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Inclusionary Housing Programs, Vulnerability to COVID-19, and Racial Segregation: An Examination of Cities in California

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Abstract

The COVID-19 pandemic underscores the urgency to advance social justice. This two-part paper examines the association between a city's Inclusionary Housing (IH) program, its vulnerability to COVID-19, and its change in racial residential segregation. The first part explores whether having an IH program is significantly associated with a city's vulnerability to COVID-19. Using a COVID-19 Social Vulnerability Index (COVIDSVI), the vulnerability of each of the 482 cities and towns in California is examined and linked to that city's presence or absence of IH programs. Statistical analysis reveals that cities with IH programs in 2019 are significantly less vulnerable to COVID-19 than cities without IH programs. The second part of the paper examines the association between IH program and racial segregation change. Using a multiple-level multiple-index approach, it is found that, depending on the segregation index used, the presence or absence of an IH program may be significantly associated with a city's residential segregation change. Whether a city has an IH program is not found to be significantly associated with that city's change in multi-race segregation or minority-white segregation, but is significantly associated with the city's change in White and Hispanic isolation. Further research is needed to discover why and how IH programs caused the changes.

Inclusionary Housing Programs, Vulnerability to COVID-19, and Racial Residential Segregation: An Examination of Cities in California[1]

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INTRODUCTION

The COVID-19 pandemic has brought unexpected and unprecedented changes to people across the globe. The social conditions and access to resources greatly impact individuals' exposure to COVID-19 and its ensuing economic and health consequences. People of low socio-economic status (SES) are more likely to live in poor housing conditions and overcrowded neighborhoods, more likely to be in occupations that do not provide opportunities to work from home, more likely to be harmed financially by responses to COVID-19 because of their unstable work conditions and incomes, and more likely to have limited or no health insurance or access to healthcare services (Patel et al. 2020). These factors together make low-SES communities much more vulnerable to COVID-19 pandemic and its aftermath.

To ensure structural support and protections are available, knowledge on the social determinants of a community's vulnerability to COVID-19 is necessary. One such determinant is housing. Lack of housing affordability and stability have been linked with poor physical and mental health outcomes (Pierse et al. 2016). Research on U.S. counties in April 2020 found that each 5% increase in households with poor housing conditions resulted in 50% higher risk of COVID-19 incidence and a 42% higher risk of COVID-19 mortality (Ahmad et al. 2020).

Before the COVID-19 pandemic, there was already a housing crisis in California. In 2019, 53.3% renters paid more than 30% of their monthly household income on rent and utilities and 51.6 % homeowners paid more than 35% of their income toward housing expenses (American Community Survey 2019). The COVID-19 outbreak in 2020 exacerbated the crisis. Emerging data shows that 1 in 7 adult renters in California are delinquent on rent payment and an estimated 10.1 million adults are in a household that is falling behind its mortgage payment (Center on Budget and Policy Priorities 2020). With state-wide social distancing guidelines and

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shelter-in-place orders, access to safe, stable, and affordable housing is more important than ever.

Inclusionary housing (IH), which is also referred to as inclusionary zoning, is developed to increase housing affordability and promoting housing stability thus hold the potential to level the health and economic playing field for vulnerable populations. Through IH, developers are required or encouraged to create housing affordable to lower-income households while building market-rate developments (Wang and Balachandran 2021). In response to the calling for urgent policy intervention during the pandemic, some municipalities in California have either relied on existing IH programs or adopted emergency housing policy tools. However, whether and how IH programs are used to stabilize housing for renters and homeowners, as well as to mitigate the inequitable housing effects of COVID-19, have not been examined. Meanwhile, the confluence of social justice and COVID-19 calls for an examination of racial segregation.

This paper examines the association between a city's IH program, its vulnerability to COVID-19, and its change in racial residential segregation from 2014 to 2019. The study is based on the 482 cities and towns in California. There are two parts in this research. The first part explores whether having an IH program is significantly associated with a city's vulnerability to COVID-19. The hypothesis is that cities with IH programs are less vulnerable than cities without IH programs. The other part of the paper explores whether having an IH program impacts a city's change in racial residential segregation. The hypothesis is that presence of IH programs reduces racial residential segregation. The rest of the paper examines these hypotheses in detail.

Part I. IH Program and Vulnerability to COVID-19

SOCIAL DETERMINANTS OF COVID-19 VULNERABILITY

Part I of the paper examines the relevance of IH program to a city's vulnerability to COVID-19. To assess a city's vulnerability, the COVID-19 Social Vulnerability Index (COVIDSVI) developed by Liu (2021) was used. COVIDSVI is adapted from the Center of Disease Control Social Vulnerability Index (CDC SVI) which describes the resilience of communities to natural and anthropogenic disasters such as hurricanes, disease outbreaks, or exposure to dangerous chemicals (Flanagan et al. 2018). Previous research by Liu (2021) has found that, at the city level, the number of COVID-19 confirmed cases in a city is mostly correlated with nine variables describing four aspects of the city: (1) socioeconomic status which is described by educational attainment, unemployment, access to health insurance and household income; (2) household composition, which is described by percentage of single-parent households, (3) minority status, which is described by the percentage of Black/African American and Hispanic population, and (4) housing, which is described by over-crowdedness, rent burden, and house ownership burden. Among the nine variables, minority status, educational attainment and single parenthood are the strongest determinants of COVID-19 rate; income, health insurance, and over crowdedness are also strong determinants while unemployment, rent burden, and housing cost burden for homeownership are moderate.

Socioeconomic status is found to impact COVID-19 vulnerability most among the four aspects. Table 1 lists the nine determinants and the four aspects.

Table 1: Social determinants of a city's vulnerability to COVID-19

	Social Determinants
Socioeconomic status	Percent persons with high school education or less
	Percent persons with no health insurance
	Median household income
	Percent civilian unemployed
Household composition	Percent single-parent households
Minority status	Percent of Hispanic and non-Hispanic Black/African American population.
Housing	Percent occupied housing units with more than one person per room
	Percent of occupied units paying more than 30% income for rent
	Percent of housing units paying more than 30% income for housing cost for homeownership

Based on the social determinants in Table 1, a COVID-19 Social Vulnerability Index (COVIDSVI) was calculated for each of the 482 cities and towns in California using data from the one-year American Community Survey in 2019 (ACS 2019). In calculating COVIDSVI, a city's vulnerability due to each determinant is compared with other cities to generate a score based on its percentile. For example, a city scores 0.95 in unemployment if its unemployment rate is lower than 95% of all cities. Once the percentile-based score is calculated for each determinant, the scores are summed and the total is a city's COVIDSVI value which is in the range of 0 to 9. A low COVIDSVI value means the city is more disadvantaged thus more vulnerable to COVID-19.

