Title

County-Level Segregation and Racial Disparities in COVID-19 Outcomes

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Abstract

Context: Segregation has been linked to unequal life chances. Individuals from marginalized communities experience more crime, higher levels of poverty, poor health, and less civic engagement; and segregated metropolitan regions witness inequality in access to basic services. This paper builds on this previous work by linking segregation to infection and deaths from COVID-19.

Methods: Using Census data matched to COVID infection and death statistics at the county level, we offer a theoretical basis for our choice of segregation measures and predictions for different racial groups. We analyze the relationship between two dimensions of segregation, racial isolation and racial unevenness, and COVID outcomes for different racial and ethnic groups.

Findings: We find that in counties where Black and Latino residents live in more isolated neighborhoods, they were much more likely to contract COVID-19. This pattern was exacerbated in counties with a high proportion of front-line workers. We also find that racial segregation increased COVID-19 death rates for Black, Latino, *and* white residents.

Conclusions: Our findings suggest that devastating outcomes of the coronavirus pandemic were linked to a long history of racial marginalization and entrenched discrimination produced by structural inequalities embedded in our geographies and should inform public health planning going forward.

Patterns of racial segregation in America embody what Paul Starr has called "strategic entrenchment." According to Starr, entrenchment is the process by which institutions become resistant to pressures for change; and strategic entrenchment is the purposeful pursuit of this irreversibility. Since the early decades of the 20th century, white Americans have utilized a variety of mechanisms to create and maintain segregated neighborhoods, purposefully walling off their communities from people of color. For more than 100 years, segregation has been reinforced by both individual action and government policy, such that the separation of demographic groups across neighborhood and city lines has become endemic. Neighborhoods in America remain highly segregated along racial lines. The typical white American lives in a neighborhood that is overwhelmingly white, while Black, Latino, and Asian Americans live in substantially more integrated places (Logan and Stults 2011).[1] These patterns have created stark divides between white and nonwhite communities (Enos 2011).

Scholars have provided extensive evidence that segregation is associated with negative outcomes for marginalized residents, including work exploring the relationship between segregation and public health. Several recent papers have shown that segregation or high proportions of residents of color are associated with high COVID infection and death rates. We add to this emerging body of work with an analysis of the relationship between segregation and COVID-19 infection and death rates for different racial groups, similar to initial efforts by Torrats-Espinosa (2021). Our particular contribution is to offer a theoretical basis for our choice of segregation measures and predictions for different racial groups, as well as linking COVID outcomes to a long history of racial marginalization and entrenched discrimination. We show

[1] African Americans, Latinos, and Asians live in neighborhoods that are comprised of 22%-46% of their own group.

that counties with more isolated communities of color had significantly higher rates of COVID-19 infection among Black and Latino residents. We also identify an important interaction effect whereby the association between segregation and infection rates is modified by the share of front-line workers in a community. In counties with a high share of front-line workers *and* segregation, COVID-19 infection was even higher among Black and Latino residents; a result that is predicted by the public health literature on the spread of infectious diseases in segregated places. Finally, we analyze the degree to which segregation is associated with COVID-19 death rates. We find that more segregated counties witnessed higher death rates across the board – for Black, Latino, and white residents – indicating that segregation is associated with negative consequences for everyone. This finding echoes existing scholarship showing that segregation causes underinvestment in public goods and poor outcomes for communities (Trounstine 2016).

This paper proceeds by offering an overview of the history of the entrenchment of segregation, followed by a discussion of known consequences of segregation. We then describe our data and research design and present our results.

History of Segregation

At the turn of the 20th century, most Americans lived on family farms in rural communities. But as industrialization, immigration, and internal migration transformed the nation, cities began to grow rapidly. Urban populations grew overall, but their compositions also changed dramatically along race and ethnic lines. White (largely home owning) residents used a variety of tactics to keep people of color out of their neighborhoods. When Black households purchased homes in white neighborhoods they were often met with acts of violence and harassment (Tuttle 1970). Hemmed in by white vigilantes, in many cities the neighborhoods where Blacks *were* able to find housing became overcrowded; with rents much higher than in

neighborhoods outside of the ghetto and public services much worse as city governments disinvested in them (Cutler, Glaeser, and Vigdor 1999, Trounstine 2018). As a result of the poor conditions in segregated neighborhoods, residents of color constantly sought access to white communities. This housing pressure led developers and white neighborhood organizations to rely on restrictions in housing deeds to preserve exclusivity (Jones-Correa 2000). Restrictive covenants blanketed neighborhoods across the nation, ensuring that housing would not be sold or rented to "persons other than members of the Caucasian race," (Gutis 1987). Before they were declared unenforceable by the Supreme Court in 1948 (and for decades afterwards), restrictive covenants worked to generate racial segregation. Even without language embedded in housing deeds, some real estate agents and lenders made white neighborhoods inaccessible to residents of color. Audit studies, sending comparable buyers and renters of different races to real estate companies and banks, have found strong evidence that racial steering has played an important role in walling off white neighborhoods (Galster 1990).

Federal, state, and city policies have had similar consequences as actions in the private market. From their introduction in the early 1900s, municipal land use regulations have intended to maintain separate neighborhoods of color and white neighborhoods. Several Southern cities' first zoning maps established separate black and white neighborhoods (Meyer 2000, Abrams 1955). When racially explicit zoning was declared unconstitutional in 1917 by the Supreme Court, cities sought other mechanisms to encourage people of color to live in neighborhoods apart from white residents. For example, in Austin, Texas city leaders encouraged Black and Latino residents to cluster in one part of town by closing segregated schools and parks in other neighborhoods (Koch and Fowler 1928, Tretter 2012). Throughout the 1940s, 50s, and 60s cities

used land use regulations like urban renewal, slum clearance, highway placement, and the siting of public housing to generate segregation along racial lines (Massey and Denton 1993).

