Paper

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Contents

Introduction

Chattahoochee County, Georgia has reported that 99.9% of their population is vaccinated against COVID-19, according to the CDC, while other counties continue to report alarming single-digit vaccination percentages. Over 600,000 Americans have died due to COVID-19. Fully vaccinated people accounted for less than 1% of all US COVID-19 deaths in May and close to the same percent of all hospitalizations, meaning that almost all current and future US COVID-19 deaths are entirely preventable. Therefore, it is self-evidently in the interest of public health to understand what factors contribute to ongoing vaccination disparities between US counties. Our investigation seeks to address this broad question by exploring the relationships between county-level vaccination and COVID-19 cases and deaths in relation to variables like politics, race, and vaccine hesitancy.

Data

`census_county` and `census_region`

We used the `tidycensus` package in R to obtain American Community Survey 5-year data for the 2014-2019 span. The ACS is an annual survey that still collect large amounts of data from every single county in the

US, so the data is more recent than the 2010 census and is still very comprehensive (2020 census data is not publicly avaiilable yet). We called two different data sets with different geographies: For one set, we got all the desired variables by county, while for the other set, we called the variables by region. The variables we called are as follows:

1. `med_income` (B19013_001 in `tidycensus`): the median income of the chosen geography's population (each county in census_county, each region in census_region).
2. `male` (B01001_002): the total number of males in the selected geography's population.
3. `female` (B01001_026): the total number of females in the selected geography's population.
4. `med_age` (B01002_001): the median age of the chosen geography's population.
5. `white` (B01001A_001): the total number of white residents in the selected geography's population.
6. `black` (B01001B_001): the total number of black residents in the selected geography's population.
7. `asian` (B01001D_001): the total number of asian residents in the selected geography's population.
8. `hispanic` (B01001I_001): the total number of hispanic residents in the selected geography's population.
9. `total` (B01001_001): the total population of the selected geography.
10. `other` (B01001F_001): the total number of residents of "other" races in the selected geography.

We then created several columns of our own data:

1. `percent_male`: the percentage of the population of the selected geography that is male.
2. `percent_female`: the percentage of the population of the selected geography that is female.
3. `percent_white`: the percentage of the population of the selected geography that is white.
4. `percent_black`: the percentage of the population of the selected geography that is black.
5. `percent_hispanic`: the percentage of the population of the selected geography that is hispanic.
6. `percent_asian`: the percentage of the population of the selected geography that is asian.
7. `percent_other`: the percentage of the population of the selected geography that is of "other" race.

Daily Covid counts

We collected 537 days' worth of Covid data—cases and deaths—from the New York Times. These data are at the county level. Some counties, such as those in Washington State where Covid was first recorded in the US, report cases as early as January; others only start reporting in March and beyond.

Variables:

1. `date` - the date of the reporting
2. `county` - the county name
3. `state` - the state name
4. `fips` - the FIPS code for that county
5. `cases` - the number of cumulative cases in that county as of that date
6. `deaths` - the number of cumulative deaths in that county as of that date

Presidential Election Results by County

This dataset gives the number of votes cast for the major Democratic and Republican candidates for 2016 in 2020, along with the total number of votes cast, for each U.S. county. It was taken from the MIT Election Data and Science Lab's County Presidential Election Returns 2000-2020 dataset by filtering the year.

Variables:

1. `year` - the year of the election results, numerical
2. `state` - the state in which the county is located, character
3. `state_po` - the two-letter abbreviation for the state in which the county is located, character
4. `county_name` - the name of the county, character
5. `county_fips` - the county FIPS code, numerical
6. `office` - the office the election results are for - President for all rows, character

7. `candidate` - the presidential candidate that the candidate votes in the row refer to, character
8. `party` - the political party of the candidate, character
9. `candidatevotes` - the number of votes cast for the candidate, numerical
10. `totalvotes` - the total number of votes cast in the county for the election, numerical

Main Vaccination Dataset

We collected county-level vaccination data from the CDC's COVID-19 Data Tracker. Texas does not report county-level vaccination information to the CDC COVID-19 Data Tracker, and California does not report information for counties with fewer than 20,000 residents. All other US counties are included in this dataset. The dataset also contains county Social Vulnerability Index (SVI) information. SVIs are produced by the CDC and Agency for Toxic Substances and Disease Registry based on US Census data and take into account factors like poverty, lack of vehicle access, and crowded housing.