COVIDSVI of CALIFORNIA CITIES

The COVIDSVI of the 482 cities and towns in California ranged widely from 0.54 to 8.54, with Piedmont in the San Francisco Bay area being least vulnerable and Orange Grove in Central Valley being most vulnerable. Table 2 and Figure 1 show the regional variation in COVIDSVI by the seven geographical regions in California – the San Francisco Bay Area, Central Valley, Orange-San Diego Counties, Los Angeles County, Inland Empire, Central Coast, and Other. Overall, the San Francisco Bay Area is the least vulnerable region followed by Orange-San Diego Counties. In contrast, Central Valley, Los Angeles and Inland Empire are much more vulnerable. A close look reveals that San Francisco Bay area primarily benefits from its advantage in the socioeconomic status dimension. Characterized by a large number of hi-tech companies, the San Francisco Bay Area has much higher educational attainment and median household income than the rest of California. Interestingly, despite the Bay Area being the most

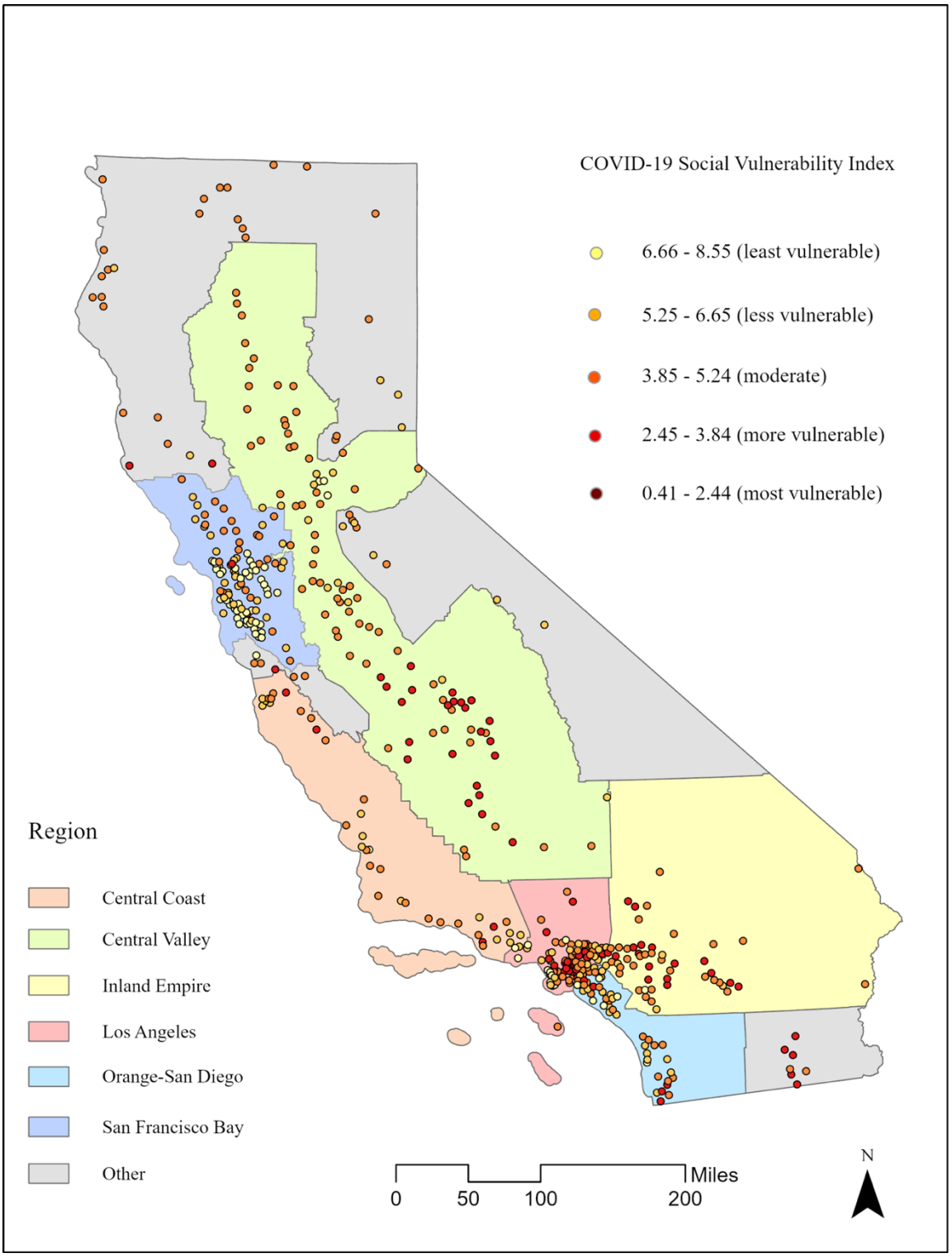
expensive in California in terms of housing price and rent, it is least vulnerable in the housing dimension compared to the other regions. Orange-San Diego Counties also benefited mainly from its socioeconomic status. Central Coast's vulnerability is close to state-wide average; its socioeconomic status is more advantaged than state average but its housing is more disadvantaged than state average. Central Valley, Los Angeles, and Inland Empire have similar overall COVIDSVI but their vulnerabilities are due to different reasons. Los Angeles county is disadvantaged because of housing, Central Valley is because of both socioeconomic status and household composition, while Inland Empire is disadvantaged in all four dimensions in particular household composition and minority.

