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Measuring the Impacts of Redlining

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1 Introduction

Housing policy has historically been a tool for racial discrimination. From the 1930s to the 1950s, the Home Owners' Loan Corporation (HOLC) and the Federal Housing Administration (FHA) used the racial makeup of a neighborhood to determine the risk of a given mortgage applicant [17]. All-white neighborhoods received the best ratings, while neighborhoods with several Black residents received the worst ratings of "Definitely Declining" or "Hazardous" [14].

This project quantifies the impacts of redlining on today's urban landscape through an analysis of digitized maps of Home Owners' Loan Corporation (HOLC) redlining, data on job accessibility via transit, and 2016 Census estimates for 17 U.S. metropolitan areas. A one-point decrease in HOLC rating correlates with the following modern-day effects:

1. **\$62,175 decrease** in median home value, controlling for housing unit size, age, and facilities;
2. **13.96% decrease** in homeownership;
3. **2.79% increase** in rent burden;
4. **25,185 additional jobs** accessible via transit;
5. **10.87% increase** in transit-dependent households;
6. **\$3,107 decrease** in annual household income, controlling for education levels; and
7. **10.66% increase** in household poverty.

Many neighborhoods remain racially segregated along the lines once drawn by HOLC and the FHA. **In 2016, Black residents were 15.153% more likely, and white residents 16.806% less likely, to live in redlined or downgraded census tracts.**

Though the 1968 Fair Housing Act prohibited housing discrimination on the basis of race, the absence of racially discriminatory housing policies has not translated into equity in terms of accessing education or building wealth through higher incomes or homeownership. The results of this project indicate the need for to both be conscious of the disparate racial impacts of urban planning and policy and to actively seek racial equity — and not merely the absence of discrimination — through the implementation of housing policy.

2 Problem Statement and Project Objective

This study is based on three premises:

1. Cities in the U.S. are racially segregated.
2. Racially discriminatory housing policies have facilitated segregation in cities.
3. The location of one's home sets the stage for one's future prospects, including access to a quality education and access to jobs for which one is qualified. These factors affect one's ability to earn an income and accumulate wealth over time.

2.1 Racial Segregation in U.S. Cities

Cities in the U.S. are racially segregated. The index of dissimilarity is a common measure of spatial segregation. In this case, it measures the percentage of residents that would need to move in order to attain racial parity throughout the metropolitan area. The index value can range from 0 to 1, where 1 indicates complete racial segregation [6]. Refer to Table 1: *Indices of Black-White Dissimilarity for 17 U.S. Metro Areas* for a measure of racial segregation in 2016.

Table 1: Indices of Black-White Dissimilarity for 17 U.S. Metro Areas

Metropolitan Statistical Area	$\mathbf{D_I}$
Atlanta, GA	0.560
Baltimore, MD	0.626
Birmingham, AL	0.649
Buffalo-Niagara Falls, NY	0.708
Charlotte-Gastonia-Rock Hill, NC-SC	0.505
Columbus, OH	0.600
Indianapolis, IN	0.627
Kansas City, MO-KS	0.574
Louisville, KY-IN	0.568
Minneapolis-St. Paul, MN-WI	0.542
New Orleans, LA	0.631
Norfolk-Virginia Beach-Newport News, VA-NC	0.472
Pittsburgh, PA	0.657
Portland-Vancouver, OR-WA	0.488
San Diego, CA	0.441
St. Louis, MO-IL	0.709
Tampa-St. Petersburg-Clearwater, FL	0.511

Author's calculations from 2016 ACS 5-Year Estimates, Table B02001 [20].

Several scholars have sought to explain segregation in U.S. cities; three primary hypotheses have emerged from their work.[1] The first is a hypothesis of "socioeconomic class": Black residents are typically poorer than white residents and therefore cannot afford to live in wealthy, majority-white neighborhoods. The second is that of "prejudice" or "voluntary segregation": residents prefer[2] to live among people of the same race and sort themselves into racially homogeneous neighborhoods. The third explanation is "discrimination" or "involuntary segregation": institutional structures and policies force residents to live in neighborhoods they might not have chosen otherwise, *ceteris paribus*. Galster's review of empirical evidence for

[1] For more on this topic, see Blalock, H.M. (1967). *Toward a theory of minority-group relations.* New York: John Wiley & Sons.

