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The modern-day effect of HOLC redlining on neighborhood development

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Abstract: Racial segregation, which happened more than one hundred years ago in the U.S., is a fundamental cause of economic inequality for people living in historically segregated neighborhoods today. Redlining was one form of federal policy that forced to separate communities by race even more after the Great Depression. The Home Owners Loan Corporation (HOLC) maps are widely used in economic research papers as one of the most comprehensive sources of data available to measure the effect of residential segregation. In this paper, using the Historical Redline Score (HRS) method, the author measured the association between modern-day population distribution, rent prices, and housing values in historically segregated neighborhoods. The key contributions of this paper that the author collected and used in the research were previously not available for public Census 2020 data combined with continuous historical redline scores across and within multiple geographic regions with a specific focus on California (CA). The key findings of the analysis proved the persisting segregation in historically redlined communities, showing a higher percent of Black vs. Whites in the historically redlined neighborhoods' population, lower value of housing and rent prices on national, state (CA), and city (San Francisco) level.

"...if we—the public and policy makers—acknowledge that the federal, state, and local governments segregated our metropolitan areas, we may open our minds to considering how those same federal, state, and local governments might adopt equally aggressive policies to desegregate."

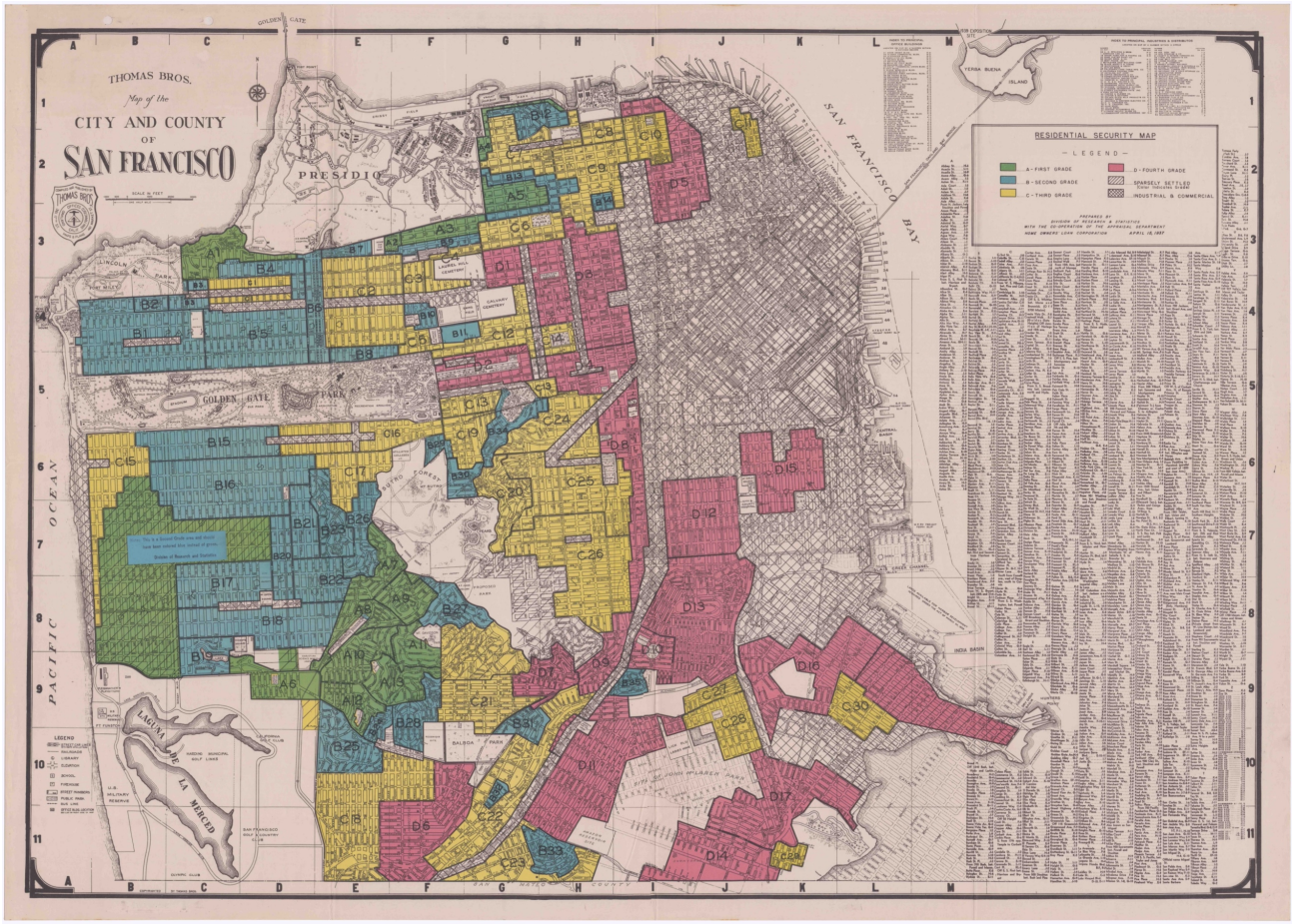
Richard Rothstein, The Color of Law: A Forgotten History of How Our Government Segregated America