Table 2: Summary of COVIDSVI* in California Cities by Geographic Region

		COVIDSVI	Socio	Household	Minority	Housing
Central Coast (37)	range	2.04-6.82	0.74-3.69	0.1-0.94	0.04-0.95	0.43-2.32
	mean	4.47	2.06	0.56	0.46	1.38
	median	4.67	1.97	0.56	0.5	1.34
Central Valley (100)	range	0.41-7.68	0.04-3.38	0.04-1	0-0.96	0.15-2.64
	mean	3.70	1.31	0.43	0.38	1.59
	median	3.71	1.23	0.38	0.33	1.62
Inland Empire (52)	range	1.07-7.12	0.16-3.28	0.01-1	0.01-0.98	0.37-2.44
	mean	3.50	1.50	0.39	0.35	1.26
	median	3.56	1.34	0.35	0.31	1.23
Los Angeles County (88)	range	0.67-7.77	0.31-3.87	0.01-1	0-0.96	0.08-2.6
	mean	4.08	1.99	0.48	0.43	1.19
	median	3.91	1.98	0.45	0.39	1.09
Orange-San Diego Counties (52)	range	1.63-7.99	0.79-3.65	0-0.95	0.14-0.97	0.32-2.64
	mean	4.88	2.35	0.62	0.58	1.33
	median	5.09	2.60	0.64	0.63	1.37
San Francisco Bay (101)	range	1.81-8.55	0.73-3.89	0.03-0.99	0.15-1	0.38-2.89
	mean	6.22	2.97	0.66	0.69	1.90
	median	6.52	3.1	0.72	0.71	1.95
Other (52)	range	1.32-6.82	0.27-3.52	0-0.98	0.01-0.98	0.63-2.87
	mean	4.04	1.55	0.32	0.58	1.58
	median	4.08	1.56	0.22	0.67	1.46
California (482)	range	0.41-8.56	0.04-3.9	0-1	0-1	0.08-2.9
	mean	4.5	2.0	0.5	0.5	1.5
	median	4.54	1.93	0.5	0.5	1.5

* Higher COVIDSVI values mean lower vulnerability to COVID-19.

Figure 1: The Spatial Distribution of COVID Social Vulnerability Index (COVIDSVI). Cities are classified as least vulnerable, less vulnerable, moderate, more vulnerable, most vulnerable based on their COVIDSVI.



IH PROGRAMS and COVIDSVI

To examine the association between having IH programs in a city and the city's vulnerability to COVID-19, data on IH programs in California were retrieved from the Inclusionary Housing Database by Grounded Solutions Network (Wang and Balachandran 2021). As of 2019, there are 228 IH programs in California. A few programs are countywide (e.g., Marin County) but the majority of the programs are at the city level. Overall, 145 cities in California have at least one IH program.

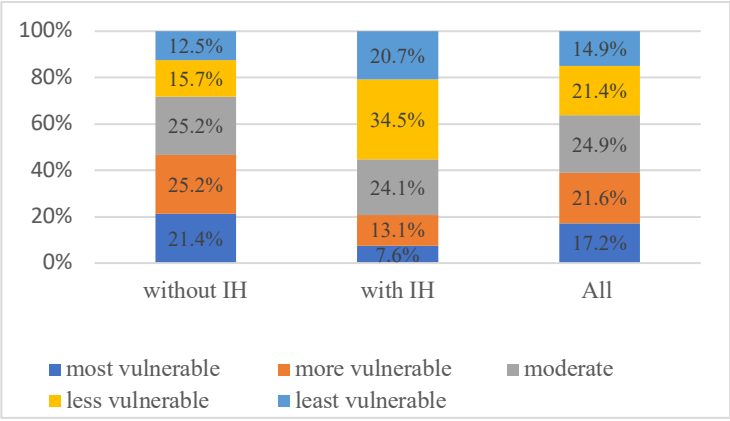
The COVIDSVI of cities with IH programs and those without IH programs are summarized in Table 3 and Figure 2. Two-sample T test was run to find whether the two groups are significantly different in their average vulnerability; F test was run to test whether they have equal variation in vulnerabilities. Results show that, at the 95% confidence level, average COVIDSVI in cities with IH programs is significantly higher than that of cities without IH program, suggesting that cities with IH program is significantly less vulnerable to COVID-19. Vulnerability varied between cities in each group, but the variances, or the spread out of the vulnerability within each group, is not significantly different.

Table 3: COVIDSVI of cities with and without IH programs

	Cities with IH	Cities without IH	All cities
N	145	337	482
Range	1.22 – 8.40	0.41 – 8.55	0.41 – 8.55
Mean	5.27	4.17	4.50
Median	5.55	4.00	4.54
Standard deviation	1.69	1.88	1.89

To further test the hypothesis that a city's vulnerability to COVID-19 is related to its having IH programs or not, Chi-squared independence test was run after cities were classified as least vulnerable, less vulnerable, moderate, more vulnerable, most vulnerable based on their COVIDSVI (Figure 1). Results confirm our hypothesis that, at the 95% confidence level, there is significant association between having an IH program and a city's vulnerability to COVID-19.

Figure 2: Vulnerability of California Cities to COVID-19



Part II. IH Program Availability and Racial Residential Segregation Change

INTRODUCTION

In Part II, I examine the association between having IH programs and a city's racial residential segregation change. Residential segregation is the spatial separation of residential space of two or more groups - a form of sorting population groups into different neighborhoods based on some criteria such as race or income. Residential segregation shapes the extent to which people occupy and experience physical and social environments. As a result, it can reinforce socioeconomic inequalities and environmental and social conditions not conducive to well-being, causing both short- and long-term consequences on residents' health and success (Williams and Collins 2001) (Quillian 2014). For example, homes in Black neighborhoods are found to appreciate less than those in comparable White neighborhoods (Jan 2022), widening the already-enormous racial wealth gap. Black population are also more likely to live in poverty-concentrated neighborhoods. Thus even middle-class black families are more likely to send their children to low-performing public schools when compared to low-income Whites (Quick and Kahlenberg, Richard 2019). Over time, groups with high levels of capital (e.g., the affluent) keep benefitting from residential segregation while groups of low levels of capital (e.g., minority groups and the poor) continue being harmed, perpetuating inequality in access to opportunities.

In this research, I study race-based residential segregation in California cities between 2014 and 2019. I hypothesize that segregation tends to improve in cities with IH programs during this period. To obtain a comprehensive understanding, I conduct the research at three levels. First, I summarize a city's overall state in racial segregation by taking into account all major racial groups – Black/African American, Hispanic, Asian, and Non-Hispanic White. For ease of discussion, Black/African American and Non-Hispanic White will be referred to as Black and White respectively hence forward. Second, I analyze bi-racial segregation, i.e., Black-White segregation, Hispanic-White segregation, and Asian-White segregation. Finally, I zoom in to each racial and ethnic group and study its segregation. By using this multi-level approach, I strive to obtain a comprehensive understanding on, at city level, whether there exists significant association between racial residential segregation and the presence of IH programs.

