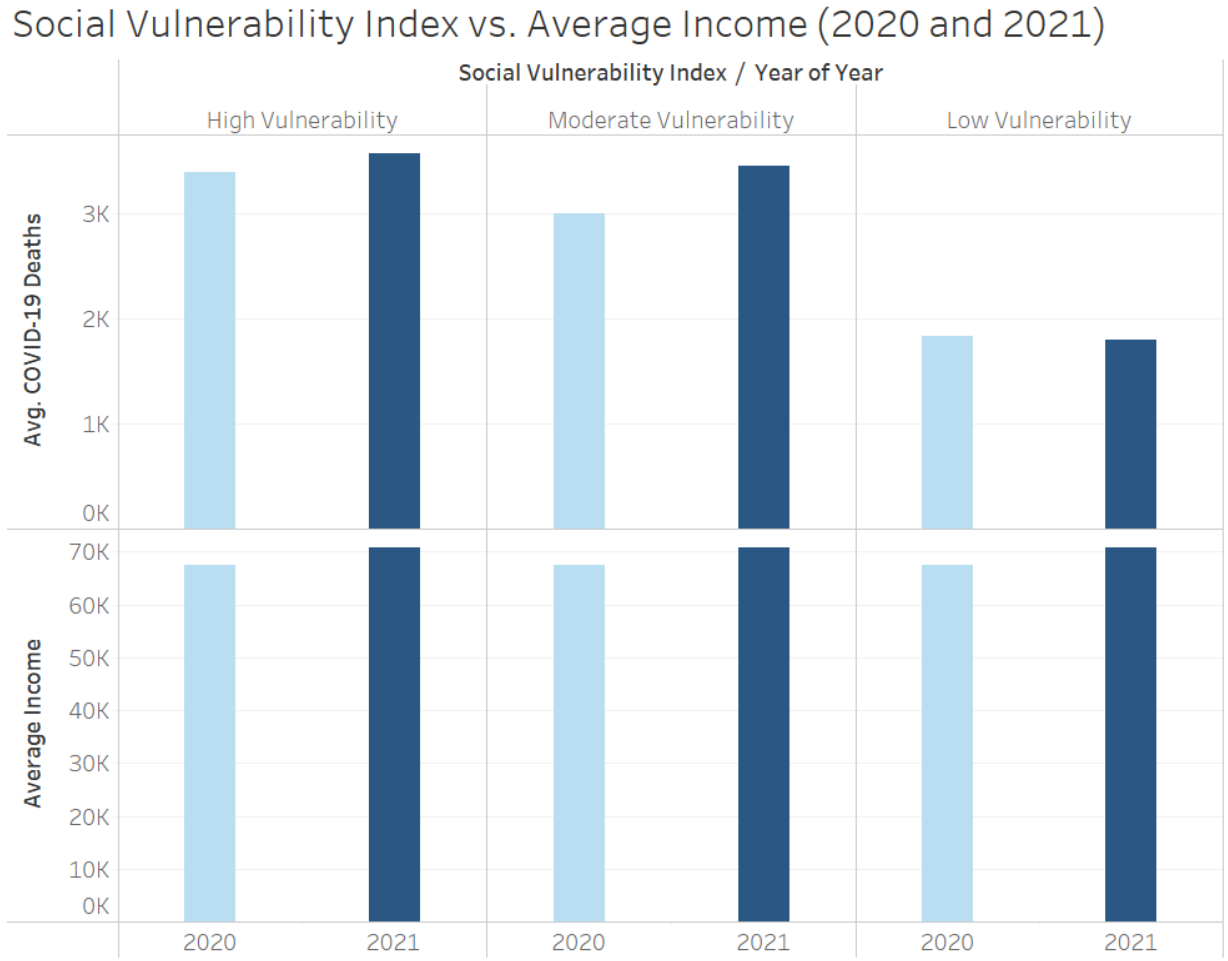

Figure 4.24: Social Vulnerability Index vs. Average Income. Vulnerability ranges from high, medium and low.