Starting in the 1930's several federal programs also contributed to segregation. Most famously, during the New Deal, the Federal Housing Administration developed programs to spur construction employment and increase home ownership. In the process, the FHA developed a system to evaluate risks associated with lending in specific neighborhoods. Neighborhoods that featured newer construction, those that were racially homogenous with a high proportion of whites, those governed by restrictive covenants, and those dominated by single family zoning were given the highest ratings, and thus constituted the bulk of FHA lending. As the history of racial zoning suggests, the FHA did not invent these standards of racial worth, but it bureaucratized them. It lent power, prestige, and the support of the federal government to the systematic practice of racial exclusion.

These federal redlining policies were in place as suburbs exploded with population in the Post World War II period. Along with the fact that race and income are highly correlated in the United States, this meant that early suburbs were much whiter than their neighboring cities; and became a welcome home to whites fleeing the diversification of central cities. This would change over time. There are now many racially and economically diverse suburbs. In an analysis of the United States' largest 56 metropolitan areas, as of 1990, suburbs were about 79% white, while they were only about 55% white as of 2020 (Frey 2022). But about 45% of suburbs in these large metro areas were more than 2/3rds white, even in 2020.

Today, public and private policies continue to reinforce segregation. Land use regulations like minimum lot sizes, restrictions on density/multi-family housing, growth controls, open space preservation, high development fees, and cumbersome review processes all work to

determine the cost and location of housing, which in turn, determines the demographic composition of neighborhoods and reinforces earlier entrenched patterns of segregation (Einstein et al 2020, Trounstine 2020). Rampant subprime lending and the foreclosure crisis that followed during the 1990s and early 2000s was highly racialized – with Black and Latino borrowers dramatically overrepresented among the households that lost their homes. Rugh and Massey (2010) reveal that racial segregation was both cause and consequence of these patterns.

Consequences of Segregation

Segregation is associated with a host of detrimental life and health outcomes. Segregation causes higher poverty rates for Blacks and lower poverty rates for whites, lower high school and college graduation rates among Blacks, higher imprisonment rates and higher rates of single-motherhood among Blacks, and lower intergenerational mobility for low income children (Chetty and Hendren 2018, Ananat 2011, Burch 2014, Cutler and Glaeser 1997). Segregated neighborhoods differ significantly with respect to "crime, poverty, child health, protest, leadership networks, civic engagement, home foreclosures, teen births, altruism, mobility flows, collective efficacy, [and] immigration" (Sampson 2012, p6). These differences, Patrick Sharkey (2013) explains, are "*not* attributable primarily to factors that lie within the home or within the individual," but rather to the <u>place</u> itself, passed down from generation to generation (p21).

Neighborhood disadvantage is also causally related to Black/white income inequality, lack of employment stability among Blacks, and larger gaps in cognitive skills between Blacks and whites (Sharkey 2013). Blacks who live in segregated metropolitan areas have lower education attainment and lower earnings (Ananat 2011). Cohen and Dawson (1993) show that neighborhood poverty undermines Blacks' attachment to and involvement in the political system. Ananat and Washington (2009) find that segregation negatively affects Black political efficacy.

Segregation has also been found to play an important role in shaping health outcomes. In the late 19th and early 20th century, *many* cities sought to residentially segregate people of color from white residents with the explicit goal of protecting the health of whites. As Brown (2021) writes of Baltimore in 1919 "Black skin [was] synonymous with disease and in keeping with the treatment protocols for highly infectious diseases, the 'treatment' required for the protection of white neighborhoods was quarantine" (p78). An 1880 Board of Health report in San Francisco declared Chinatown a public nuisance and health inspectors aggressively cited residences and businesses for violations of public health codes (Shah 2001). But as Shah explains, the trouble for San Francisco city leaders was that many Chinese residents did not live within the boundaries of Chinatown. So, in 1890 the city passed an ordinance requiring Chinese residents to move the industrial area of the city, asserting that Chinese residents were harmful to public health. The ordinance was struck down by the court, but the precedent for segregating communities of color was set, with devastating consequences. Today, we have substantial evidence that people of color suffer worse health outcomes, including incident cardiovascular disease, incident HIV infection, stroke mortality, and cancer outcomes, in more segregated cities (Kramer and Hogue 2009, Acevedo-Garcia et al 2003, Kershaw et al. 2015, Greer et al. 2011, Poulson et al. 2021, Ibragimov et al. 2019).

Why does Segregation Affect Health?

In the public health literature, segregation has long been viewed as a cause of health disparities. Fundamental cause theory, first proposed by Link and Phelan in 1995, seeks to explain how associations between socioeconomic status and racism and morbidity and mortality persist across time and place, even though the diseases afflicting humans — and their concomitant risk and protective factors — evolve and change (Clouston & Link 2021). In 2001,

Williams and Collins proposed that segregation was a "fundamental cause" of racial health disparities through multiple mechanisms and for multiple disease outcomes. Although most of the ensuing literature focused on how racial segregation was related to overall mortality and chronic disease outcomes, new scholarship suggests that segregation may also be a fundamental cause of COVID-19 morbidity and mortality (Moran et al. 2020, Hendryx and Luo 2020, Zalla et al. 2021, Anderson et al 2021, Brown et al.).