MEASUREMENTS OF RESIDENTIAL SEGREGATION

Implementation of this multi-level approach requires quantification of racial segregation status, but racial residential segregation manifests itself in different ways. For members of a disadvantaged group, they may be unevenly distributed in a city, causing it to be overrepresented in some neighborhoods and underrepresented in others; they may have limited exposure to members of advantaged groups because the two groups rarely share neighborhoods; they may be circumscribed to a very small area, occupying less residential space than others; and they may also be spatially clustered to form one large contiguous enclave. While these segregation aspects are not absolutely harmful – for example, enclaves may shelter minorities from racial discrimination and immigration stigma, racial segregation is a fundamental mechanism of socioeconomic stratification. When segregated groups are persistently deprived of opportunities to success, racial integration becomes important for the society as a whole.

Indices have been developed to measure different aspects of segregation. Massey and Denton (1988) grouped them into five categories: evenness, exposure, concentration, centralization, and clustering. Because an individual index only captures one aspect of segregation, multiple indices are often used simultaneously in order to reach an understanding of the status and nature of segregation. This paper uses three indices that are widely used in residential segregation research: divergence index, dissimilarity index, and isolation index.

Divergence index

Divergence index measures the degree of "divergence" in racial diversity between neighborhoods and the overall city. This index does not concern the over- and under-representation of a specific group; it only concerns how racial composition in each neighborhood deviates from that of the overall city. A city is considered to have no racial residential segregation if each of its neighborhood has the exact racial composition as the overall city. On the other hand, a city would be most segregated if all residents in a neighborhood are from the same racial group. A key advantage of Divergence Index over other segregation indices is that it takes into account multiple racial groups simultaneously (Roberto 2016), thus it is used by increasing number of studies.

To calculate the Divergence Index of a city, the Divergence Index of each neighborhood i is calculated first by

$$DI_i = \sum x_{im} \ln \left({}^{x_{im}}/_{x_m} \right)$$

where x_{im} is the proportion of racial group m living in neighborhood i , x_m is the proportion of racial group m within the city. The Divergence Index of the city is population weighted average of the divergence for all neighborhoods, i.e.

$$DI = \sum \frac{t_i}{T} DI_i$$

where T is the overall population in the city, t_i is the population count in neighborhood i. A city gets a divergence index of 0 if all of its neighborhoods have a Divergence Index value of 0, indicating the same racial composition across neighborhoods hence the city hence no segregation.

Dissimilarity Index

Dissimilarity Index used to be considered the best overall measurement of residential segregation. This index compares the evenness in the distribution between two racial groups in a city. It tells the fraction of one group that would have to move to another neighborhood in order to equalize its distribution across neighborhoods. As such, its value ranges between 0 and 1, with 0 being perfect integration and 1 being perfect segregation. A city with 0.3 in Black-White segregation, for example, means that 30% of Blacks in the city would have to exchange residence with Whites in other neighborhoods so that the percentage of Blacks in each neighborhood matches that of the city overall. Dissimilarity Index is calculated by:

$$D = .5 * \sum_{i}^{n} \left| \frac{a_i}{A} - \frac{b_i}{B} \right|$$

where n is the number of neighborhoods in the city, a_i and b_i are neighborhood i's population in the two racial groups respectively, A and B are the city's population in the two groups respectively. In this research, Dissimilarity Index is calculated for Black-White segregation, Hispanic-White segregation, and Asian-White segregation.

Isolation Index

Interracial contact and interaction is beneficial for society by and large as it improves understanding of cultural differences, enhances trust, breaks down racial stereotypes and prejudices etc. A racial group is considered isolated if it only interacts with members of the same group and language. Isolation index measures the degree of potential contact between members of a racial group and other members in a neighborhood. The value of Isolation Index varies between 0 and 1, with higher values indicating more isolation. The Isolation Index of a group x , denoted as P_x is calculated by:

$$P_x = \sum_{i} \frac{b_i}{B} * \frac{b_i}{t_i}$$

where b_i and B are the group's population in neighborhood i and city respectively, t_i is the total population in neighborhood i . In this research, isolation index is calculated for each of the major races and ethnicity – Asian, Black, Hispanic, and White.

RACIAL DATA

The key to segregation index calculation is racial data. In the United States, American Community Survey (ACS) conducted by the U.S. Census Bureau is the main source of race and ethnicity data for years like 2014 and 2019 which are in between decennial censuses. ACS reports race data using a set of predefined geographical units. It provides the population count of each racial group for each city, but sub-city racial data is necessary in order to evaluate residential segregation in the city. In Census and ACS geography, there are three geographical units that may be smaller than city – census block, census block group, and census tract. Census block would be the ideal geographical unit for this research, but ACS does not release data at this level. Census tract, which on average has of 1000 households or 4000 population, is too aggregated for small cities. Block group, which generally contain 600 to 3000 people, is much smaller than census tract; it is also the finest scale that ACS race data is publicly available. Block group is thus used as the source of race and ethnicity data.

A block group, however, does not always nest in a single city. It is not uncommon to have a block group crossing several cities or a city crossing multiple block groups. When a block group does not fall completely in a city, it is necessary to disaggregate its race data so that the portion belonging to the city can be estimated. The disaggregation process calls for spatial allocation, a technique in Geographical Information Science to redistribute data from source

zones to target zones (Lam 1983). The most widely used spatial allocation method is dasymetric mapping (Wright 1936). In dasymetric mapping, ancillary information such as land use, transportation network, addresses points, or satellite images is used to divide the mapped area into zones of relative homogeneity, population of each source zone is then distributed to the homogenous zones before being aggregated to target zones. Dasymetric mapping is used in this research to obtain sub-city race data which is necessary to study a city's racial residential segregation.