Figure 4.26 compares the Social Vulnerability Index to the Average Income in 2020 and 2021. "Social Vulnerability refers to the potential negative effects on communities caused by external stresses on human health" (Centers for Disease Control and Prevention/Agency for Toxic

Substances and Disease Registry, 2022). It seems like both the average number of COVID-19 deaths and average income increased between 2020 and 2021 for the High and Moderate Vulnerabilities, however, the average number of COVID-19 related deaths decreased for those with Low Vulnerability. There seems to be a connection between social vulnerability and the average income. The higher the social vulnerability of a community, the lower the average income. This is because low-income communities are more vulnerable to negative health outcomes due to inadequate access to healthcare, poor housing conditions, and limited access to resources such as healthy food or fitness centers. Another observation is the average number of COVID-19 related deaths decreased for communities with low vulnerability between 2020 and 2021. This is because low vulnerability communities tend to have a higher average income, meaning they have access to better healthcare resources.

22. How has the average length of hospital stays changed throughout the COVID-19 pandemic between age groups?

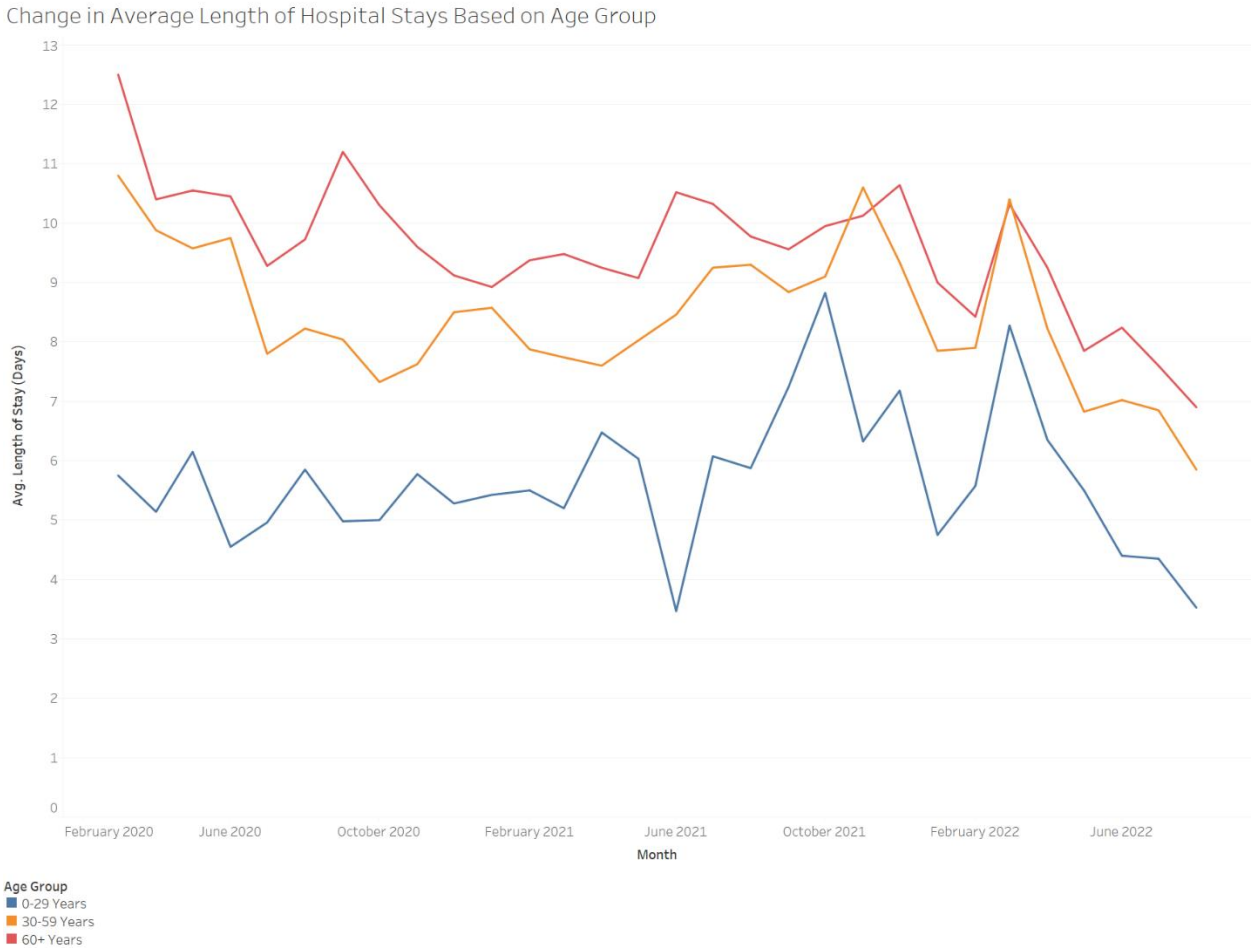

Figure 4.25: Change in Average Length of Hospital Stays Based on Age Group. Age groups are 0-29 years, 30-59 years, and 60+ years.