[2] There is evidence against this theory in the context of the dissimilarity index. Between 1970 and 1990, the dissimilarity index fell 17%, coinciding with the elimination of several racially discriminatory barriers to housing after the Fair Housing Act of 1968 [10]. If residents preferred to segregrate themselves, the dissimilarity index would not have changed so substantially.

these three theories suggests that "discrimination" or "involuntary segregation" has the most explanatory power [8].

2.2 Housing Policy and Racial Segregation

Racially discriminatory housing policies have facilitated segregation in cities. Beginning in 1933 and 1934, repspectively, the Home Owners' Loan Corporation (HOLC) and the Federal Housing Administration (FHA) provided Americans the opportunity to purchase homes through mortgage lending. However, these federally-created programs were racially discriminatory in their administration. Real estate agents employed by the HOLC and the FHA created color-coded maps of U.S. cities, grading neighborhoods along a four-point scale from *A* to *D*. Applications to purchase homes in green neighborhoods — "Class A" — were nearly guaranteed approval; applications to purchase homes in red neighborhoods — "Class D" — were almost always denied. "Class A" neighborhoods were all-white neighborhoods; "Class D" neighborhoods were home to at least some Black residents. The first FHA *Underwriting Manual* of 1935 offered the guidance: "If a neighborhood is to retain stability it is necessary that properties shall continue to be occupied by the same social and racial classes. A change in social or racial occupancy generally leads to instability and a reduction in values." [17] HOLC and FHA lending practices gave birth to the term "redlining," after those neighborhoods downgraded by the agencies [17].

HOLC and FHA lending practices were as biased in their effects as in their administration. First, redlining enforced racial segregation in cities, because it encouraged white residents to purchase homes in all-white neighborhoods and prevented Black residents from moving into these neighborhoods. Second, redlining encouraged a divergence in wealth between Black and white residents. White residents received a generous opportunity to build generational wealth through home equity. Meanwhile, Black residents were systematically discriminated against in the housing market, forced to pay exorbitant prices for substandard rental housing [15], and barred from the chance to buy homes that often serve as a valuable financial investment. Redlining is but one example among a legacy of racially discriminatory housing policies.

Redlining can be attributed both to the HOLC and the FHA. For brevity's sake, references in this paper to the neighborhood scoring mechanism associated with redlining will use the term "HOLC rating."

2.3 Home as a Platform for (Dis)Opportunity

The location of one's home sets the stage for one's future prospects, including access to a quality education and access to jobs for which one is qualified. These factors affect one's ability to earn an income and accumulate wealth over time. The educational quality of children has lifelong impacts on earnings and educational attainment. Students placed in small classrooms in grades K through 3 had a 1.8% higher rate of college attendance by age 20 compared to their peers in larger classrooms. [5] In addition, children who moved to low-poverty neighborhoods at a young age had higher rates of college attendance, a 30.8% increase in annual earnings, and a lifetime income boost of $302,000. [4].

Employment matters for at least two reasons: it is a means of earning income and a key component of self-worth [1]. Historically, Black residents have had higher rates of unemployment [22]. Some of the explanations in the literature have been spatial in nature, as the opportunities one pursues are partially a function of one's home location. Higher rates of unemployment among Black residents in the city center have been attributed to prohibitive distance to relevant job opportunities, or "spatial mismatch" [12], and the decentralization in low-wage and service-sector employment, or "job sprawl" [2].

Whether one considers it consequential or coincidental, the Black-white disparity in wealth is stark and well-documented: in 2011, "white households could draw on $92,000 to tide them over the rough times, while black families had to stretch a nest egg of $4,900." [11]

2.4 Project Objective

Recognizing the role of racial segregation in housing and the effects of home location on education, income, and wealth, this project has two aims: first, to **quantify the impact of HOLC redlining** on education, work, income, and wealth today; and second, to **evaluate redlining's disparate and lingering racial effects** between Black and white residents.