Our dasymetric mapping method used land cover data to redistribute race data. Under the assumption that people live in residential lands only, and people in each racial or ethnical group are uniformly distributed in each block group, the process takes several steps. First, race and ethnicity data at block group level were collected from 5-year 2014 ACS and 5-year 2019 ACS respectively. These data were then mapped for entire California. Next, land cover data in 2019 and 2013 were obtained from The National Land Cover Data (NLCD) hosted by Multi-resolution Land Characteristic Consortium (https://www.mrlc.gov/data). NLCD are 30-meter resolution land cover data derived through satellite imagery analysis. Because NLCD does not provide data for 2014, the 2013 NCLD data was used to approximate land cover in 2014. Using NLCD datasets and ACS geographical data, residential lands in each block group in California in 2014 and 2019 were mapped. The next step is to intersect the race maps created in step one and the residential land cover map created in step two, so that the proportion of each block group's residential land in each city can be calculated. The block group's race data are then allocated accordingly. For example, if 20% of the residential area of a 1000-people block group falls in a city, the 20% residential area forms a sub-city unit (or neighborhood) which receives 200 people. If another 2000-people block group crosses the city and 50% of its residential area falls in the city, then the 50% residential area from that block group becomes another sub-city unit which receives 1000 population allocation. In this way, sub-city race and ethnicity data, which are necessary for segregation index calculation, become available.

Using the sub-city race data estimated by dasymetric mapping, I calculated the following indices for each city in 2019 and 2014: divergence index which described the segregation between all major races, dissimilarity index which describes the segregation between major minority groups and White, and isolation index which describes the segregation of each individual race. These indices together provide a multi-level, multi-aspect description of a city's racial residential segregation.

Once index calculations were completed, the 2019 and 2014 segregation status were compared to detect the change in each city. Statistical analyses were conducted to understand racial segregation and IH programs from several angles: (1) paired Wilcoxon signed rank test to test whether overall segregation in California cities changed significantly, and if yes, whether the change happened in both groups of cities; (2) Komogrove-Sminov test to examine whether segregation in cities with IH programs differ significantly from that in cities without IH programs. No significant difference means the two groups of cities have similar statistical distribution in segregation, thus IH program is irrelevant to racial segregation. When applicable, paired T test test is also run in conjunction with Komogrove-Sminov test to find whether average segregation in one group is significantly better than that in the other group.

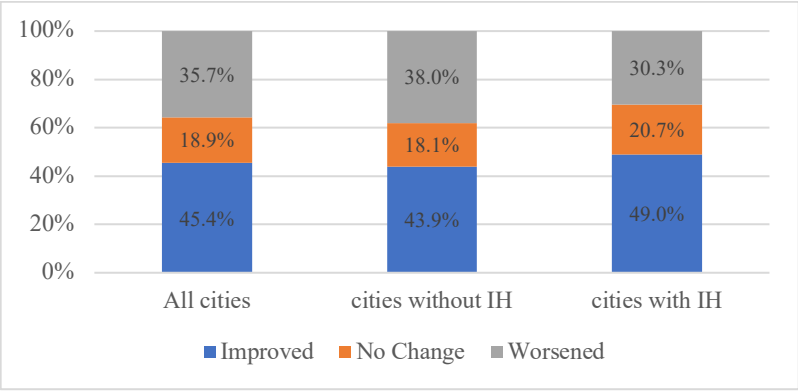
To further examine the association between having IH programs and segregation change, cities are classified according to their segregation change. Changes less or equal to 5% are deemed insignificant to accommodate the uncertainties in dasymetric mapping. Changes more than 5% suggest segregation improvement or worsening. Chi-squared independence test is applied to test whether a city's segregation change improved, worsened, or not changed is independent of the city's having IH programs or not. In all analyses, a significance level of 0.05 is used meaning that one can be 95% confident about the significant difference found by statistical analyses.

RESULTS

Multi-racial Divergence

Figure 3 summarizes the change in multi-racial divergence in California cities between 2014 and 2019. While more cities saw segregation improved than worsened, no significant difference in segregation was found when counting all cities together. In other words, California did not change significantly in its multi-racial segmentation. Between the two groups of cities –with IH programs and without, there exists significant difference in their divergence distribution. Average divergence in cities with IH programs is found significantly higher, meaning more segregated, in both years. However, as far as change is concerned, no significant difference was found between the two groups. This is echoed by Chi-squared analysis which found no association between having IH programs and a city's segregation change (improved, worsened, or no change). These findings together suggest that whether a city has IH programs is significantly related to its multi-race segregation but not the *change* in its segregation. The cause of this is likely complex and requires further examination.

Figure: 3: Change in Multi-Race Divergence in California Cities

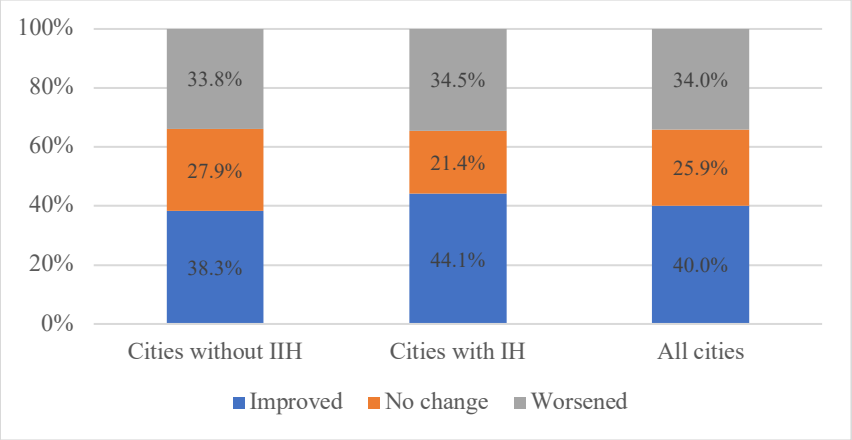


Two-Race Dissimilarity

The segregation between each major Minority group and White is calculated. On Black-White segregation (Figure 4), statistical analysis found no significant difference between 2014 and 2019 when taking all cities together, suggesting the lack of statewide progress. Statistical analysis also found no significant difference between the two groups of cities in their Black-