Figure 4.27 represents the average length of hospital stays for those infected with COVID-19 in different age groups from February 2020 to July 2022. The older the age group, the longer the average hospital stay was. All age groups followed a similar trend. This is because of different COVID-19 variants hospitalizing those infected for longer. Other factors relating to these trends may include improvement of treatment and medicine, hospital capacity and staff availability, and vaccination statuses of patients. There seems to be spikes in early 2020, mid-late 2020, mid 2021, late 2021, and early 2022. This relates to the Alpha variant being discovered in September 2020, Beta variant being discovered in May 2020, Gamma variant being discovered in November 2020, Delta variant being discovered in December 2020, and Omicron variant being discovered in November 2021 (World Health Organization, 2022).

23. How has the average length of hospital stays changed throughout the COVID-19 pandemic changed depending on whether a person was discharged alive or dead?

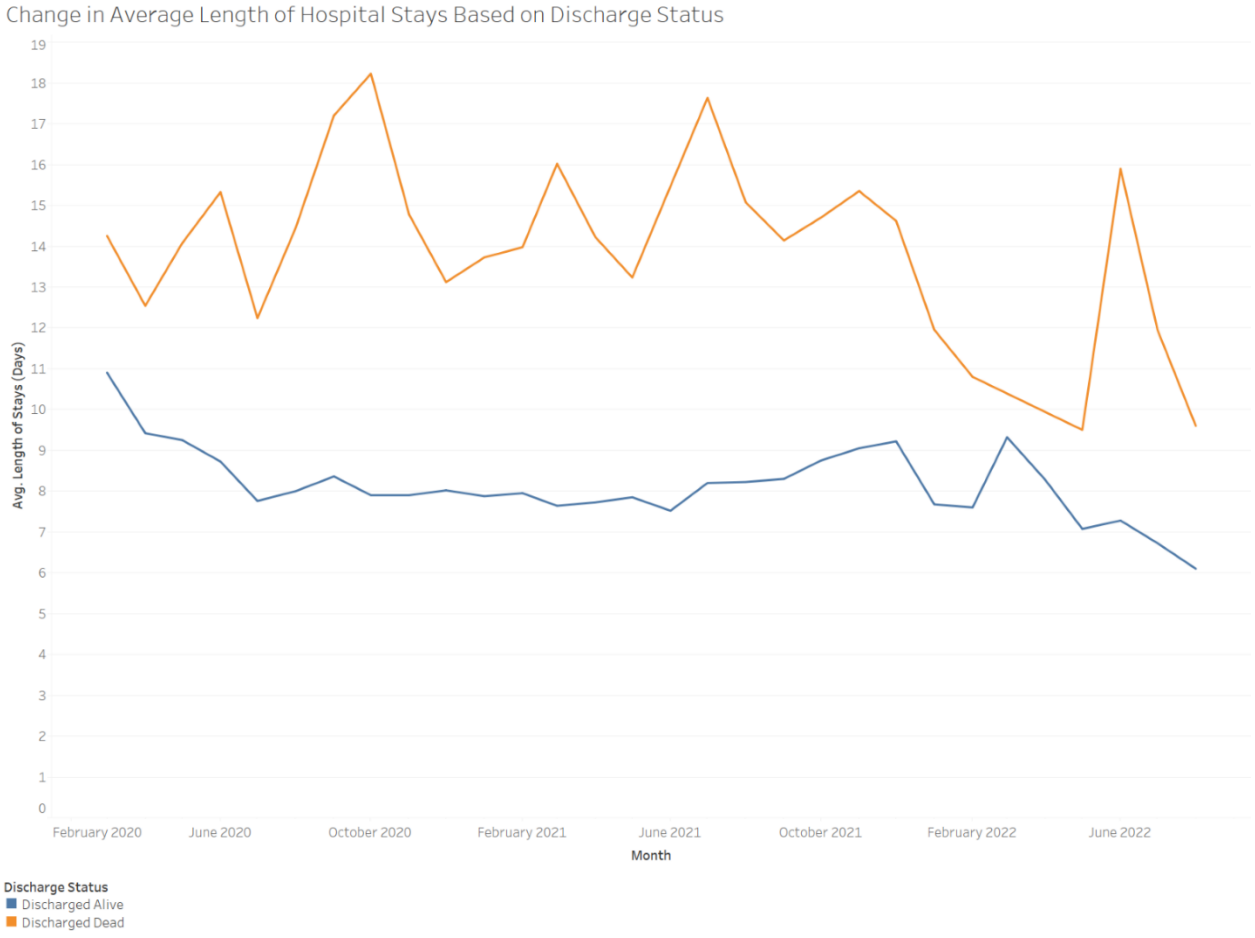

Figure 4.26: Change in Average Length of Hospital Stays Based on Discharge Status.

Figure 4.28 represents the average length of hospital stays for those infected with COVID-19 who were either discharged alive or dead from February 2020 to June 2022. Those who were discharged dead have a higher average hospital stay length than those who were discharged alive. For the discharge alive trend, it seems to be more stable than the trend of those discharged dead, which seems to have many spikes in the average length of hospital stay. This relates to the COVID-19 variants causing more severe symptoms and a higher risk of hospitalization as they arose. These variants were nullifying the immunity caused by existing vaccines, which led to a higher risk of severe illness, resulting in a longer hospital stay.