Variables:

1. `Date` - the date for which the data in the row is reported in the format mm/dd/yyyy, character
2. `FIPS` - the county FIPS code, character
3. `MMWR_week` - the Morbidity and Mortality Weekly Report week, numerical
4. `Recip_County` - the county name, character
5. `Recip_State` - the two-letter state abbreviation for the state in which the county is located
6. `Series_Complete_Pop_Percent` - the percentage of the population that is fully vaccinated, numerical
7. `Series_Compete_Yes` - the total number of people in the county who are fully vaccinated, numerical
8. `Series_Complete_12Plus` - the total number of people in the county over 12 years old who are fully vaccinated
9. `Series_Complete_12Plus_Pop_Percent` - the percentage of the population over 12 years old that is fully vaccinated, numerical
10. `Series_Complete_18Plus` - the total number of people in the county over 18 years old who are fully vaccinated, numerical
11. `Series_Complete_18Plus_Pop_Percent` - the percentage of the population over 18 years old that is fully vaccinated, numerical
12. `Series_Complete_65Plus` - the total number of people in the county over 18 years old who are fully vaccinated, numerical
13. `Series_Complete_65Plus_Pop_Percent` - the percentage of the population over 18 years old that is fully vaccinated, numerical
14. `Completeness_pct` - an estimate of how complete the vaccination data is for the county, numerical
15. `Administered_Dose1_Recip` - number of first vaccine doses administered, numerical
16. `Administered_Dose1_Pop_Pct` - percentage of the population that has received dose 1, numerical
17. `Administered_Dose1_Recip_12Plus` - number of first vaccine doses administered to people over 12 years old, numerical
18. `Administered_Dose1_12PlusPop_Pct` - percentage of the population over 12 years old that has received dose 1, numerical
19. `Administered_Dose1_Recip_18Plus` - number of first vaccine doses administered to people over 18 years old, numerical
20. `Administered_Dose1_18PlusPop_Pct` - percentage of the population over 18 years old that has received dose 1, numerical
21. `Administered_Dose1_Recip_65Plus` - number of first vaccine doses administered to people over 65 years old, numerical
22. `Administered_Dose1_65PlusPop_Pct` - percentage of the population over 65 years old that has received dose 1, numerical
23. `SVI_CTGY` - Social Vulnerability Index category (Low, Low-Mod, Mod, Mod-High, High), character
24. `Series_Complete_Pop_Pct_SVI` - categorizes vaccination levels and SVI (Low, Low-Mod, Mod, Mod-High, High), character

25. `Series_Complete_Pop_Pct12Plus_SVI` - categorizes vaccination levels in the population over 12 years old and SVI (Low, Low-Mod, Mod, Mod-High, High), character
26. `Series_Complete_Pop_Pct18Plus_SVI` - categorizes vaccination levels in the population over 18 years old and SVI (Low, Low-Mod, Mod, Mod-High, High), character
27. `Series_Complete_Pop_Pct65Plus_SVI` - categorizes vaccination levels in the population over 18 years old and SVI (Low, Low-Mod, Mod, Mod-High, High), character

Texas Vaccination

To complete our county-level vaccination data, we collected vaccination data from the Texas Department of Health and Human services COVID-19 Vaccination in Texas Summary.

Variables:

1. `County_Name` - character
2. `PHR_critical_Pop` - Public Health Region in which the county is located, character
3. `Estimated_Coverage_(12+_1Dose)` - estimated percentage of the population over 12 that has received one dose (taking into account probable completeness of reporting), numerical
4. `Estimated_Coverage_(12+_Fully)` - estimated percentage of the population over 12 that has been fully vaccinated (taking into accouCOVIDnt probable completeness of reporting), numerical
5. `Estimated_Coverage_(65+_1Dose)` - estimated percentage of the population over 65 that has received one dose (taking into account probable completeness of reporting), numerical
6. `Estimated_Coverage_(65+_Fully)` - estimated percentage of the population over 65 that has been fully vaccinated (taking into account probable completeness of reporting), numerical
7. `People_Fully_Vaccinated` - actual reported number of people who have been fully vaccinated, numerical
8. `People_with_at_least_One_Dose` - actual reported number of people with at least one vaccine dose, numerical
9. `Percentage_Vaccinated` - percentage of total population that has been reported as fully vaccinated, numerical
10. `Population_16Up` - total population of people at least 16 years old, numerical

Small California Counties Vaccination

To complete our county-level vaccination data, we obtained the total number of people vaccinated and the total number of people who have received at least one dose from all counties in California with fewer than 20,000 residents from democratandchronicle.com.

Variables:

1. `County` - the name of the county, character
2. `FIPS` - county FIPS code, numerical
3. `One_Dose` - number of people who have received at least one vaccine dose, numerical
4. `Two_Doses` - number of people who are fully vaccinated, numerical

Vaccine Hesitancy

We obtained county-level estimates of the percentage of the population who is hesitant to receive the COVID-19 vaccine from the CDC. The CDC calculates and compiles these estimates based on Household Pulse Survey data. The dataset also includes racial demographics and SVI (Social Vulnerability Index) information (see Main Vaccination Dataset for details on SVI), as well as geographical information because it was designed to produce a map.