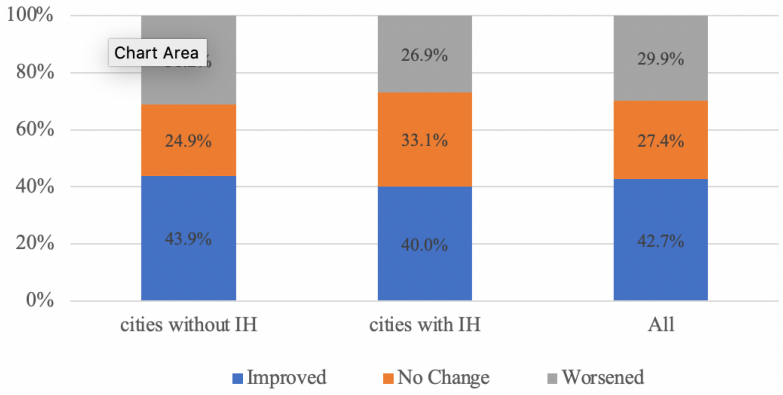
White segregation, though cities with IH programs had significantly higher average Black-White segregation in both years. In terms of segregation change, no significant difference was found in the distribution of segregation change between the two groups. This is echoed by Chi-squared independence test which did not find significant association between having IH programs and a city's segregation change type (improved, no change, or worsened). These findings together suggest that the presence or absence of IH programs in a city impacts neither the city's Black-White segregation status, nor the change in Black-White segregation.

Figure 4. Change in Black-White Segregation in California Cities



On Hispanic-White segregation, more cities in California saw improvement than worsening between 2014 and 2019 (Figure 5). Statistical analysis confirmed that statewide Hispanic-White segregation indeed improved significantly, and the improvement is shared by both groups of cities. No significant difference was found between their changes though, suggesting that having IH programs does not impact a city's improvement in Hispanic-White segregation. However, statistical analysis does find that cities with IH programs had worse Hispanic-White segregation in both years. These findings suggest that, while having IH programs or not is relevant to a city's Hispanic segregation status, it has no impact the *change* of Hispanic segregation.

Figure 5: Change in Hispanic-White Segregation in California Cities



On Asian-White segregation, more cities saw improvement in it than in Hispanic-White and Black-White segregation. However, no significant difference was found between 2014 and 2019 in either group of cities. This is echoed by Chi-squared independence test which found that having IH programs in a city is not significantly associated with how segregation changed in that city. No significant difference was found in Asian-White segregation between the two groups, suggesting that a city's Asian-White segregation status is independent of its having IH programs or not. These findings together suggest that having IH programs in a city impacts neither the city's Asian segregation nor its change in Asian segregation.

Figure 6: Change in Asian-White Segregation in California Cities

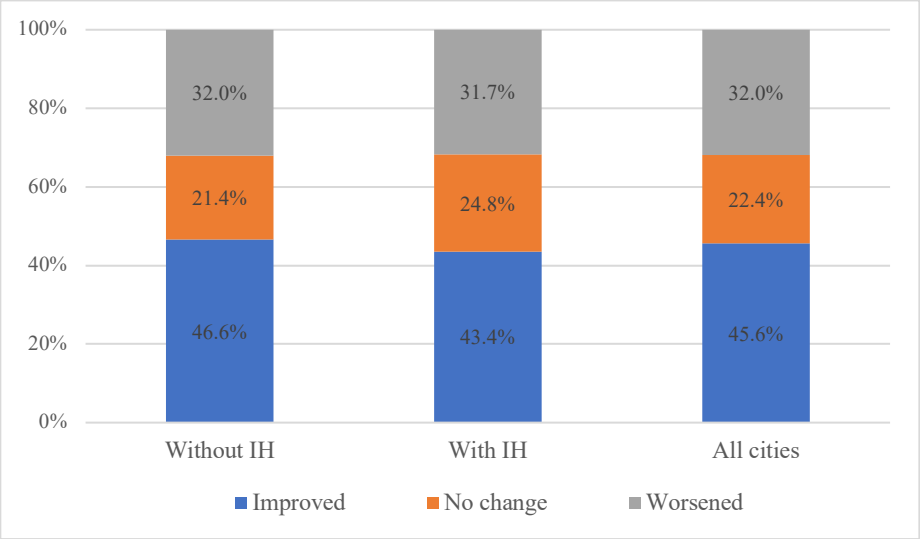


Table 4 summarizes Black-White, Hispanic-White, and Asian-White segregation in California cities in 2014 and 2019. Comparison of the segregation status across race groups reveals several findings. The first is that Black-White segregation is much higher than Asian-White or Hispanic-White segregation. In both years, statewide Black-White segregation index had a value of 0.5, suggesting strong segregation. In contrast, Hispanic-White and Asian-White segregation were moderate. The three groups also differ in their segregation's dependence on IH program availability. Black-White segregation and Hispanic-White segregation were found worse in cities having IH programs, but Asian-White segregation status did not differ between the two groups of cities. Black-White segregation and Asian-White segregation did not change significantly in either group, but Hispanic-White segregation improved in both groups. For all three racial groups, having IH programs did not impact their segregation change.

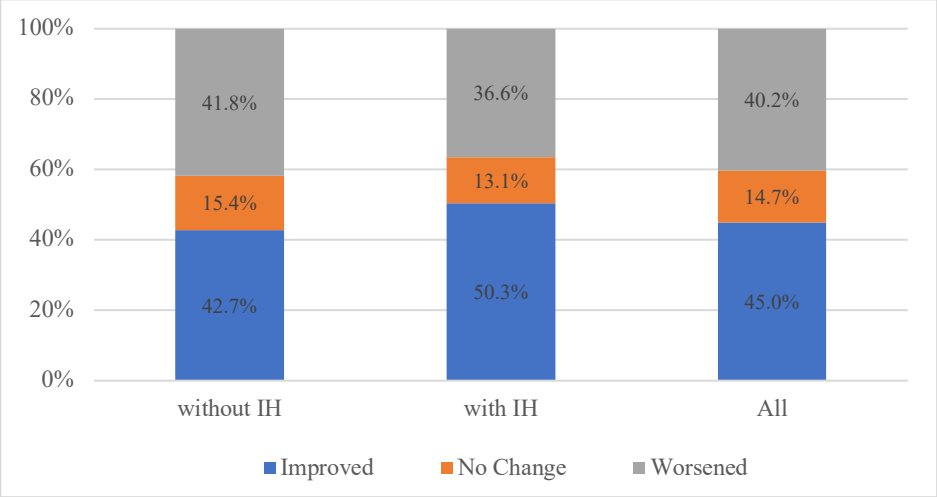
Table 4. Median segregation status, measured by dissimilarity index, between Minority and White in California cities