1. Introduction

Over the last century, racial segregation in the United States has gone through multiple transformations. The first one occurred during Jim Crow Laws enforced racial segregation in the American South between 1877 and the beginning of the civil rights movement in 1950 (Edwards, et al., 2010). However, one policy that basically established the racially segregated neighborhood structure, which continue to persist in many cities today, is "redlining" (Rothstein, 2017). In order to evaluate the riskiness of mortgages after the Great Depression, the Home Owners' Loan Corporation (HOLC) created "residential security" maps of the major American cities. Those maps documented how real estate agents, loan officers, and appraisals could evaluate specific neighborhoods' potential riskiness for mortgage default. The project of four universities *Mapping Inequality* digitalized HOLC maps and made them public, which allowed researchers to explore and measure the impact of the historical policy on the life of modern Americans (Nelson, et al., 2022).

The HOLS maps were created between 1935 and 1940 and recorded neighborhoods around 200 cities and included the following information: the site location, structural condition, prior evaluation of the property, and social and demographic information of the neighborhoods. The creators of the HOLC maps used a four-tier grading system in order to classify neighborhoods: "A" – "the best" neighborhood, which was colored green on the map, and "D" – "hazardous" was marked red. The heavy influence on grading had a population pattern that had a high percent of immigrants or African Americans (Winling, et al., 2021).

Neighborhoods with grades "D" or "C" mainly were denied access to any types of landing, which not only harmed economic mobility (for example, children born into low-income families in segregated cities tend to have lower earnings in adulthood (Chetty, 2021)), but also affect rent and housing prices, development of the neighborhoods (Shapiro, 2004), create racial caste system (Anderson, et al., 2012) and increase social vulnerability (Richardson et al., 2020).



HOLC Map for San Francisco, "Mapping Inequality," American Panorama, ed.

In this paper, we overlaid the HOLC maps with 2020 Census tract boundary files for 142 cities across the U.S. using ArcGIS, and determined the proportion of HOLC residential areas within these boundaries. In addition, a numerical value has been assigned to each HOLC category grade: 1 for "A", 2 for "B", 3 for "C", 4 for "D". As a result, continuous Historical Redline Score (HRS) has been created

as a method to measure how historical policy (the HOLC Maps) associated with modern day population size, rent price and housing values.

The analysis provided in this paper proved the strong association between HRS and lower rent and housing prices in historically redlined communities and its heavy impact on the demographic composition of neighborhoods with significantly higher percent of people of color and lower population density.

2. Literature Review

2.1. Racial Segregation History in the U.S.

Starting from the 1950s, researchers have analyzed and systematized racial segregation and how it influences the development of society and specific demographic groups.

The Great Migration from the Jim Crow South to northern cities was the critical element of the evolution of segregation history. Moving to the North for black families was associated with a higher wage rate and significant occupational status improvement (Boustan, 2016). However, even after decades, racial wealth gap has never been closed. Researchers mainly explained that with a not-inclusive educational system, which prevents black people from gaining higher education and accumulating wealth (Colins, et al., 2017).