Variables:

1. `FIPS Code` - county FIPS code, numerical
2. `County Name` - character
3. `State` - state in which the county is located, character
4. `Estimated Hesitant` - estimated percentage of the population with any degree of vaccine hesitancy, numerical
5. `Estimated Hesitant or unsure` - estimated percentage of the population that is either hesitant to receive the vaccine or unsure about how they feel about the vaccine, numerical
6. `Estimated Strongly Hesitant` - estimated percentage of the population that is strongly hesitant to receive the vaccine, numerical
7. `Social Vulnerability Index (SVI)` - CDC/ATSDR Social Vulnerability Index, numerical
8. `SVI Category` - Social Vulnerability Index category (Low, Low-Mod, Mod, Mod-High, High), character
9. `level of concern for vaccination rollout` - CDC's estimated level of concern for getting the population of the county vaccinated on a scale of 0 to 1, numerical
10. `CVAC Level of Concern` - categorical variable describing CDC's level of concern (Very High Concern, High Concern, Moderate Concern, Low Concern, Very Low Concern), character
11. `Percent adults fully vaccinated against COVID-19 (as of 6/10/21)` - character
12. `Percent Hispanic` - numerical
13. `Percent non-Hispanic American Indian/Alaskan` - numerical
14. `Percent non-Hispanic Asian` - numerical
15. `Percent non-Hispanic Black` - numerical
16. `Percent non-Hispanic Native Hawaiian/Pacific Islander` - numerical
17. `Percent non-Hispanic White` - numerical
18. `Geographical Point` - ordered pair (longitude, latitude) marking the starting point for the county boundary - character
19. `County Boundary` - a series of ordered pairs (longitude, latitude) marking the boundary of the county - character

Methods

Note: This is an outline of our methods section.

- Linear regression to find predictors of vaccine hesitancy, specifically race and partisanship
- Linear regression to find predictors of vaccination rate, specifically race, partisanship, vaccine hesitancy, and other demographics (e.g. income)
  - Together, this can suggest whether vaccine hesitancy is a mediator, moderator, or neither
- Linear regression to examine relationship between vaccination rate and cumulative deaths, controlling for race and partisanship
  - This can shed light on whether the severity of the pandemic in a county influences residents' desire to get vaccinated

t test for SVI data

Difference in Means	Mean, Vulnerable	Mean, Not Vulnerable	p value	95% Confidence Lower Bound	95% Confidence Upper Bound	Alternative Hypothesis
-0.06	0.338	0.398	0	-Inf	-0.052	less