		White	Black	Hispanic	Asian
2014	With IH	0.59	0.06	0.32	0.14
	Without IH	0.51	0.05	0.4	0.10
	All	0.54	0.05	0.37	0.11
2019	With IH	0.58	0.06	0.32	0.15
	Without IH	0.48	0.06	0.43	0.10
	All	0.50	0.06	0.39	0.11

Single-race Isolation

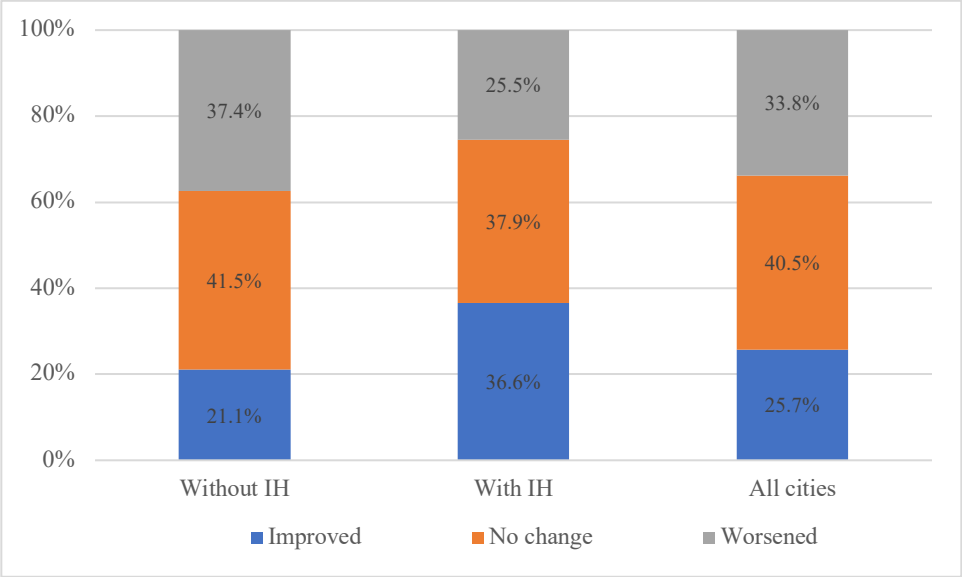
Isolation is about the potential exposure of members of a racial group to members in other groups. For Blacks, the extent that they only interact with other Blacks did not change significantly in either group of cities. No significant difference in Black segregation status was found between the two groups of cities. These findings suggest that having IH programs or not does not impact Blacks on their interracial interaction or its change.

Figure 7: Change in Black Isolation in California Cities.



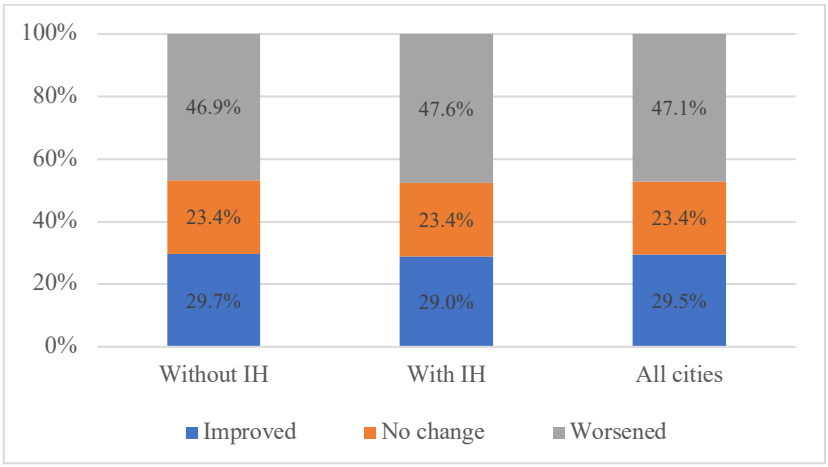
For Hispanics, isolation was found to be significantly worse in cities without IH programs. This city group also saw Hispanic isolation worsened from 2014 to 2019. This means Hispanics in these cities not only interact less with residents in other racial groups, the interaction also decreased over time. In contrast, Hispanic isolation did not change significantly in cities having IH programs. Taking all cities together, Hispanics' interaction with other Hispanics increased and their interaction with other racial groups decreased. This suggests that having IH programs in a city is not only associated with Hispanics' interracial exposure but also the change in interracial exposure.

Figure 8: Change in Hispanic Segregation in California Cities



For Asians, their interaction with members of other racial groups was significantly lower in cities with IH programs. Both groups saw Asians' interaction with other Asians increased from 2014 to 2019, but no significant difference was found between the changes of the two groups. When cities are classified as improved, no change, and worsened based on their Asians' interracial interaction, Chi-squared test suggests that having IH programs is significantly associated with the class a city falls in. These findings together suggest that having IH programs is relevant to Asian segregation status but may or may not be relevant to the change in Asian segregation.

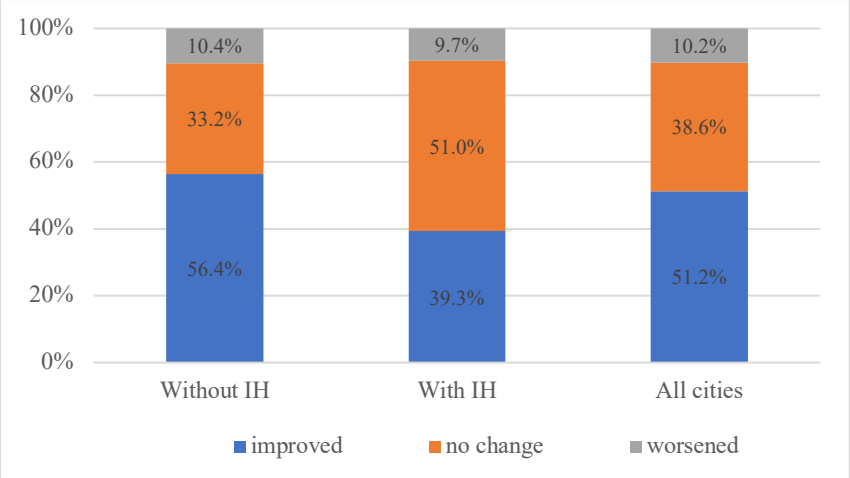
Figure 9: Change in Asian Isolation in California Cities.