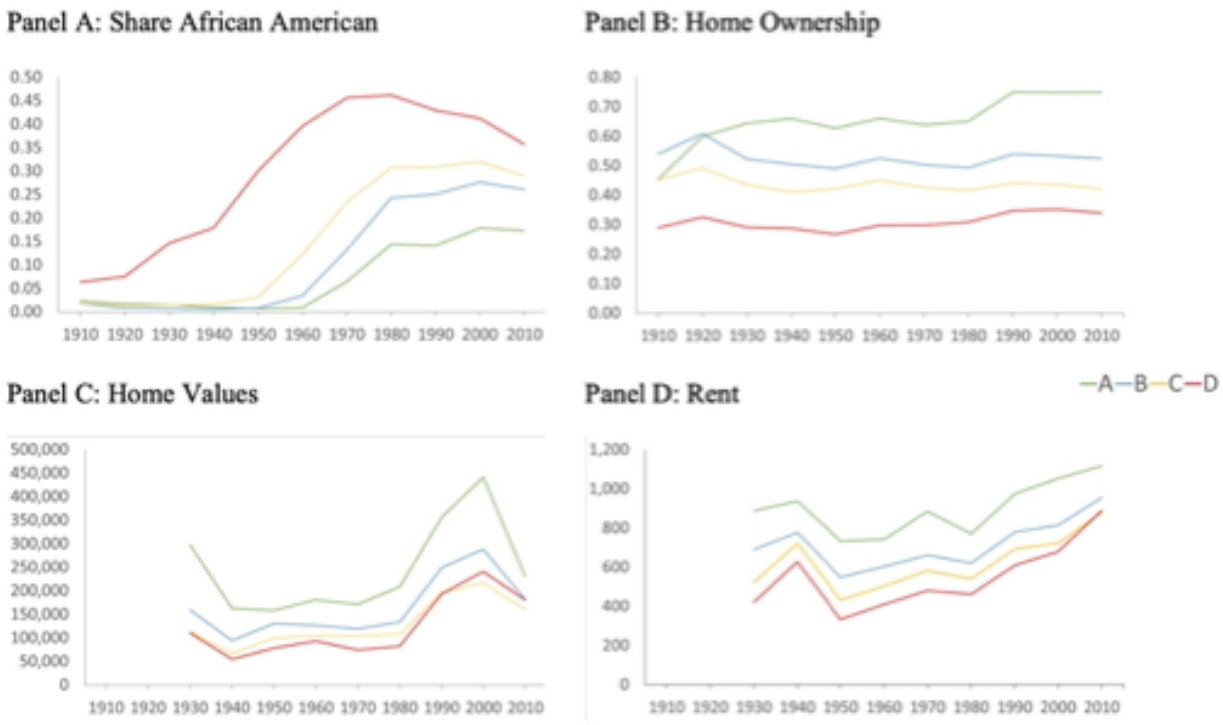
A big part of the residential discrimination played discriminatory public policies (Rothstein, 2017), which step by step, limited access to education, business, and private loans and created a hostile environment towards people of color in the neighborhoods. No surprise that real estate markets and housing policies were created clear disadvantages for black families. Housing prices in the neighborhoods with the black population were significantly lower, rent price were higher.

Researchers claimed that there is evidence that gentrification started at the beginning of the 20th century was related to the neighborhood diversity and

severally impacted spatial relations between social groups (Freeman, 2009). The study used two measures of gentrification to detect how it is related to neighborhood-level diversity and city-level segregation by race. However, researchers identified that gentrification reduced income segregation, with less evidence that it increased racial discrimination.

2.2. HOLC Maps influence on neighborhood development

Digitalization of HOLC Maps helped the researchers measure racial discrimination's effect. The most robust research has been done to measure the effect of segregation on neighborhood development (Aaronson et al., 2017). They used a boundary design and propensity score methods to identify that the maps led to reduced homeownership rates, house values, and rents and increased racial segregation using census data starting from 1910 until 2010.



Daniel Aaronson, Daniel Hartley, and Bhashkar Mazumder 'The Effects of the 1930s HOLC "Redlining" Maps', 2017

HOLC maps or "redlining" was one of many public policies that made access to credit impossible, especially for black and immigrants (Shapiro, 2004). While white families rarely faced the difficulties with a mortgage or any loans, allowing them to buy new homes, invest in their education, and build equity. Families, that had been trapped in redlined areas, were denied the same opportunity. They couldn't purchase the properties in the newly developed neighborhoods. As a result, redlined areas had a lower rate of homeownership which continues influence the big difference between white and minority households (Bhutta et al., 2020). So decades of discriminatory lending practices cemented racial segregation, that even 50 years after Fair Housing Act (1970) removed lending discrimination and made it illegal, we still see consequences of the discriminatory today.