There are several pathways by which segregation can affect health independently of individual-level attributes. One pathway is through what sociologists and economists refer to as peer-effects. Many outcomes in life, including health, are affected by who we live and work among. Differential rates of infectious disease contraction across races may be exacerbated by segregation. In her conceptual framework of the effect of segregation on tuberculosis, Acevedo-Garcia (2000) argues that segregation could facilitate the spread of airborne, infectious diseases among residentially isolated groups both by increasing the probability of transmission within the isolated group and by preventing transmission to the rest of the population. Acevedo-Garcia proposes several different pathways by which segregation could affect TB cases: exposure to disadvantage (including poverty, overcrowding, dilapidated housing, and inadequate medical care), racial isolation, and high levels of density.

Another pathway by which segregation affects health is through a greater concentration of disadvantage for people of color. Racial segregation is associated with overcrowding in both housing and transportation, substandard housing, higher rates of drug-use and crime victimization, and higher rates of poverty and unemployment in neighborhoods of color (Hagan 1977, Wallace 1991, Massey and Denton 1993, Potter 1991). Black residents of segregated cities suffer higher rates of infant and adult mortality and scholars have largely connected these

outcomes to the concentration of poverty (LaVeist 1993, Polednak 1996, Collins and Williams 1999). Importantly, scholars have found that patterns of racial segregation are not simply the result of differences in socioeconomic status across groups. For whites, higher household incomes allow households to locate in more advantaged residential areas featuring higher income neighbors and better neighborhood amenities like higher quality schools and lower crime rates (Lieberson 1963, Massey 1985). But for Black Americans, rising incomes *do not* equate to access to integrated neighborhoods on average. At all income levels, Black Americans tend to live in neighborhoods with high concentrations of poverty. Latinos with moderate (or lower) incomes also tend to live in neighborhoods with high concentrations of poverty (Intrator, Tannen, and Massey 2016). As a result of these patterns, racial segregation persists at much higher rates than class segregation in the United States (Fischer et al 2004).

A third important pathway connecting segregation to health outcomes are inequities in resource distribution. Segregation is associated with limited access to health care in neighborhoods of color, which, like the concentration of poverty, could lead to larger gaps in health outcomes between people of color and whites in more segregated counties (McBridge 1991). However, other work has shown that segregation has negative consequences for all residents – not just those in marginalized neighborhoods. Trounstine (2016) provides evidence that segregation is associated with lower public goods expenditures for roads, law enforcement, parks, sewers, housing, public welfare, and health as a result of higher levels of racial political polarization.

Dimensions of Segregation

As Reardon and O'Sullivan (2004) explain, there are two primary dimensions of segregation – the degree to which members of a group encounter other racial groups or not

(isolation/exposure), and the extent to which groups are similarly distributed across residential locations (evenness/clustering). Isolation measures capture Black, Latino, and white residents' typical neighborhood environment. For example, the mean isolation score for whites in our dataset is 0.76, indicating that the average white resident lives in a neighborhood that is 76% white. Evenness measures capture the degree to which residents of different racial groups are dispersed or clustered geographically. Lower scores on evenness measures indicate that each neighborhood looks demographically similar to the county as a whole, while higher scores suggest that racial groups live in their own neighborhoods.

Figure 1, adapted from Reardon and O'Sullivan, offers a graphical depiction of these two dimensions. The figure shows four cities (A,B,C, and D), each with four equally populated neighborhoods. The cities have two racial groups – black circles represent the minority population and white circles represent the majority. The horizontal axis depicts the isolation of the majority population (with the cities on the left revealing more isolation than the cities on the right). The vertical axis describes the degree of evenness in each city with those at the top displaying more even distributions of both racial groups and the cities at the bottom revealing more clustering. Table 1 reports the evenness and isolation scores for these cities.

[FIGURE 1 ABOUT HERE]

Table 1: Evenness and Isolation Scores for Cities in Figure 1

City	Evenness	White Isolation	Black Isolation	Share Black
A	0.007	0.841	0.165	16%
B	0.004	0.652	0.353	35%
C	0.187	0.853	0.285	17%
D	0.098	0.687	0.419	35%

Both isolation and evenness could have an effect on COVID-19 health outcomes. Our empirical approach is to analyze these dimensions separately.

How Might Segregation Affect COVID-19 outcomes?

We are interested in two different COVID-19 outcomes in this paper: infection rates and death rates by race.[2] COVID-19 is an airborne infection, primarily spread through exposure to respiratory droplets produced by an infected person. Reitsma et al (2021) study racial inequalities in Covid outcomes in California. They find that Latinx Californians are particularly vulnerable due to a higher likelihood of living in high-exposure-risk households (defined as having one or more essential workers and fewer rooms than inhabitants) compared to other racial/ethnic groups. Bassett, Chen, Krieger (2020) provide evidence that Black and Latinx populations are dying at much higher rates in younger ages, leading to more "Years of Potential Life Lost" compared to whites. These authors find that Latinx and Black people who died of COVID-19 lost three to four times as many years of life before the age of 65 as whites who died.

If it is the case that Latino and Black Americans are more likely to be infected with COVID-19 than are whites, then we should expect high levels of isolation of Latino and Black residents to exacerbate this effect, as contact with infected individuals both inside and outside of the home is likely to be higher. We hypothesize that people of color who live in counties where their group is more isolated will have higher rates of COVID-19 infection compared to those living in counties with less racial isolation. Referring to Figure 1, our first hypothesis is that Black/Latino residents of cities B and D will have higher COVID-19 infection rates than Black/Latino residents of cities A and C.