24. How did unemployment during the COVID-19 pandemic affect mental health help?

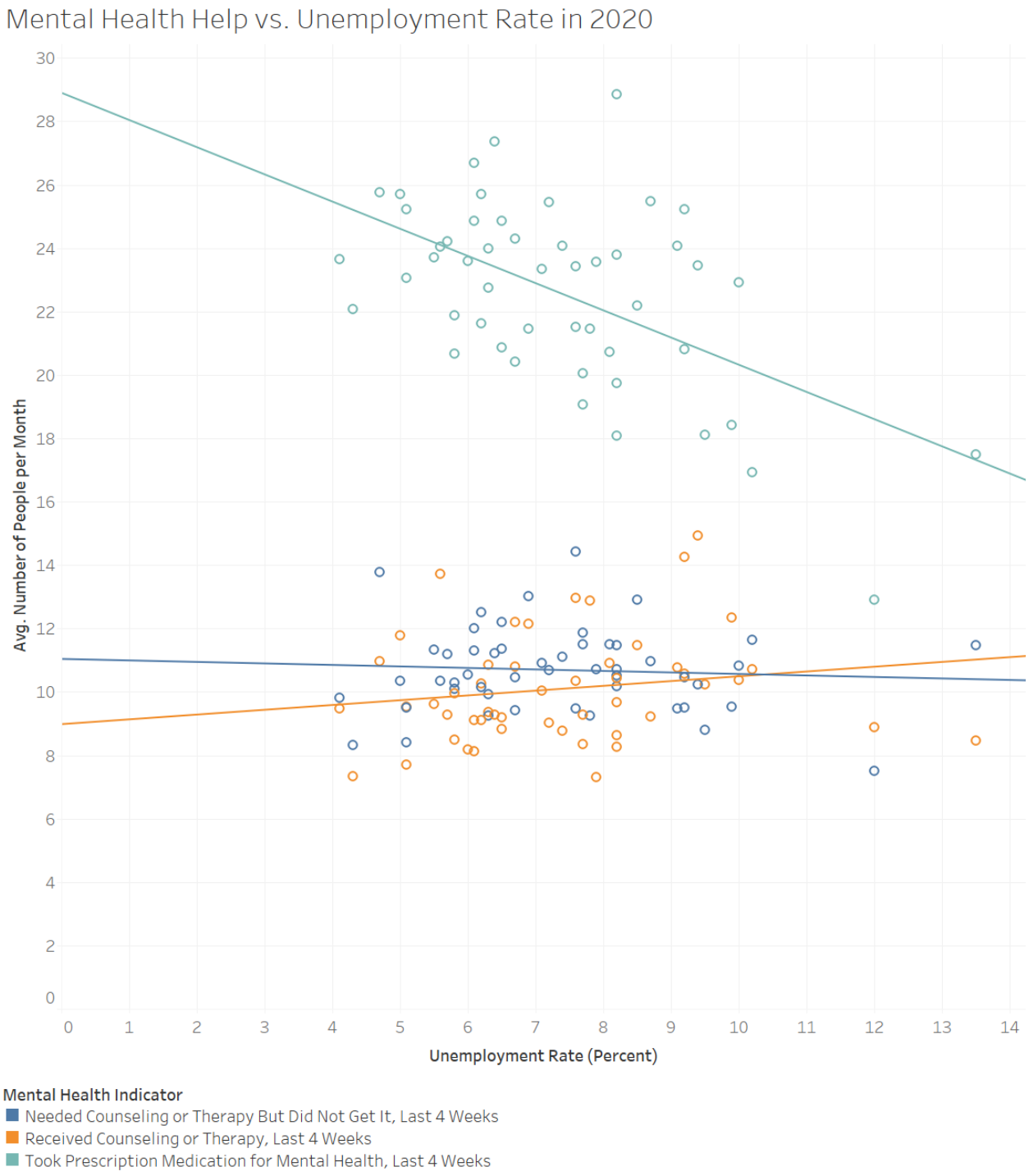

Figure 4.27: Mental Health Help vs. Unemployment Rate in 2020.

Figure 4.29 represents the average number of people per month who receive mental health help for COVID-19 per state compared to the unemployment rate in 2020. There are three categories for mental health: people who needed counseling or therapy but did not receive it, people who received counseling or therapy, and people who took prescription medication for mental health. There seems to be a negative correlation between the average amount of people who took prescription medication for mental health and the unemployment rate. For those who needed or received counseling or therapy, there does not seem to be much change in the average number of people when the unemployment rate increases.

Chapter 5: Recommendations and Conclusions

We explored a handful of different areas and asked a few questions about each. These areas were location, demographic, well-being and employment and income. Future researchers may want to explore one of the categories more deeply or explore more broad impacts of COVID-19. Future work may include more organization of data sets, a website with interactive visualizations, and expansion on currently answered questions. We recommend that researchers use the graphs we have produced as a starting point for their individual work.

Through the research our team conducted on the COVID-19 disease, we have gained a better understanding of the social, economic, and wellbeing of the United States population. Despite the significant progress in our understanding of its impact, there is still much more research to be done. As COVID-19 is still a relatively new disease, a pressing area of research is the long-term effects of the disease. It is a complex disease that will require continuous research to fully understand it’s effects and develop effective interventions. Other areas of research consist of employment, tourism, education, and mental health. Using other datasets may also provide new perspectives into the questions we have already answered. The CDC datasets limited the questions we were able to ask, and kept our scope limited to the data we had at hand.