Denied access to financial services in redlined neighborhoods resulted in a higher level of social vulnerability (Richardson et al., 2020). The first research paper on social vulnerability used HOLC Maps to measure the impact of the policy of greenspace development (Lewis, 2021). Researchers used 2010 satellite imagery to calculate the average NVDI for each HOLC neighborhood. Their primary outcomes were 2010 annual average NDVI and summer NDVI. As a result, the annual average NDVI decreased as the HOLC grade worsened. The second paper (Lynch et al., 2021) examined historic redlining about current neighborhood lending discrimination and three critical social health factors (mental and physical health, infant mortality rate). Researchers using weighted historic redline scores from HOLC Maps identified that greater historic redlining score was associated with current landing discrimination, higher infant mortality rate and worsened physical and mental health.

3. Data and Methodology

3.1. Data

We collected cross-sectional data from the American Community Survey (ACS), a demographic survey program conducted by the U.S. Census Bureau. The data was aggregated decennially (from 2010 to 2020) and by census tract. The aggregated data set contains information about demographic characteristics, rent prices, housing values for 142 cities, and 13488 census tracts around 40 states. However, for the analysis, only ratio of black population, rent, and house prices have been used. In addition, the data was limited to the census tracts that historically had any redlining grades from A to D.

The cross-sectional data was matched with HRS 2020 data set (Meier et al., 2021), which was constructed by overlaying the HOLC maps with 2020 census tracts for 142 cities across the U.S. using ArcGIS. The score determined the proportion of HOLC residential security grades contained within the HOLC boundaries and assigned a numerical value to each HOLC risk category as follows: 1 for "A" grade, 2 for "B" grade, 3 for "C" grade, and 4 for "D" grade.

3.2. Methodology

This paper follows the method for tracking the origins of housing segregation by creating a historic redlining score (HRS).

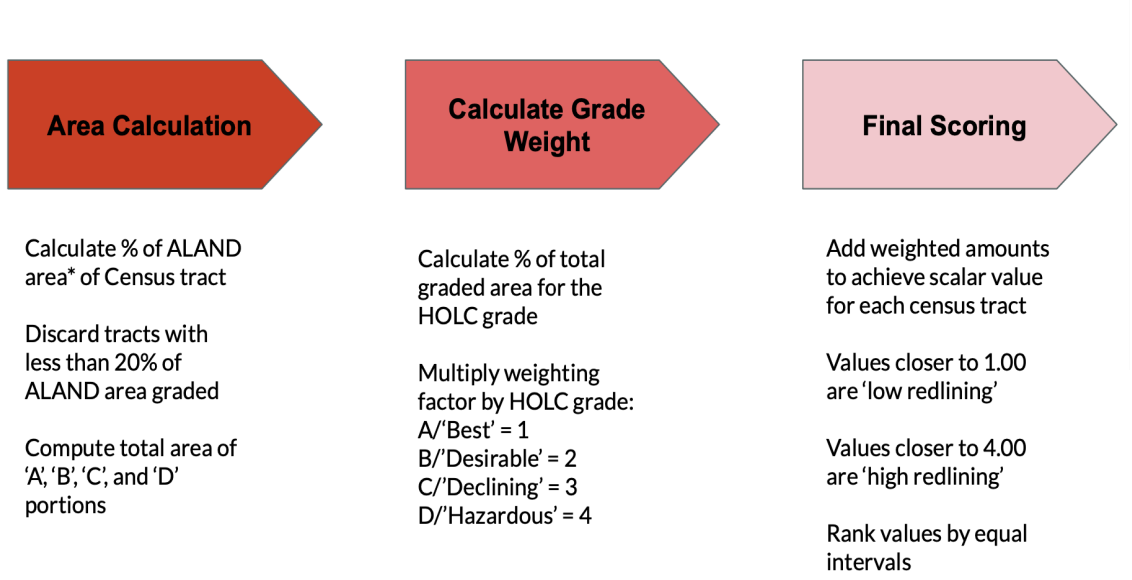


Figure 1: Methods of calculating the neighborhood-level historic redlining score

A higher HRS means greater redlining or segregation of the census tract with a value of 4.0 corresponding to completely redlined ("hazardous").

HRS score was merged with data on housing and rent from census 2020. Data were available for demographic counts, with housing data related to price and rent median values, the ratio of black and white population, and the housing ownership rate.