[2]We would have liked to analyze positivity rates as well, but these data are unavailable by race at the county level.

Scholars have also highlighted the potential for segregation to lead to worse COVID-19 outcomes through the clustering of individuals who work in essential industries and cannot work from home (Anderson, Lopez & Simburger, 2021). Thus, we expect COVID infection rates among people of color to be even more pronounced in counties with a high share of workers employed in front-line industries, generating a much higher degree of exposure to the disease for those workers.

Unlike isolation, unevenness does not have a clear direct theoretical link to transmission of infectious diseases because "even if a group is highly unevenly distributed across the urban space, it may have a fair amount of contact with other groups," (Acevedo-Garcia 2000 p.1153) and individuals from all groups may be just as likely to encounter infected individuals. This is clearly demonstrated in city C of Figure 1. Instead, unevenness is most likely to affect COVID infection through the concentration of disadvantage. Segregated neighborhoods of color have higher rates of poverty, more unstable employment, and worse housing (Cutler and Glaeser 1997, Massey, Condran and Denton 1987). To the extent that people with lower incomes and less stable employment were less able to work from home during the COVID-19 pandemic, and to the extent that they were more likely to share housing with others in the same situation, residents of these neighborhoods would be more likely to have been exposed to COVID (including at high viral "doses", which may influence risk of clinical disease) (Spinelli et al 2011).

Additionally, segregated neighborhoods of color often have worse public goods and government services and higher concentrations of poor air quality (Trounstine 2018, Ejdemyr et al 2018, Zalla et al 2021). Thus, we expect that people of color who live in counties with more unevenness in the distribution of racial groups to have higher rates of COVID infection. Again,

referring to Figure 1, we hypothesize that residents of cities C and D will have higher COVID-19 infection rates than residents of cities A and B, because the neighborhoods with large clusters of Black/Latino residents are likely to have a variety of features that correlate with higher COVID-19 infection rates including disadvantage and disinvestment. This effect should be most pronounced for Black and Latino residents of segregated counties but could also extend to whites living in these places.

The theoretical connection between segregation and COVID-19 death rates is more complicated than the relationship to infection rates because death rates are affected by many factors in addition to encountering an infected individual. As explained above, segregation (both isolation and unevenness) is likely to affect COVID infection rates. But segregation may affect death rates above and beyond infection rates because of the way that resources are distributed. The concentration of disadvantage in segregated neighborhoods of color means that these residents are less likely to have access to health care (Gaskin et al 2012) and less likely to have access to COVID testing sites (Dalva-Baird et al 2021). They are also more likely to have higher rates of chronic diseases (Landrine and Corral 2009), which are a known risk factor for COVID-19 mortality (OpenSafely Collaborative 2020).

Scholarship suggests that unevenness is strongly linked to neighborhood disadvantage for people of color (Krivo et al 1998). Predictions for whites are less clear. Some scholars have found that segregation offers *benefits* to white residents, as they are able to channel resources to their neighborhood (Ananat 2011). If segregation has a similar effect for COVID-19 death rates as it does for other causes of morbidity and mortality, we might expect that people of color will suffer worse outcomes relative to whites in more segregated counties compared to less

segregated counties (Pirtle 2020).[3] On the other hand, Trounstine (2016) finds that segregation is related to lower governmental spending in the categories of health and public welfare, making all residents worse off – not just people of color.[4] If more segregated communities suffer from overall underinvestment in public health infrastructure (e.g., COVID-19 testing sites, hospitals), we should see higher COVID-19 mortality rates for all residents.

Much literature examining racial residential segregation and COVID-19 outcomes has emerged since the beginning of the pandemic. Most of it, however, does not examine COVID-19 outcomes among specific racial groups. One of the few that does, Torrats-Espinosa (2021), finds that racial residential segregation is associated with higher aggregate COVID-19 mortality and infection rates. Data limitations at the time of his writing meant that Torrats-Espinosa was only able to analyze death by race for a small subset of counties (n=243). He finds that segregation increases the gap between Black and white death rates, but not between Latino and white death rates. Other studies (e.g. Hendryx and Luo 2020, Anderson et al 2021, Brown et al 2021, Yang et al 2021, Yu et al 2021, Khanijahani and Tomassoni, 2021) have examined how segregation is associated with COVID-19 testing, infection rates, and mortality, generally finding that higher segregation predicts worse outcomes. However, in these studies, all COVID-19 outcome data were aggregated across racial/ethnic groups and in many cases the independent variable captures racial composition *not* racial segregation — limiting our understanding of the ways in which segregation produces negative outcomes, and for whom. Our particular contribution is to

[3] Alternatively, some scholars argue that segregation can *promote* health and well-being of marginalized groups. Under extreme models of racial segregation, poor people of color may benefit from living among wealthier people of color. Integration may allow wealthier, residents of color the opportunity to move to higher quality (white) neighborhoods, thereby decreasing life opportunities for poorer residents of color who are left behind (Wilson 1987, Cutler and Glaeser 1997). If these scholars are right, we should see better outcomes for people of color in more segregated cities.

[4] Importantly, Trounstine finds this effect only for measures of unevenness, not for isolation.

generate racially specific predictions for different patterns of segregation.[5] We expect that measures of isolation and unevenness will be associated with more negative infection outcomes for people of color compared to white residents due to high levels of exposure. We hypothesize that measures of unevenness will be associated with higher death rates for all racial groups as a result of underinvestment in public goods and health infrastructure.