3 Hypothesized Relationships

3.1 Hypotheses

1. **Access to Education:** Current educational attainment will be lower in downgraded HOLC neighborhoods.

2. **Access to Jobs via Transit:** Because downgraded HOLC neighborhoods are typically located close to the city center, more jobs will be accessible via transit.

3. **Income and Wealth:** Current incomes, home value, and homeownership will be lower in downgraded HOLC neighborhoods; poverty, unemployment, and rental burdens will be higher.

3.2 Variable Selection and Expectation

1. **Access to Education**
   Description: The percentage of residents who have completed the following: 1) high school diploma or its equivalent; 2) some college; 3) four-year degree; and 4) graduate or professional degrees. Note that educational attainment serves here as a rough proxy for access to quality education services in general. (All measures at the census tract level.)
   Expected Relation to HOLC redlining: As the HOLC rating decreases:

   a) The percentage of residents with a high school diploma or its equivalent will increase;

   b) The percentage of residents with some college will increase;

c) The percentage of residents with a four-year degree will decrease; and

d) The percentage of residents with a graduate or professional degree will decrease.

2. **Access to Jobs via Transit**
Description: The number of jobs accessible within 30 minutes of a census tract using transit. Note that the data says nothing about job sector, pay, or skill requirements. (All measures at the census tract level.)
Expected Relation to HOLC redlining: As the HOLC rating decreases, the access to jobs via transit will increase, because redlined neighborhoods, transit service, and jobs are all concentrated in the urban core.

3. **Income and Wealth**
Description: 1) Median household income, with educational attainment as a control factor. 2) The percentage of owner-occupied housing units. 3) Median home value, with housing age, size, and facilities as control factors. 4) Percentage of households below 100% and 150% of the Federal Poverty Level (FPL) respectively. 5) Percentage of unemployed residents in the labor force. 6) Median gross rent as a percentage of annual income. (All measures at the census tract level.)
Expected Relation to HOLC redlining: As the HOLC rating decreases:

a) Median household income will decrease;

b) The percentage of owner-occupied housing units will decrease;

c) Median home value will decrease;

d) The percentage of households in poverty will increase;

e) The percentage of unemployed residents will increase; and

f) Renters will spend a larger percent of their income on rent.

4 Study Area, Data Sources, Methodology, and Analysis

4.1 Study Area

Two of the data sources used in this study are limited in their geographic coverage. First, the University of Richmond's "Mapping Inequality" project has digitized HOLC redlining maps for 128 cities. Some of the digitized maps must be merged together to better correspond to one MSA (e.g. St. Louis, MO and East St. Louis, IL), resulting in fewer than 128 potential study areas. Second, the University of Minnesota's "Access Across America" project has computed job accessibility by transit for 46 of the 50 largest metro areas. Any MSAs with areas present in both the HOLC redlining maps and the job accessibility files are included in the study area (see Figure 1).

These MSAs include: Birmingham, AL; San Diego, CA; Tampa-St. Petersburg-Clearwater, FL; Atlanta, GA; St. Louis, MO-IL; Indianapolis, IN; Kansas City, MO-KS; Louisville, KY-IN; New Orleans, LA; Baltimore, MD; Minneapolis-St. Paul, MN; Buffalo-Niagara Falls,