Summary statistics are provided below. The outliers have been removed.

sumtable {vtable} Summary Statistics

Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
HRS2020	12735	2.943	0.777	1	2.43	3.55	4
Population	12735	3490.405	1479.736	119	2368	4398	12448
Ratio_white	12735	0.529	0.287	0	0.291	0.779	0.997
Ratio_black	12735	0.251	0.297	0	0.029	0.378	1
Median_gross_rent_total	12735	1242.631	503.026	99	871	1511.5	3501
Median_house_value	12735	385386.893	355410.087	9999	116100	550650	2000001
Ownership Rate	12735	0.418	0.209	0.012	0.256	0.57	0.983

Figure 2: Summary statistics

Using aggregated data, we ran log OLS regressions on the national (around all historically redlined states only), state (California), and city-level (San Francisco) to reduce the extremes of rent and housing values. In addition, we included in the analysis the OLS regressions with the state fixed effect to observe the association of HRS2020 score with population, ration white and ratio black, rent and housing prices without influence of the specific state.

$$Y_i = \beta_0 + \beta_{HRS} + \varepsilon_i$$

$$Y_i = \beta_0 + \beta_{HRS} + \beta_{black\_ratio} + \beta_{white\_ratio} + \varepsilon_i$$

$$Y_{ist} = \beta_0 + \beta_{HRS} + \beta_{st} + \varepsilon_{ist}$$

$$Y_{ist} = \beta_0 + \beta_{HRS} + \beta_{black\_ratio} + \beta_{white\_ratio} + \beta_{st} + \varepsilon_{ist}$$

where Yi and Yist: Population, Rent price, housing value.

4. Results

4.1 Population

The analysis showed a strong association between the share of the white and black population and HRS2020. As HRS2020 increases, the percent of the black population in these neighborhoods increases.

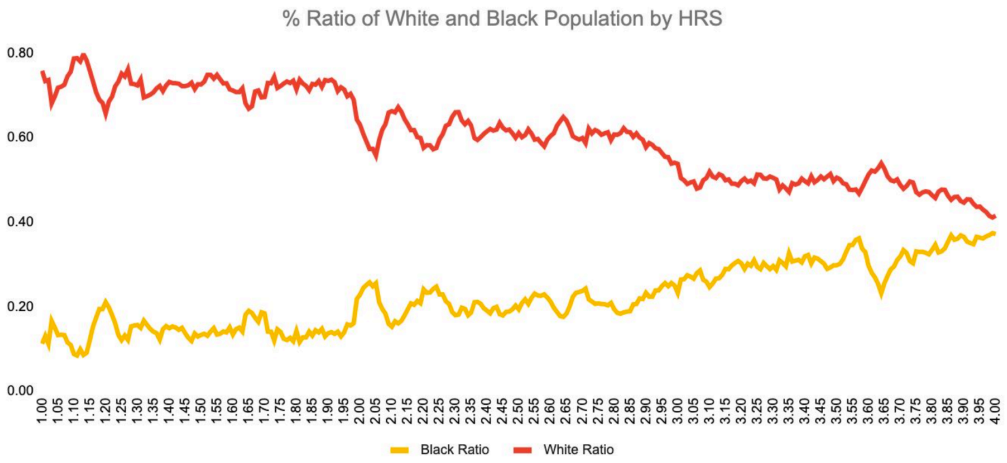


Figure 3: Share of white and black population by HRS2020

OLS regressions with dependent variable HRS2020 and two independent variables (ratio of white population and ratio of the black population). From the table below, we see that HRS2020 is associated with a 6% decrease in population per unit (SE=0.005). If we include the fixed effect on the state level, the association got even more robust – a 6.2% decrease in population per unit (SE = 0.005).

Table#1: Population regressions with/without fixed effect

	Dependent variable:		
	log(Population)		
	(1)	(2)	(3)
HRS2020	-0.060***	-0.063***	-0.062***
	(0.005)	(0.005)	(0.005)
Ratio_white		-0.487***	
		(0.022)	
Ratio_black		-0.722***	
		(0.021)	
Constant	8.240***	8.687***	
	(0.015)	(0.024)	
Fixed effect: state	No	No	Yes
Observations	12,735	12,735	12,735
R^2	0.011	0.101	0.997
Adjusted R^2	0.011	0.100	0.997
Residual Std. Error	0.446 (df = 12733)	0.426 (df = 12731)	0.421 (df = 12696)
F Statistic	137.965*** (df = 1; 12733)	474.318*** (df = 3; 12731)	119,722.400*** (df = 39; 12696)
Note:			*p<0.1; **p<0.05; ***p<0.01

Figure 4: Population regressions with/without fixed effect by HRS2020

4.2 Rent price

The visualization below shows the strong association between HRS2020 and the average rent price. The higher HRS2020 score, the lower the average rent price.