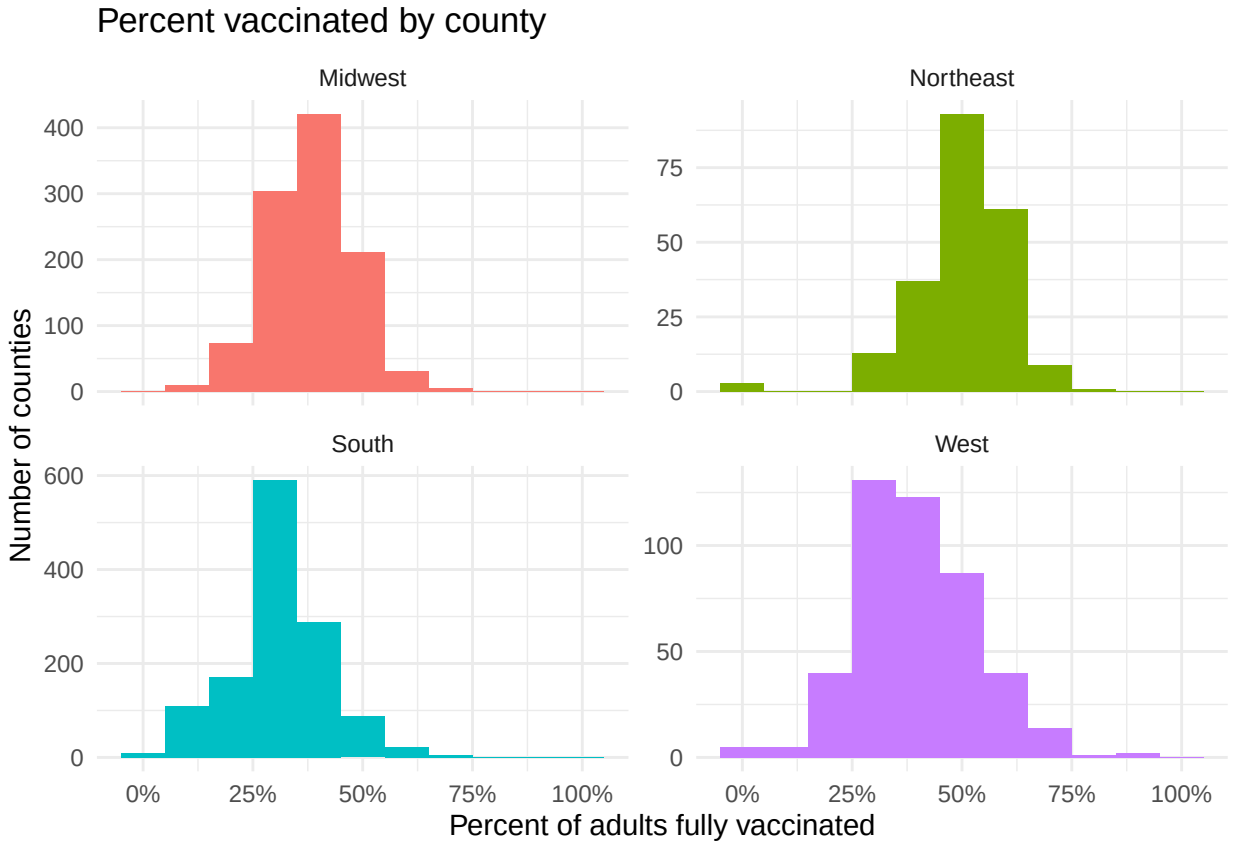
Results

County Vaccination Histogram by Region

The faceted histogram above demonstrates several important ideas. First, the Northeast region of the country displays a clear lead in the percentage of counties that have higher levels of full vaccination among residents. A large majority of counties in the Northeast are at least 65% fully vaccinated, and many are reaching the 70-75% full vaccination levels that can signal the beginnings of herd immunity. Furthermore, the data is more centralized in the Northeast compared to the other regions, suggesting that there is not a large level of hesitancy or belief in misinformation about the vaccine.

Meanwhile, the South is lagging behind the other three regions as a large portion of its counties are still in the 35-45% fully vaccinated range. Additionally, there is wider range in the data, and there are many counties that are still below a 25% full vaccination threshold. This could be a result of or correlated to several influencing factors which will be discussed in other results, including demographics, hesitancy, and politics.

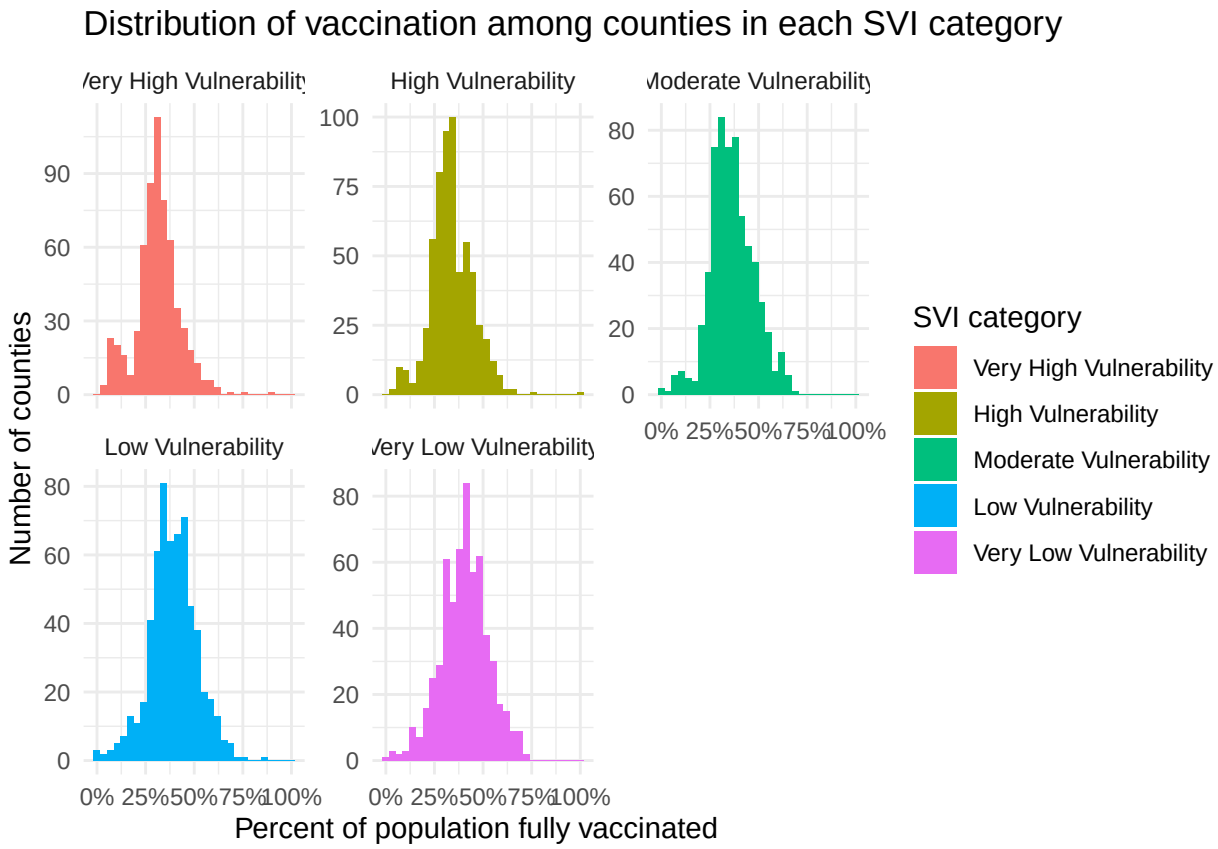
The Midwest and West are very similar in that they both have a peak around the 45-55% range. Both regions display a wide range of vaccination levels in both directions, suggesting that there is a wide array of willingness to get vaccinated within those regions.