A primary concern in studying the effect of segregation on any outcome is disentangling neighborhood treatment effects from composition/selection effects (Oakes 2004, Roux 2001). That is, we would like to know whether differences in outcomes across areas are due to characteristics of the areas themselves, or to differences between the types of individuals who live in or move to different areas. Because we cannot randomly assign residents to segregated versus integrated communities, we cannot be sure that some underlying set of background factors is not actually the cause of both poor health outcomes and residence in a segregated county, even with a long list of controls.[6] We have no solution to this problem of causal inference. As such, our results should be seen as correlational, not causal.

Data and Research Design

To study the relationship between segregation and COVID-19 outcomes, we built a cross-sectional county-level dataset drawing on several different sources. We gathered data on COVID-19 case rates, death rates, and vaccination rates from the United States Centers for

[5] The bulk of Torrats-Espinosa's paper analyzes overall mortality and infection rates, but as we discuss above, the theoretical rationale for such a prediction is unclear. When he turns to a race specific analysis, he studies *gaps* in mortality between whites and Blacks and between whites and Latinos and he shows no effect for the Latino-white mortality gap. Our analysis reveals that this is likely because whites also saw increased mortality in more segregated places – a result that is predicted by our theory.

[6] Some scholars have turned to instrumental variables to separate composition effects from neighborhood/context effects (Ananat 2011, Cutler and Glaeser 1997).

Disease Control and Prevention (CDC).[7] The case rate data derive from case reports routinely submitted to the CDC by public health jurisdictions using nationally standardized case reporting forms, and encompass both laboratory-confirmed and probable COVID-19 cases. The death data derive from provisional mortality data submitted to the National Vital Statistics System, and comprise laboratory-confirmed and clinically confirmed COVID-19 deaths (those with an *International Statistical Classification of Diseases and Related Health Problems*, version 10 [ICD-10] code of U07.1), which includes deaths where COVID-19 is listed as a "presumed" or "probable" cause. The vaccination rate is defined as the percent of people in the county aged ≥ 12 years who are fully vaccinated, and is derived from data collected by state, local, and territorial immunization information systems, the Vaccine Administration Management System, and other sources.

Case rate data and vaccination rate data were current through October 2021. Death rate data were current through November 2021. We also gathered county level survey data on the prevalence of mask wearing from the New York Times.[8] We use 2015-2019 American Community Survey data at the tract and county level to measure segregation, population, and frontline workers.[9]

Our primary dependent variables are *Total COVID Deaths per 1000 people* and *COVID Case Rates*. We analyze these variables for Blacks, Latinos, and Whites separately. Our primary independent variables measure our two dimensions of segregation – isolation and

[7] https://data.cdc.gov/Case-Surveillance/COVID-19-Case-Surveillance-Public-Use-Data-with-Ge/n8mc-b4w4; https://data.cdc.gov/NCHS/Provisional-COVID-19-Deaths-by-County-and-Race-and/k8wy-p9cg; https://data.cdc.gov/Vaccinations/COVID-19-Vaccinations-in-the-United-States-County/8xkx-amqh

[8] https://github.com/nytimes/covid-19-data

[9] Frontline industry data are drawn from the 2019 American Community Survey. They include: service occupations in ag, construction, mfg, wholesale, transportation, ed/health/soc+ nat res occupations in ag, construction, mfg, wholesale, transportation, ed/health/soc+ production occupations in ag, construction, mfg, wholesale, transportation, ed/health/soc

evenness. To measure *Isolation*, we calculate an *Isolation Index* for each racial group (Black, Latino, and White):

$$I = \sum_{i=1}^{n} \left(\frac{r_i}{r_c} \right) \left(\frac{r_i}{p_i} \right)$$

Where r is the racial group population of the neighborhood i or county c, p is the total population of the area, and n is the total number of neighborhoods in the county. The isolation index can be interpreted as the racial makeup of the neighborhood in which the typical member of the racial group lives.

Scholars often use the dissimilarity index to measure evenness. However, this index does not account for the relative size of the racial group or the neighborhood – two factors that are crucial from a resource distribution standpoint. When a government decides how and if resources are allocated, what matters is not just how individuals from different racial groups are distributed across neighborhoods, but also how large each racial group is relative to others and large each neighborhood is relative to others. That is, we need a measure that weights diversity by group size and weights evenness by population size. The *H* index developed by Theil (1972) meets these criteria.

Theil's *H* Index measures the difference between the diversity of the city and the weighted average diversity of individual neighborhoods. Diversity scores for each neighborhood and the city as a whole are influenced by the relative size of racial groups, while the overall index is influenced by the relative size of each neighborhood, giving more weight to larger than to smaller places. Both types of weighting are key to understanding the political implications of segregation. We should expect the effect of segregation to be most pronounced when minority

groups are unevenly dispersed across geographic units *and* represent a substantial share of the population.

Theil's *H* Index is built from Theil's entropy score which is a measure of diversity

$$E = \sum_{r=1}^{R} (\pi ¿ ¿ r) \ln \frac{1}{\pi_r} ¿$$

where π_r represents the proportion of the population in racial group r (or class group r if the index is measuring class segregation). The higher the entropy score, the more diverse an area is.[10] It is maximized when individuals are evenly distributed among the different groups. Entropy is calculated for each neighborhood individually and for the county as a whole.