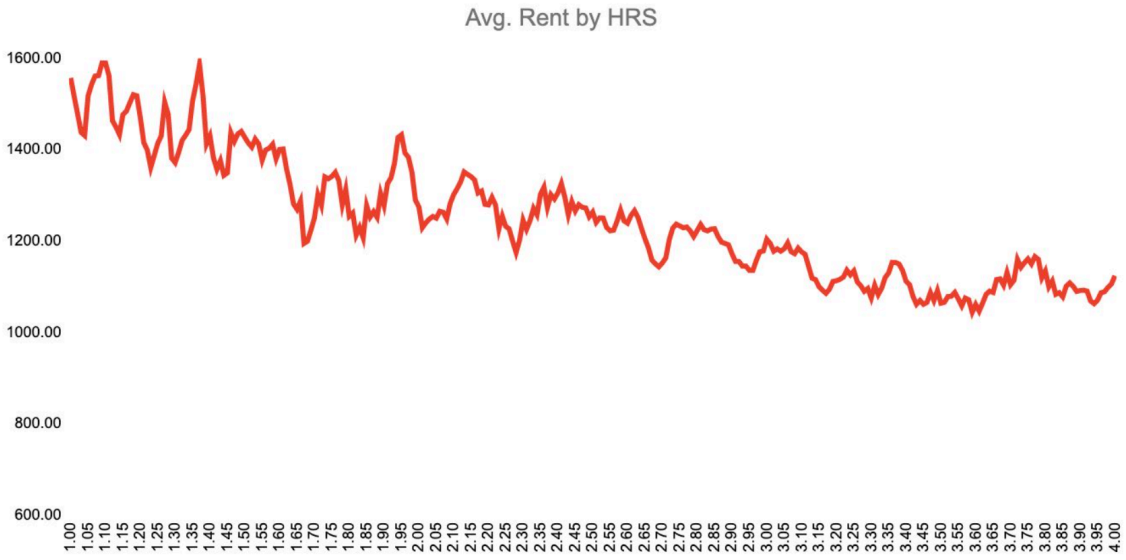


Figure 5: Average rent price by HRS2020

The OLS regressions show the same negative association between rent price and HRS2020. 6.3% (SE = 0.004) decrease rate per unit observed in the redlined areas. However, when we use fixed effect in the regression, we see even higher

negative association between HRS2020 and average rent price – 8.7% (SE = 0.004) with R^2 = 0.998.

Table #4:Rent price regressions with/without state fixed effect

	Dependent variable:			
	log(Median_gross_rent_total)			
	(1)	(2)	(3)	(4)
HRS2020	-0.063***	-0.058***	-0.087***	-0.062***
	(0.004)	(0.004)	(0.004)	(0.004)
Ratio_white		-0.463***		0.133***
		(0.018)		(0.018)
Ratio_black		-0.813***		-0.206***
		(0.017)		(0.018)
Constant	7.234***	7.668***		
	(0.013)	(0.020)		
Fixed effect: state	No	No	Yes	Yes
Observations	12,735	12,735	12,735	12,735
R^2	0.016	0.182	0.998	0.998
Adjusted R^2	0.016	0.182	0.998	0.998
Residual Std. Error	0.386 (df = 12733)	0.352 (df = 12731)	0.301 (df = 12696)	0.288 (df = 12694)
F Statistic	204.038*** (df = 1; 12733)	942.953*** (df = 3; 12731)	179,201.800*** (df = 39; 12696)	185,758.200*** (df = 41; 12694)
Note:				*p<0.1; **p<0.05; ***p<0.01

Figure 6: Rent price regressions with/without state fixed effect

4.3 Housing value

The strong negative association between HRS2020 and the median house price is observed in the visualization below. The higher HRS2020, the lower the median house value.