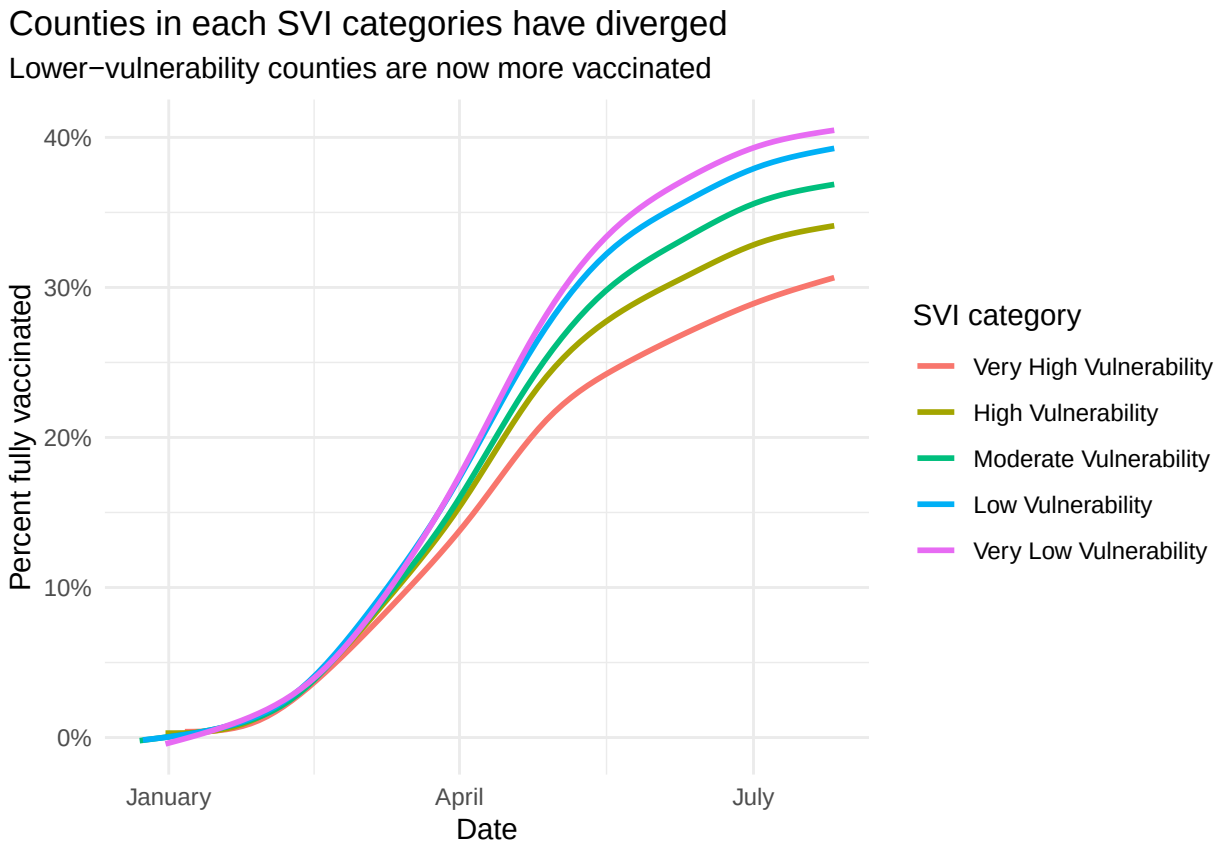


How is a county's Social Vulnerability Index related to its rate of vaccination?