The *H* Index measures the degree to which the diversity in each neighborhood differs from the diversity of the county, expressed as a fraction of the county's total diversity and weighted by the neighborhood's share of the total population.

$$H = \sum_{i=1}^{n} \frac{p_i}{p_c} \left(\frac{E_c - E_i}{E_c} \right)$$

Where *p* represents total population of neighborhood *i* or county *c* and E is the entropy of *i* or *c*. *H* varies between 0, where all neighborhoods have the same composition as the entire city, and 1 where all neighborhoods contain only one group.[11] Our *H*-Index measures segregation between *Whites and People of Color*.

Results

We begin by regressing each racial group's COVID-19 case rates per thousand persons on the group's measure of isolation and then, on the county level measure of unevenness. We

[10] Where any group's share of the population is 0, the natural log is set to zero, as is the convention in the literature (Iceland 2004).

[11] In all analyses, neighborhoods are represented by Census tracts, which are relatively stable, contiguous geographic areas containing approximately 4,000 people. Most studies of segregation (e.g. Massey and Denton 1998) use Census tracts as a proxy for neighborhood (although this is not without debate, see for instance Logan et al. 2015).

control for the total population of the county (in millions), the share of households in the county with incomes below the poverty line and the share of the county that works in front-line industries. Counties with large populations differ in a variety of ways from counties with small populations. They generally house larger cities which can be more segregated, denser, and more urban, and they may have better public health infrastructure. Poverty rates are a strong predictor of COVID-19 infection as poor individuals are both less able to shelter at home and more likely to live in overcrowded housing. Poverty rates are also correlated with segregation, particularly for Black residents. Individuals who work in front-line industries are much more likely to be exposed to COVID-19, and people of color are generally overrepresented in these jobs. Because the segregation measures that we use (the isolation index and Thiel's H index) are affected by the relative size of racial groups, our models control for the racial makeup of the county population. Finally, we include two controls for possible protection from COVID-19 infection and death: the prevalence of mask wearing in the county and community vaccination rates. Generally, we expect that opposition to public health measures should be associated with higher COVID infection and these attitudes may correlate with demographic and segregation patterns. So, we control for the share of the county population that said that they rarely or never wear masks. Vaccination rates varied significantly across place and time during the course of the pandemic, so we control for the share of the population that was fully vaccinated as of October 1, 2021.

Our models include fixed effects for states, allowing us to compare variation in county segregation patterns *within* states, rather than across them. These fixed effects account for state level factors such as mandated lockdowns and school closings. Although these state policies

varied over time, because our models are pooled across years, we are unable to account for changes in state law.[12]

[12] None of our models suffer from multicollinearity. The strongest bivariate correlation between our independent variables is between countywide race and poverty segregation at 0.49.

Table 2: COVID-19 Case Rates per Thousand Persons

	Black			Latino			White		
	β	S.E.	P>|t|	β	S.E.	P>|t|	β	S.E.	P>|t|
Isolation	229.73	17.40	0.000	215.25	19.24	0.000	49.21	23.78	0.039
% in Poverty	-170.74	65.01	0.009	-89.35	43.58	0.041	-22.67	38.30	0.554
% Frontline Workers	-100.50	15.97	0.000	-46.62	12.12	0.000	16.34	9.78	0.095
% No Masks	11.67	17.62	0.508	8.33	12.44	0.503	53.85	10.72	0.000
% Vaccinated	-0.07	0.14	0.630	0.08	0.10	0.454	-0.20	0.09	0.019
Population (millions)	2.96	2.56	0.247	0.095	1.88	0.615	2.34	1.63	0.152
% Racial group	-119.09	24.14	0.000	-82.82	24.50	0.001	-30.90	19.39	0.111
Constant	59.13	11.12	0.000	5.41	7.92	0.495	75.94	9.12	0.000
N	1,595			1,596			1,596		
R^2	0.425			0.460			0.648		

Table 3: COVID-19 Case Rates per Thousand Persons

	Black			Latino			White		
	β	S.E.	P>|t|	β	S.E.	P>|t|	β	S.E.	P>|t|
Unevenness	157.95	17.38	0.000	86.34	11.97	0.000	30.26	10.79	0.005
% in Poverty	-171.63	66.94	0.010	-164.03	45.71	0.000	-25.21	38.25	0.510
% Frontline Workers	-129.69	16.30	0.000	39.05	12.42	0.002	17.43	9.78	0.075
% No Masks	7.38	18.11	0.684	9.39	12.75	0.462	54.27	10.71	0.000
% Vaccinated	-0.22	0.14	0.128	0.12	0.10	0.263	-0.21	0.09	0.018
Population (millions)	5.90	2.62	0.024	3.19	1.91	0.095	2.52	1.59	0.115
% Racial group	126.28	12.32	0.000	152.77	10.26	0.000	14.72	5.70	0.010
Constant	75.62	11.36	0.000	4.19	8.12	0.605	72.68	8.93	0.000
N	1,595			1,596			1,596		
R^2	0.392			0.435			0.650		

OLS Regressions; fixed effects for states included but not presented.

The results in Table 2 indicate that racial isolation is associated with unequal outcomes across racial groups' COVID case rates. Black and Latino case rates were significantly higher in counties with higher levels of isolation. Moving from the 10th to the 90th percentile for Black isolation (and holding all other variables at their mean value) increases the predicted COVID infection rate for Black residents 9 to 102 per thousand persons. Predicted Latino infection rates increase from 2 to 64 per thousand persons when comparing the 10th to the 90th percentile of Latino isolation. Interestingly, white case rates were also higher where whites were more isolated, but the effect is substantively much smaller compared to Black and Latino residents. This effect for white isolation was unexpected and warranted additional exploration. We found that the relationship was driven by counties in which Black and Latino residents comprised a majority of the population and those where vaccination rates were low. It could be that such counties faced larger public health challenges associated with higher COVID infection rates.