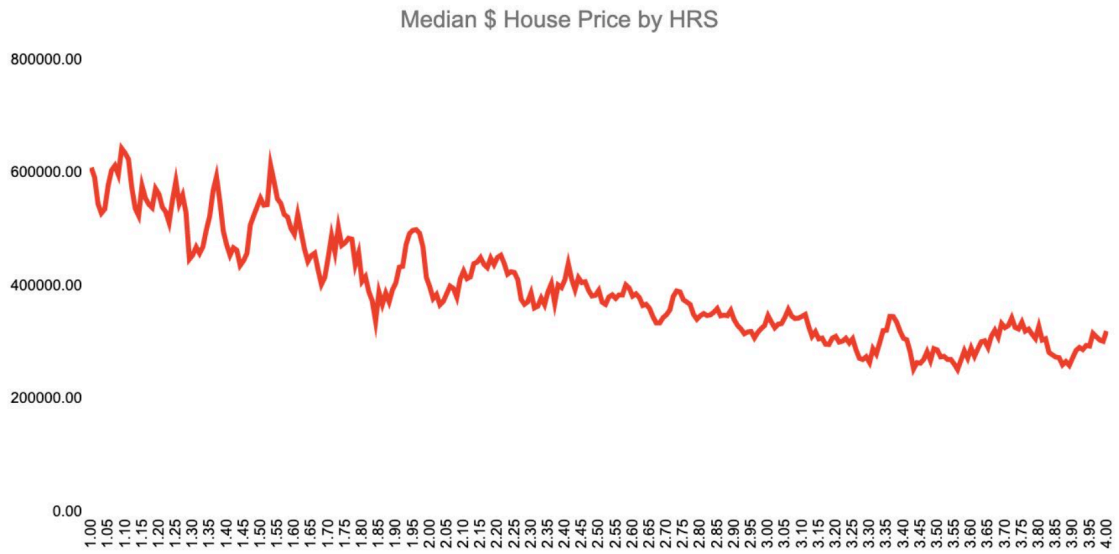


Figure 7: Median house price by HRS2020

The OLS regressions show a 12.8% (SE = 0.011) decrease in the median housing price per unit. However, with state fixed effect we see even stronger association between HRS2020 and the median house value – a 19.6% rate decrease per unit (SE = 0.008) and R^2 = 0.997.

Table#7: House value regressions with/without state fixed effect

	Dependent variable:			
	log(Median_house_value)			
	(1)	(2)	(3)	(4)
HRS2020	-0.128***	-0.113***	-0.196***	-0.126***
	(0.011)	(0.010)	(0.008)	(0.007)
Ratio_white		-1.444***		0.282***
		(0.044)		(0.038)
Ratio_black		-2.503***		-0.692***
		(0.041)		(0.037)
Constant	12.812***	14.161***		
	(0.034)	(0.048)		
Fixed effect: state	No	No	Yes	Yes
Observations	12,735	12,735	12,735	12,735
R^2	0.010	0.259	0.997	0.998
Adjusted R^2	0.010	0.259	0.997	0.998
Residual Std. Error	0.971 (df = 12733)	0.841 (df = 12731)	0.657 (df = 12696)	0.608 (df = 12694)
F Statistic	132.861*** (df = 1; 12733)	1,482.358*** (df = 3; 12731)	117,358.600*** (df = 39; 12696)	130,537.900*** (df = 41; 12694)
Note:				*p<0.1; **p<0.05; ***p<0.01

Figure 8: House value regressions with/without state fixed effect

4.4 Results on the state and city levels

In addition, we ran regressions on the state (California) and city (San Francisco) levels. California and specifically San Francisco, historically have been the most liberal place to live. However, they also had some neighborhoods that had been racially segregated at the beginning of the 20 century.

From the tables below, we see that the population of California has not been showing a robust negative association with HRS2020. However, rent price showed the strong negative association with HRS2020 – a 13.3% decrease rate per unit for

rent prices (SE=0.009) and a 24% decrease rate per unit for the median housing values (SE = 0.015).

Table#2: CA population regressions

	Dependent variable:	
	log(Population)	
	(1)	(2)
HRS2020	0.005	-0.025**
	(0.011)	(0.011)
Ratio_white		-0.378***
		(0.044)
Ratio_black		-0.217***
		(0.074)
Constant	8.232***	8.528***
	(0.033)	(0.048)
Observations	1,835	1,835
R^2	0.0001	0.039
Adjusted R^2	-0.0004	0.037
Residual Std. Error	0.348 (df = 1833)	0.341 (df = 1831)
F Statistic	0.229 (df = 1; 1833)	24.561*** (df = 3; 1831)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table #5:CA Rent price regressions

	Dependent variable:	
	log(Median_gross_rent_total)	
	(1)	(2)
HRS2020	-0.133***	-0.096***
	(0.009)	(0.008)
Ratio_white		0.412***
		(0.034)
Ratio_black		-0.237***
		(0.056)
Constant	7.754***	7.461***
	(0.027)	(0.037)
Observations	1,835	1,835
R^2	0.116	0.228
Adjusted R^2	0.116	0.227
Residual Std. Error	0.277 (df = 1833)	0.259 (df = 1831)
F Statistic	241.450*** (df = 1; 1833)	180.743*** (df = 3; 1831)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table#8: CA House value regressions