Over time, vaccination levels in higher vulnerability counties have tapered off at lower percentages than those of lower vulnerability counties, which the second plot (showing the average vaccination rate of counties over time grouped by SVI category) clearly demonstrates. However, the distributions of vaccination rates in counties of broadly differing SVI categories overlap considerably, as indicated by the histograms, showing that SVI alone is not a strong predictor of county vaccination rates.

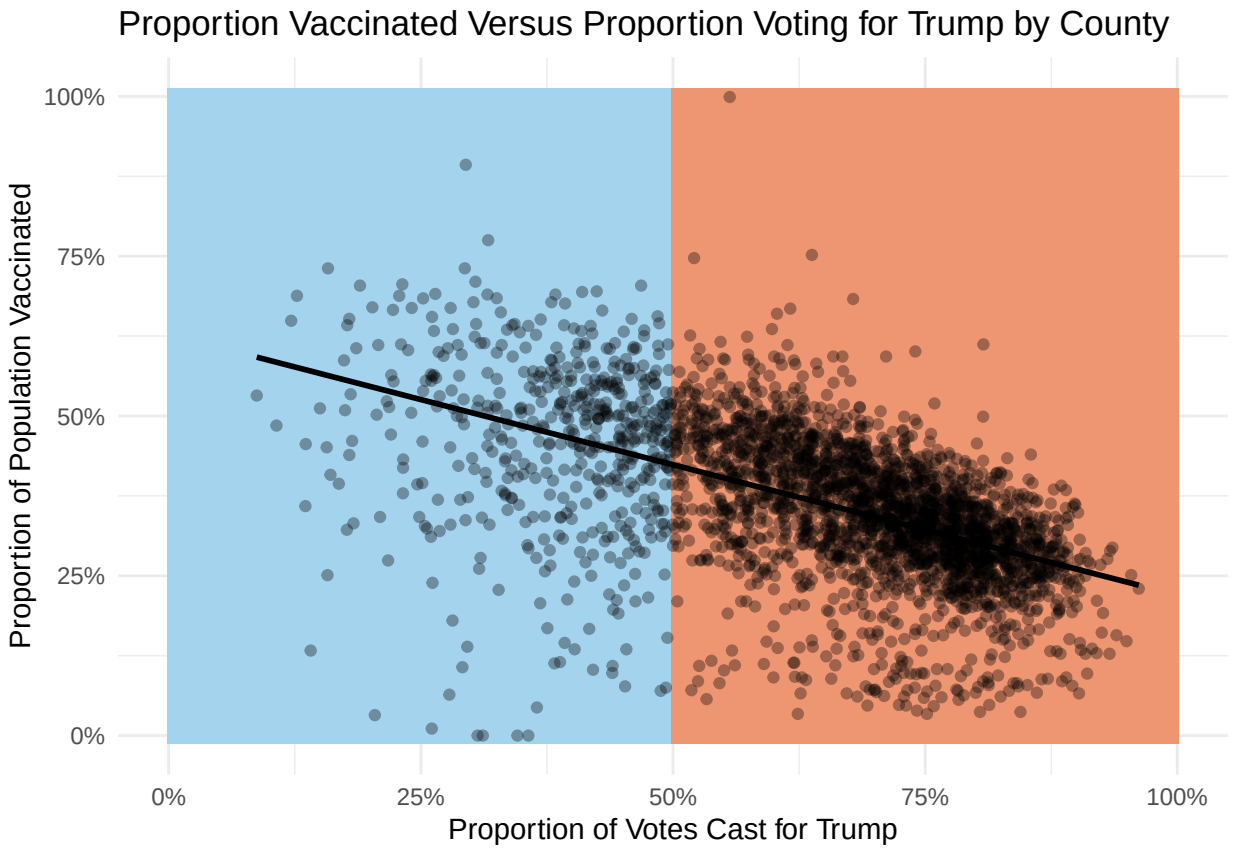
An intriguing feature of the county-level vaccination rate distributions by SVI category is that the very high, high, and moderate vulnerability counties all appear to have a bimodal distribution, with a small peak of very low vaccination levels and a large peak of more moderate vaccination levels. This led us to consider whether there might be a subclass of vulnerable, very low vaccination rate counties in which vaccination rates are influenced by some other variable.