For Whites, their interaction with residents in other racial groups is significantly lower in cities with IH programs. Both groups saw Whites' interracial interaction increased which explains statewide improvement observed. However, no significant difference was found

between the changes in the two city groups. When cities are classified as improved, worsened or no change based on their White isolation change, Chi-squared test finds that having IH programs is significantly associated with segregation change type. These findings suggest that having IH programs is relevant to White interracial interaction but may not be relevant to segregation change.

Figure 10: Change in White Isolation in California Cities



A comparison between Black, Hispanic, Asian, and White isolation reveals that White remains most isolated, followed by Hispanic. This means that people in these two groups interact more with people in their own racial group. Asian and Black isolation are much lower perhaps because of their smaller population count in most cities. Over time, Black isolation remained nearly the same regardless of having IH programs or not. Asian isolation changed little but the difference between the two groups is significant. Hispanic isolation is higher in cities without IH programs, while White isolation is higher in cities with IH programs. Overall, having IH programs in a city is significantly associated with the city's change in White isolation and Hispanic isolation but may not be associated with Asian isolation or Black isolation.

Table 5: Median isolation of major racial groups in 2014 and 2019

		White	Black	Hispanic	Asian
2014	With IH	0.59	0.06	0.32	0.14
	Without IH	0.51	0.05	0.4	0.10
	All	0.54	0.05	0.37	0.11
2019	With IH	0.58	0.06	0.32	0.15
	Without IH	0.48	0.06	0.43	0.10
	All	0.50	0.06	0.39	0.11

SUMMARY

The COVID-19 pandemic brought unprecedented changes to our society, underscoring the urgency of social justice in many aspects. In this research, I studied the relationship between IH policy, vulnerability to COVID-19 pandemic, and racial segregation change in California cities. Through statistical analysis, I find that having IH programs in a city is significantly associated with its vulnerability to COVID-19. Cities with IH programs are found less vulnerable than cities without IH programs. The causality in this relationship requires further examination though. While it is possible that having IH programs in a city can reduce its vulnerability to COVID-19, it is also possible that a city's vulnerability, combined with other factors, prompted the creation of IH programs in the first place. As found in this research, less vulnerable cities are characterized by having low proportion of Blacks and Hispanics, low proportion of single-parent households, and high educational attainment. In fact, the least vulnerable cities are also, not surprisingly, among the wealthiest and whitest cities in the state. Homeownership cost and rent in such cities are unaffordable to lower-income population which are found more often among Blacks and Hispanics. Perhaps exactly because of this, some cities created IH programs. This research only examined IH program availability in 2019; how long a city has had IH programs was not taken into account. Thus, one direction for future research is to examine the relationship between IH programs and vulnerability *change*. Meanwhile, the COVID-19 vulnerability map can also be updated from time to time to track vulnerability change and identify the most vulnerable cities so that resource allocation and prioritization become more efficient.

In contrast to the clear association between COVID-19 vulnerability and IH program availability, the association between having IH programs and racial residential segregation is less conclusive. As discussed already, racial residential segregation has multiple dimensions – racial diversity, interracial interaction, even distribution across neighborhoods, fair share of residential space, spatial clustering etc. Only when all aspects are measured simultaneously that the status and nature of segregation in a city and our society can be revealed. To this end, this research examined diversity, evenness, and isolation aspect of residential segregation. Findings from this multi-dimensional assessment suggests that, in terms of multi-race divergence, e.g. how neighborhood demographic diversity diverges from the city overall, no change was found, regardless of a city having IH programs or not. While average divergence is higher in cities with IH programs, suggesting stronger segregation, having IH program does not impact the change in multi-race segregation.

Individual racial groups have rather different segregation status and change trends. The impact or association of having IH programs to their segregation also differ. Black segregation is strong and remained nearly unchanged, meaning having IH programs or not had no impact on it. This echoes the finding that Black segregation is intense and impenetrable to socioeconomic interventions (Massey 2012). Hispanic segregation, on the other hand, improved from 2014 to 2019 in terms of more even distribution in neighborhoods. In cities without IH programs, Hispanics are found more evenly distributed but they are less exposed to people from other racial groups. Having IH programs did not change how evenly Hispanics live across neighborhoods, but the change in Hispanics' interracial interaction is not independent of IH program availability. This finding is encouraging as it offers the possibility of changing Hispanic segregation through housing intervention. Asian segregation is weaker compared to Blacks and Hispanics. The

evenness of its distribution in a city did not change, but its exposure to other racial groups increased. Having IH programs did not impact these changes though. Overall, having IH programs seem most promising to reduce Hispanic segregation, less to reduce Asian segregation and least to reduce Black segregation in California.

The above findings, however, should be taken with a grain of salt. Unlike other research which studied racial segregation in large metropolitan areas and using decennial census data thus having no challenge in obtaining neighborhood-level racial data, this research is about cities in California whose population range from 130 (Vernon city) to nearly 4 million (Los Angeles city). Seventy-two percent of the cities are small (less than 65,000 people) and do not have sub-city racial data readily available. This research overcame the challenge by using dasymetric mapping, but the method is not perfect, resulting in omission and commission errors which can be propagated to segregation analysis. Future research can probably stratify the 482 cities first based on their population size and number of neighborhoods; then examine the racial residential segregation for each stratum.

This research studied the association between IH program availability and racial residential segregation change. How IH program impacts segregation (or promotes integration) remains to be explored. For example, this research found that the absence or presence of IH programs in a city is associated with its change in Hispanic exposure to other racial groups. But why such an association exists? Do IH programs perpetuate segregation or are segregated cities more likely to adopt IH programs? Recently, our team has completed a survey on emergency housing policies in California cities during the COVID-19 pandemic, to understand where and in what ways HCD Directors and the cities they work for were concerned with equity in developing or implementing emergency housing policies in response to this crisis (Shea & Mamo 2022). They find that a majority of California cities included components of equity into their COVID-era emergency housing policy goals and implementation practices. Their report identifies policy goals and practices that, if replicated and sustained, could effectively address long-standing racial, economic, and health disparities. Bringing this work together will lay the groundwork for future research that will further explore the impact of housing policies on racial residential segregation.

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