	Dependent variable:	
	log(Median_house_value)	
	(1)	(2)
HRS2020	-0.240***	-0.183***
	(0.015)	(0.015)
Ratio_white		0.633***
		(0.059)
Ratio_black		-0.389***
		(0.098)
Constant	14.136***	13.687***
	(0.046)	(0.064)
Observations	1,835	1,835
R^2	0.125	0.216
Adjusted R^2	0.125	0.214
Residual Std. Error	0.479 (df = 1833)	0.454 (df = 1831)
F Statistic	262.899*** (df = 1; 1833)	167.661*** (df = 3; 1831)
Note:		*p<0.1; **p<0.05; ***p<0.01

Figure 9: Persistent effect of HRS2020 in California

Surprisingly, in San Francisco, the persistent effect of HRS2020 on population, rent prices, and the median house value are still compelling. For example, we observed a 9.3% negative rate per unit for the population (SE = 0.03), a 13.2% negative rate per unit for rent prices (SE = 0.027), and a 14.5% negative rate per unit for the median house value (SE = 0.016), which proves the hypothesis that the HOLC Maps influence persistent even in one of the most liberal cities in the U.S.

Table#3: SF population regressions

	Dependent variable:	
	log(Population)	
	(1)	(2)
HRS2020	-0.093***	-0.092***
	(0.030)	(0.028)
Ratio_white		-0.760***
		(0.106)
Ratio_black		-0.696**
		(0.287)
Constant	8.536***	8.938***
	(0.097)	(0.103)
Observations	172	172
R^2	0.053	0.276
Adjusted R^2	0.048	0.263
Residual Std. Error	0.316 (df = 170)	0.278 (df = 168)
F Statistic	9.559*** (df = 1; 170)	21.386*** (df = 3; 168)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table #6:SF Rent price regressions

	Dependent variable:	
	log(Median_gross_rent_total)	
	(1)	(2)
HRS2020	-0.132***	-0.063***
	(0.027)	(0.022)
Ratio_white		0.434***
		(0.082)
Ratio_black		-1.466***
		(0.224)
Constant	8.067***	7.714***
	(0.085)	(0.080)
Observations	172	172
R^2	0.127	0.479
Adjusted R^2	0.122	0.469
Residual Std. Error	0.279 (df = 170)	0.217 (df = 168)
F Statistic	24.714*** (df = 1; 170)	51.426*** (df = 3; 168)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table#9: SF House value regressions

	Dependent variable:	
	log(Median_house_value)	
	(1)	(2)
HRS2020	-0.145***	-0.102***
	(0.024)	(0.016)
Ratio_white		0.844***
		(0.060)
Ratio_black		-0.422**
		(0.164)
Constant	14.479***	13.952***
	(0.078)	(0.059)
Observations	172	172
R^2	0.174	0.683
Adjusted R^2	0.169	0.677
Residual Std. Error	0.254 (df = 170)	0.159 (df = 168)
F Statistic	35.766*** (df = 1; 170)	120.568*** (df = 3; 168)
Note:		*p<0.1; **p<0.05; ***p<0.01

Figure 10: Persistent effect of HRS2020 in San Francisco

5. Conclusion

5.1. Limitations

First, there are limitations to the HRS2020 dataset that are worth to be mentioned. Neighborhood and city boundaries have expanded and significantly changed since the HOLC grading occurred. The HRS methodology can only be applied to historically redlined areas. Neighborhoods created after the 1930s do not have a corresponding HRS. Second, only residential areas have been digitized for the analysis. Third, in 2022 only limited data for Census 2020 was available – the information about the homeownership rate is inconclusive due to missing values around this variable. No information about the average wage of the population in redlined areas or the mortgage rate has been found for public use.

5.2. Discussions

The results of the analysis demonstrated how racial segregation shaped residential patterns visible today. We can observe the clear split between the HOLC better graded and lower graded neighborhoods even in 2020 census data. The persistent pattern of residential segregation in areas where redlining was most concentrated (HRS increases – population decreases, black ratio increases,

rent price, and median house value decrease). The same effect stays constant at the national, state, and city level. The next step for the following research to measure the effect of the HOLC maps on neighborhood development using difference-in-difference methodology once more Census 2020 data would be available for public use.

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