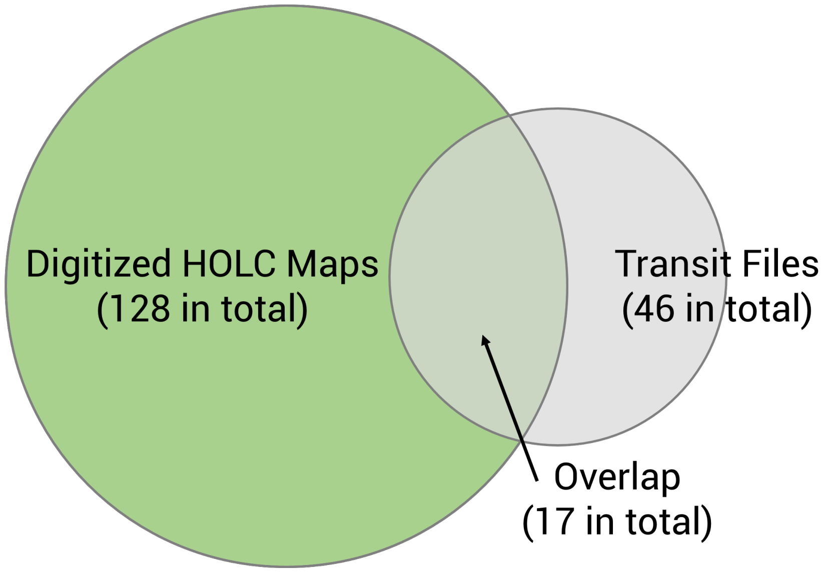

Figure 1: Overlap of MSAs present in digitized HOLC maps and transit accessibility files

NY; Charlotte-Gastonia-Rock Hill, NC-SC; Columbus, OH; Portland-Vancouver, OR-WA; Pittsburgh, PA; and Norfolk-Virginia Beach-Newport News, VA-NC.

4.2 Data Sources, Methodology, and Analysis

This project utilizes four primary sources of information:

1. **Shapefiles from the Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER/Line) collection.** [21]
   TIGER/Line shapefiles are available for every state at the census tract level. Because some MSAs span state borders, 21 state shapefiles are used, including AL, CA, FL, GA, IL, IN, KS, KY, LA, MD, MN, MO, NC, NY, OH, OR, PA, SC, VA, WA, and WI. These files are subset by *GEOID* to match the spatial extent of MSAs, and census tracts outside MSA boundaries are removed from the files to speed computation.

2. **Digitized Shapefiles of Redlining Maps from the University of Richmond's Digital Scholarship Lab.** [14]
   American Panorama's "Mapping Inequality" project has digitized HOLC maps from 128 cities and towns. These shapefiles trace the boundaries of HOLC neighborhoods and include the HOLC rating as an attribute. Historic HOLC neighborhood boundaries do not align with present-day census tract boundaries. As an approximation of HOLC rating at the census tract level, each HOLC rating is assigned a numeric value ("Class A" = 4; "Class D" = 1). A union operation is performed in GIS with all census tract shapefiles at the MSA level. The union produces three scenarios, which are handled in statistical software:

   a) When a unique *GEOID* is associated with only one HOLC rating, it is given that rating. These cases occur when the HOLC neighborhood encompasses the entire census tract or when the census tract is located on the periphery of the historic HOLC map, thereby overlapping with only one HOLC neighborhood.

b) When a unique *GEOID* is associated with multiple HOLC ratings, it is assigned the mean of these ratings. Note that this methodology is imperfect and does not account for the area of overlap. One way to account for the area of overlap is to rasterize both the census tract and HOLC rating shapefiles and then to compute the mean HOLC rating by *GEOID*. See §5.3, *Proposed Alterations and Additions.*

c) When a unique *GEOID* is not associated with any HOLC rating, it is given the value `NA`. These cases typically occur when the MSA falls outside the periphery of the historic HOLC map or when the MSA is located in the Central Business District.

3. **Job Accessibility Files from the University of Minnesota's *Access Across America: Transit 2014* Study.** [16]
   The *Access Across America* project quantifies the number of jobs that can be accessed within 30 minutes of one's home, as approximated by the census block. However, the spatial unit of this study was the census tract and not the block. It is not suitable to collapse the blocks into tracts and add the number of observations, because jobs will then be counted several times. As an approximation of job accessibility at the census tract level, the job accessibility observations at the block level are collapsed to the tract level, and the mean job accessibility of the constituent block groups is assigned to the tract.

4. **Demographic and Commuting Characteristics from the Census Bureau's 2016 American Community Survey (ACS) 5-Year Estimates.** [20]
   Tables B01001, B06011, B08122, B02001, B03001, B25064, B25077, B25035, B25003, B25041, B25048, B25051, B23025, B15003, B08201, B25071, B11001, C15002A, and C15002B are used in the analysis.