Similarly, in Table 3, we find that unevenness has a powerful relationship with COVID infections. When racial groups are unevenly distributed across neighborhoods, Black and Latino case rates are higher. White case rates are also higher, but the effect of segregation is much weaker – presumably because some whites live in more advantaged neighborhoods within these segregated counties. Segregation appears to be associated with COVID infection through both direct and indirect pathways. These effects are substantively large.

Next, we explore whether these inequalities are exacerbated by exposure to COVID-19 through front-line work. In these models, we transform the measure of the share of the county population working in front-line industries into a binary variable to reduce the effect of outliers and make the analysis clearer. The variable is coded 1 if the county's share of front-line workers

is at or above the nationwide median of 33% and coded 0 if it is below this share. We interact this measure with our measure of racial isolation, as indicated by our theory.

Table 4: COVID-19 Case Rates per Thousand Persons

	Black			Latino			White		
	β	S.E.	P>|t|	β	S.E.	P>|t|	β	S.E.	P>|t|
Isolation	229.36	17.50	0.000	208.66	19.35	0.000	55.98	24.36	0.022
Hi Frontline	-16.68	3.04	0.000	-5.62	2.24	0.012	11.01	7.22	0.127
Isolation* Hi Frontline	35.25	13.98	0.012	36.33	11.21	0.001	-12.88	8.71	0.139
% in Poverty	-233.47	64.55	0.000	-116.28	42.83	0.007	-16.50	38.00	0.664
% No Masks	6.02	17.64	0.733	-0.65	12.40	0.958	57.11	10.67	0.000
% Vaccinated	0.09	0.13	0.491	0.24	0.10	0.010	-0.26	0.08	0.001
Population (millions)	5.39	2.55	0.034	4.43	1.90	0.020	2.23	1.63	0.170
% Racial group	-131.72	24.47	0.000	-109.22	24.81	0.000	-33.41	19.45	0.086
Constant	32.94	9.70	0.001	-9.52	6.82	0.162	73.99	9.07	0.000
N	1,595			1,596			1,596		
R^2	0.421			0.459			0.649		

OLS Regressions; fixed effects for states included but not presented.

As predicted, Table 4 reveals a significant interaction effect between racial isolation and front-line work. Where racial groups are more isolated, front-line work disproportionately affects people of color. Latino and Black case rates significantly increase with high shares of front-line workers. But white case rates are not significantly affected (if anything, the result points in a negative direction); indicating that segregation might be associated with a protective effect for whites in settings where exposure is high.

For our last analysis, we turn to an investigation of racially specific death rates. Here we regress each racial group's COVID-19 deaths per thousand persons on countywide segregation between whites and people of color as measured by unevenness (as this is the best measure to capture variation in resource distributions). To isolate the contribution of racial segregation to

COVID-19 *mortality*, we control for the race-specific case rate that served as our dependent variable in the previous analyses. We also add a control for the share of the racial group that is under age 65 because racial groups have very different age structures (Black and Latino communities tend to be younger than whites), and because COVID-19 has a much higher mortality rate for older people. Finally, as in the previous models we control for the total county population, the share of the county below the poverty line, the share of the population that is vaccinated, and include fixed effects for states. The results of these regressions are plotted in Figure 2 (full regression models available upon request). The graphs present the marginal effect of our measure of unevenness, with all other variables held at their mean values.

[FIGURE 2 ABOUT HERE]

Figure 2 reveals that moving from a hypothetical county with complete integration to one with total segregation increases the death rate for all racial groups by 2.27 to 3.18 deaths per thousand persons. This evidence is consistent with the theory presented above that segregation has a depressive effect on public goods investment.

Conclusions

The long history of segregation between neighborhoods and across jurisdictional lines in the United States has embedded in our geography the opportunity for inequalities across many domains. Where their populations are more isolated, Black and Latino residents have witnessed higher rates of COVID infection. In segregated places where the share of front-line workers is high, the spread of COVID is even worse. Furthermore, segregation produces worse outcomes for all racial groups when death rates are considered. The results in this paper highlight the ways in which the pandemic has had wildly different consequences for different communities.

Our results contribute to the body of literature suggesting that racial segregation facilitates the spread of airborne infectious diseases among residentially isolated groups (Acevedo-Garcia 2000). Although we could not directly test the mechanisms responsible for these observed associations, our findings are consistent with the hypothesis that isolated residential contexts, populated by people who predominantly work in frontline settings, serve to concentrate risk of exposure in those communities while shielding other communities from that same risk.

Beyond the risk of infection, our results also highlight the excess risk of COVID-19 mortality faced by residents of segregated counties. Our findings are consistent with theoretical predictions regarding underinvestment in public health infrastructure (e.g., testing sites, contact tracing, etc.) in more segregated places. We find that death rates for Blacks, Latinos, *and* whites were higher in more segregated counties. However, we were not able to rule out the possibility that this excess mortality was due to compositional effects (e.g., residents of segregated counties being more likely to have underlying health conditions that increased their risk of death once infected with COVID-19).[13] Future epidemiologic research using individual-level prospective data on COVID-19 infection incidence, death, and residential segregation, along with information on potential mediating pathways and confounding factors like pre-existing physical health conditions, could help shed light on the causal nature of these associations.