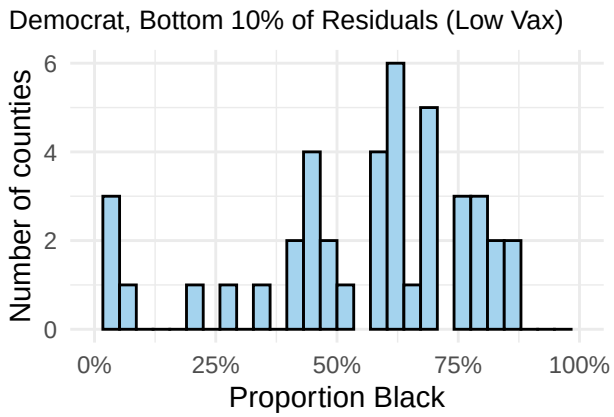
How are the prevailing political views of a county related to its rate of vaccination?

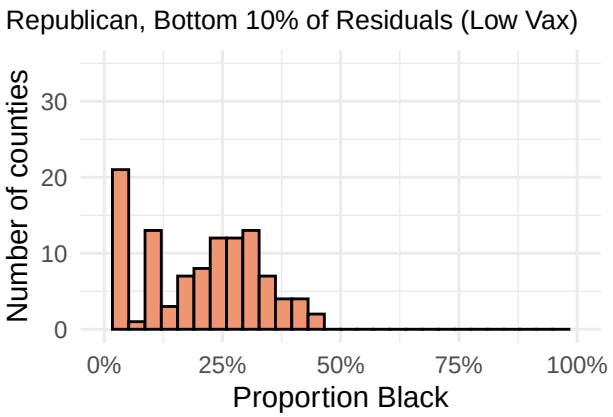
As anticipated, there appears to be a definite negative correlation between the percent of the county that voted for Donald Trump in 2020 and the percent of the population that is vaccinated. Donald Trump and other Republicans have consistently shown themselves to be less in favor of lockdown orders, mask mandates, and COVID-19 vaccinations than Democrats, so the counties in which a larger percentage of the votes were cast for Donald Trump in the 2020 presidential election are likely to be those for whom these anti-COVID precautions seemed reasonable. However, there are outlier counties in the lower left quadrant of the plot with far more or fewer people vaccinated than would have been predicted based solely on their political views. The next section explores race as a potential contributing factor predicting COVID-vaccination rates in these outlier counties.

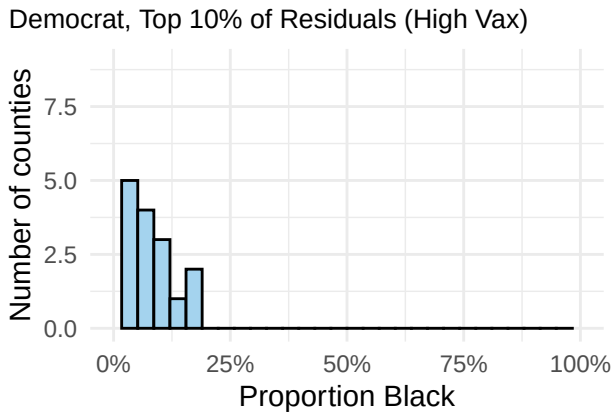


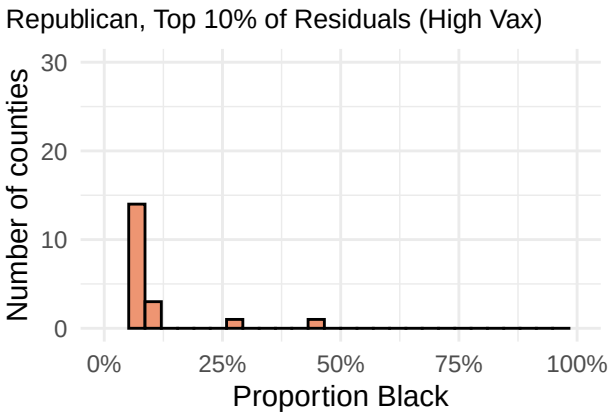
What are the racial demographics of counties that do not conform to the expected relationship between politics and vaccination?

There appeared to be a distinct cluster of democratic counties with unexpectedly low vaccination rates in the lower left corner of the plot on the previous page. We hypothesized that these may be counties with high percentages of non-white residents. To investigate these and other outlier counties, we performed a linear regression on the relationship between proportion of votes cast for Trump and proportion of population vaccinated. We then examined both Democratic (<40% of all votes in the 2020 presidential race cast for Trump) and Republican (more than 60% of all votes cast for Trump) in the top 10% (unexpectedly high vaccination rates) and bottom 10% of residuals (unexpectedly low vaccination rates) from this linear regression. We then produced histograms of the proportion of Black residents in each of these four categories of counties. For the counties with unexpectedly high vaccination rates (both Democratic and Republican), the distribution of proportion Black residents peaked near 0. For the low-vaccination Republican counties, many counties also had a proportion of Black residents near 0, but there was another peak around 0.25. For the Democratic low-vaccination rate counties, the results were even more striking: a majority of counties had more than 35% Black residents. Clearly, counties with lower vaccination rates than predicted by their political leanings are much more likely to have more Black residents than counties with higher vaccination rates than predicted by their political leanings.