While all data is available at the city or MSA level, the primary aim of the study is to identify trends that are not specific to a single city. This requires that all cities be analyzed simultaneously. However, OLS methods are not suitable because an inherent two-class hierarchical (city, nation) structure is present in the data. Variable coefficient, fixed-slope multilevel models are used because they control for within-city correlation.

Table 2: Summary of Census Tract Characteristics by HOLC Rating

Variable	Class A	Class B	Class C	Class D
Number of Observations	5	60	188	140
Avg. Tract Population	3,680	3,222	2,974	2,490
Housing				
Median Home Value, 1000s	\$388.4	\$250.1	\$172.7	\$168.1
Pct. Owner-Occupied Housing Units	78.65	57.77	38.51	33.30
Median Home Age, Years	79.0	74.2	66.6	65.0
Median Monthly Rent	\$1097	\$1008	\$876	\$839
Median Gross Rent as % of Ann. Inc (GRAPI)	27.36	30.06	34.54	36.81
Job Access				
No. Jobs Accessible by Transit	40,675	52,348	53,014	79,074
Pct. Zero-Car Households	2.79	13.95	20.25	28.84
Pct. Unemployed in Labor Force	3.85	7.27	11.49	13.61
Income and Poverty Trends				
Annual Median Household Income	\$50,849	\$34,640	\$23,236	\$19,542
Pct. Households Below 150% FPL	1.74	6.88	14.18	17.78
Pct. Households Below 100% FPL	2.65	6.28	10.77	12.66
Pct. Single-Parent Households	7.99	16.39	25.88	28.82
Education				
Pct. HS Degree or Equivalent	7.17	18.69	25.73	28.13
Pct. Some College, No Degree	11.84	17.53	20.99	18.96
Pct. 4-Year College Degree	38.07	26.53	18.59	12.43
Pct. Grad./Prof. Degree	36.05	21.77	11.22	8.33
Race & Ethnicity				
Pct. White Residents	86.69	62.24	47.04	40.71
Pct. Black Residents	4.59	28.47	40.55	45.07
Pct. Asian Residents	4.51	3.37	4.27	3.38
Pct. Hispanic Residents	2.65	6.03	13.02	22.57
Pct. Majority-White Tracts	100	75	47	29
Pct. Majority-Black Tracts	0	25	47	61
Pct. Majority-Asian Tracts	0	0	1	0
Pct. Majority-Hispanic Tracts	0	0	4	10

Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* Owen & Levinson (2014) [16] *(3)* 2016 ACS 5-Year Estimates, Tables B01001, B06011, B08122, B02001, B03001, B25064, B25077, B25035, B25003, B25041, B25048, B25051, B23025, B15003, B08201, B25071, and B11001 [20]. All means are weighted by tract population.

HOLC Rating and Home Value. A one-point decrease in HOLC rating corresponds to a \$62,175 decrease in median home value, controlling for housing unit size, age, and facilities. Interestingly, there is a negative relationship between median home values and housing unit size: census tracts with higher percentages of larger homes are associated with lower home values. This may be because smaller homes are more frequently located in the city center, where housing costs are the highest. Going forward, a more reliable method will use appraisal data to relate home value to HOLC rating and control by housing unit characteristics at the parcel level. See §5.3, *Proposed Alterations and Additions*.