Appendices

Appendix A: Datasets Used

#	Name of dataset	Accessed when (find download date)	From where (CDC, National Pulse Survey)
1	Provisional COVID-19 Death Counts in the United States by County	10/10/2022	CDC
2	COVID-19 Vaccinations in the United States County	1/30/2023	CDC
3	Personal Income by County, Metro, and Other Areas	1/30/2023	https://www.bea.gov/data/income-saving/personal-income-county-metro-and-other-areas
4	American Rescue Plan (ARP) Rural Payments	1/30/2023	CDC
5	Difficulty Paying Household Pulse Survey	2/15/2023	Household Pulse Survey
6	AH Cumulative Provisional COVID-19 Death Counts by Place of Death and Age Group from 2/1/2020 to 7/18/2020	1/30/2023	CDC
7	Household Telehealth	2/8/2023	Household Pulse
8	Provisional COVID-19 Deaths by Sex and Age	3/13/2023	CDC
9	United States by Density 2022	11/2022	World Population Review

10	Excess Deaths Associated with COVID-19	9/2022	CDC
11	Food Scarcity	1/2023	Household Pulse
12	Worked Onsite at a Workplace	2/2023	Household Pulse
13	COVID-19 Associated School Closures	10/2022	CDC
14	COVID-19 Vaccination Demographics in the United States National	9/2022	CDC
15	U.S. State and Territorial Orders Closing and Reopening Restaurants Issued from March 11, 2020 through August 15, 2021 by County by Day	2/2023	CDC
16	Provisional COVID-19 Deaths by Week and County Social Vulnerability Index	2/2023	CDC
17	COVID-19 Hospital Data from the National Hospital Care Survey	2/2023	CDC
18	Mental Health Care in the Last 4 Weeks	2/2023	CDC
19	Unemployment Rates for States, 2020 Annual Averages	2/2023	https://www.bls.gov/lau/lastrk20.htm

20	Unemployment Rates for States, 2021 Annual Averages	2/2023	https://www.bls.gov/lau/lastrk21.htm

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