Irrespective of whether our observed associations are causal, our findings have potential implications for public health resource planning. Greater attention to the role of entrenched

[13] Additionally, the data used for this analysis had some limitations that should be taken into account when interpreting the results. Information on the race and ethnicity of COVID patients and decedents was not uniformly available, especially in the early months of the pandemic, and to the extent that this missing information was correlated with county levels of segregation, our results could be subject to bias. Data on mask wearing is self-reported and could be inaccurate.

racial bias and disparities could held guide policy decisions and future research agendas. For example, with respect to policy and public health planning decisions, hospitals whose catchment areas encompass segregated communities could use this information when planning staffing levels and bed capacity during surges of COVID-19 infection; public health agencies could use it when planning vaccination drives and other prevention efforts. State governments should also be attentive to the fact that segregated counties are likely to have lower capacity for public health management and incorporate research like ours when planning geographically-based allocations of scarce resources like testing facilities, vaccination doses, and other public health prevention resources.

Researchers should be aware that neighborhood measures of disadvantage, such as socio-economic status or racial composition, are more meaningful when they are embedded in the context of segregation. To facilitate future research in this area, the Federal Center for Disease Control could add community-level segregation measures to their social vulnerability index to help officials identify places that are most likely to need support to manage emergencies, including future epidemics or pandemics that may have very different disease characteristics than the COVID-19 virus. Having easy access to such segregation measures would benefit researchers, as well as planners and public health officials. As the current pandemic evolves, and as new infectious disease threats mount, understanding and mitigating the abiding influence of segregation on public health will be essential for ensuring health equity among all U.S. residents.

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Figure 1: Hypothetical Depiction of Segregation Patterns

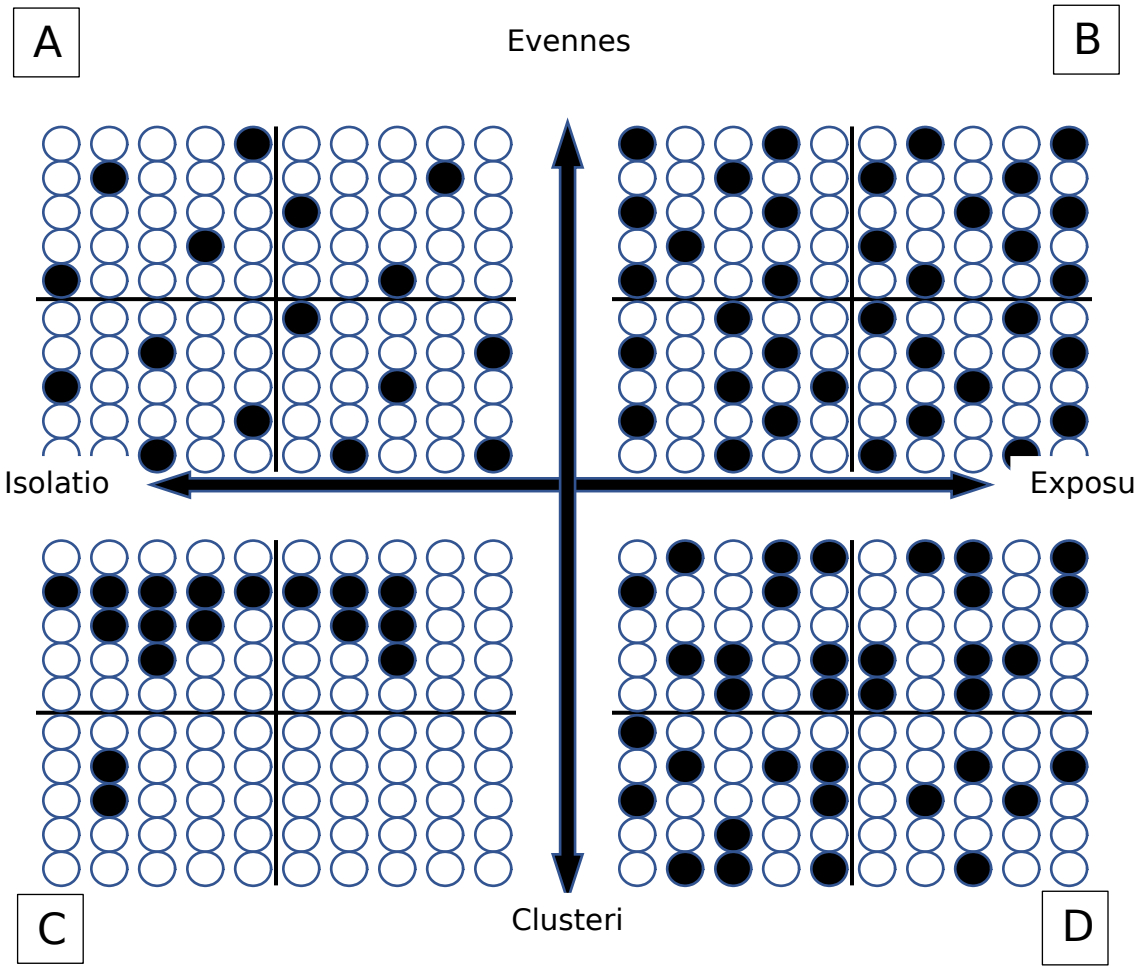

Figure 2: Relationship Between Segregation (unevenness) and COVID Death Rates by Race