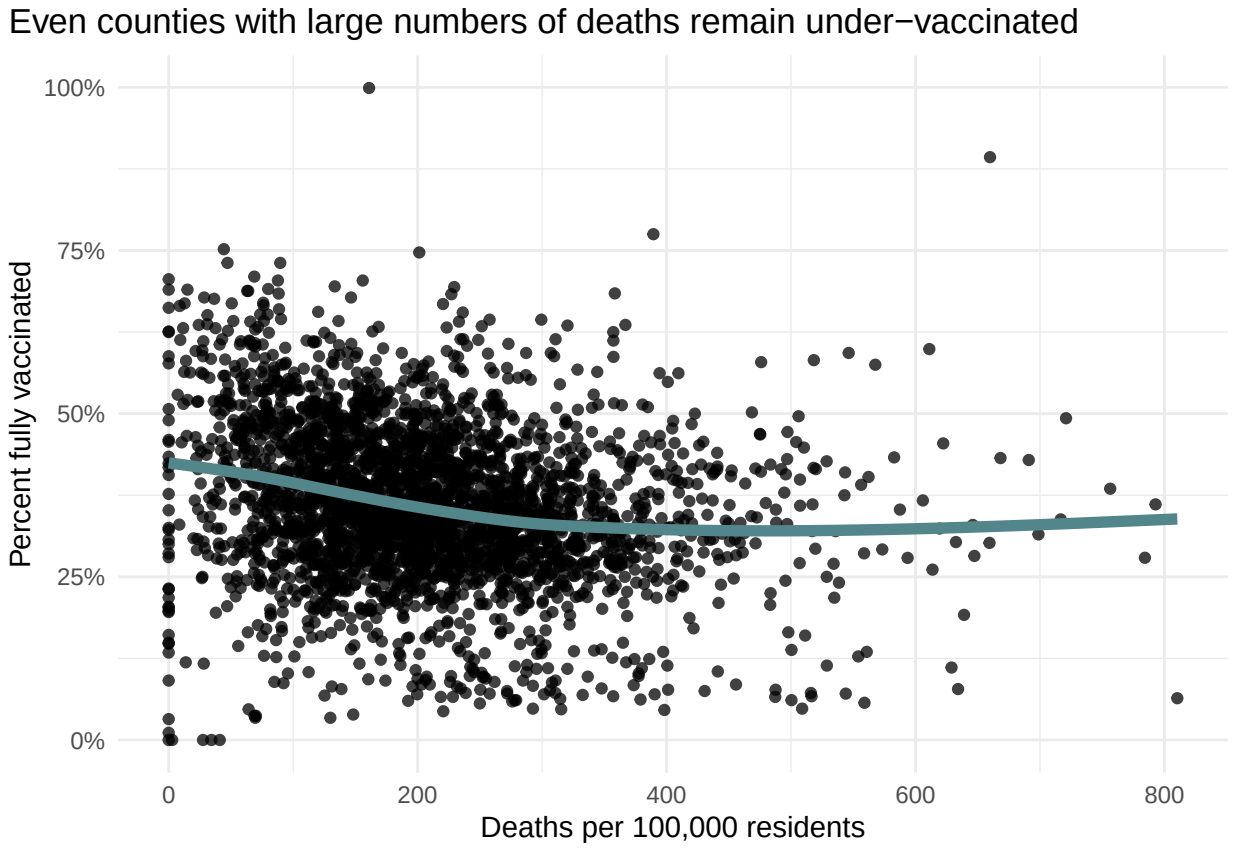




Comparison	Difference in Mean Proportion Black	95% Confidence Lower Bound	95% Confidence Upper Bound	p-value
bottom_red-bottom_blue	-0.3297	-0.3847	-0.2747	0.0000
top_blue-bottom_blue	-0.4430	-0.5222	-0.3639	0.0000
top_red-bottom_blue	-0.4620	-0.5163	-0.4077	0.0000
top_blue-bottom_red	-0.1134	-0.1857	-0.0410	0.0004
top_red-bottom_red	-0.1323	-0.1761	-0.0885	0.0000
top_red-top_blue	-0.0190	-0.0908	0.0529	0.9042

Did the severity of the pandemic within a county affect residents' desire to get vaccinated?

As far as we can tell from this chart, no. However, we haven't yet completed any regressions, so all we have is the plot. We want to regress controlling for demographics and vaccine hesitancy.



Discussion

Appendix