Table 3: Multilevel Model: Home Value, \$1000s

Variable	β	SE	p
Intercept	-172.806	486.170	0.722
HOLC Score	62.175	7.545	0.001***
0 Bedrooms	-3.235	1.911	0.091*
1 Bedroom	-4.339	1.404	0.002***
2 Bedrooms	-5.768	1.332	0.001***
3 Bedrooms	-7.101	1.374	0.001***
4 Bedrooms	-2.787	1.869	0.137
Age of Home	0.474	0.404	0.241
Complete Plumbing Facilities	9.436	4.549	0.039**
Complete Kitchen Facilities	-2.021	0.540	0.001***
Birmingham, AL	94.098	91.656	0.305
San Diego, CA	209.557	86.443	0.016**
Tampa, FL	15.954	91.818	0.862
Atlanta, GA	154.585	98.984	0.119
St. Louis, MO	-75.060	86.462	0.386
Indianapolis, IN	-18.228	85.483	0.831
Kansas City, MO	-50.450	86.560	0.560
Louisville, KY	-64.334	88.052	0.465
New Orleans, LA	132.570	86.993	0.128
Baltimore, MD	14.845	86.299	0.864
Minneapolis, MN	-22.681	85.886	0.792
Buffalo, NY	-70.195	90.658	0.439
Charlotte, NC	114.962	95.065	0.227
Columbus, OH	-12.475	89.531	0.889
Portland, OR	81.021	128.403	0.528
Pittsburgh, PA	-48.048	86.774	0.580
Norfolk, VA	NA	NA	NA

$SE = 84.05$ on 361 degrees of freedom. *Adj.* $R^2 = 0.587$. $F = 22.96$ on 25 and 361 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Tables B25035, B25041, B25048, B25051, and B25077 [20].

HOLC Rating and Home Ownership. A one-point decrease in HOLC rating corresponds to a 13.962% decrease in home ownership.

Table 4: Multilevel Model: Percentage Home Ownership

Variable	β	SE	p
Intercept	16.829	16.790	0.317
HOLC Score	13.962	1.323	0.001***
Birmingham, AL	-6.927	17.788	0.697
San Diego, CA	-16.784	16.719	0.316
Tampa, FL	9.923	17.867	0.579
Atlanta, GA	-14.675	19.063	0.442
St. Louis, MO	-7.313	16.640	0.661
Indianapolis, IN	5.645	16.630	0.734
Kansas City, MO	6.406	16.731	0.702
Louisville, KY	2.007	17.043	0.906
New Orleans, LA	2.548	16.792	0.879
Baltimore, MD	-1.682	16.634	0.920
Minneapolis, MN	-4.847	16.627	0.771
Buffalo, NY	-11.866	17.597	0.501
Charlotte, NC	-20.407	18.412	0.268
Columbus, OH	-20.846	17.136	0.225
Portland, OR	-27.509	23.289	0.238
Pittsburgh, PA	-5.618	16.718	0.737
Norfolk, VA	NA	NA	NA

$SE = 16.46$ on 374 degrees of freedom. *Adj.* $R^2 = 0.301$. $F = 10.9$ on 17 and 374 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Table B25003 [20].

HOLC Rating and Rent Burdens. A one-point decrease in HOLC rating corresponds to a 2.794% increase in median census tract income spent on rent (GRAPI, or "Gross Rent as a Percentage of Annual Income"). While median rents are lower in census tracts with lower HOLC ratings, incomes are also lower in these tracts, leading to higher rental burdens. This may partially explain the negative relationship between GRAPI and median rent: census tracts with high median rents often have residents with high incomes who can afford the rent. However, it is worth noting that all census tracts in the study area had GRAPI values on the cusp of or exceeding the U.S. Department of Housing and Urban Development (HUD) standard of affordability. HUD defines a housing unit as affordable if it costs less than 30% of a resident's income, or GRAPI below 30%. (See Table 2, *Summary of Census Tract Characteristics by HOLC Rating.*)

Table 5: Multilevel Model: Median Gross Rent as a Percentage of Annual Income

Variable	β	SE	p
Intercept	53.444	7.986	0.001***
HOLC Rating	-2.794	0.682	0.001***
Median Rent ($100s)	-0.790	0.214	0.001***
Birmingham, AL	-8.728	8.323	0.295
San Diego, CA	-3.187	7.808	0.683
Tampa, FL	-1.643	8.337	0.844
Atlanta, GA	-11.817	8.898	0.185
St. Louis, MO	-3.554	7.784	0.648
Indianapolis, IN	-6.377	7.765	0.412
Kansas City, MO	-7.294	7.820	0.352
Louisville, KY	-7.561	7.965	0.343
New Orleans, LA	-5.347	7.838	0.496
Baltimore, MD	-6.439	7.761	0.407
Minneapolis, MN	-8.115	7.758	0.296
Buffalo, NY	-11.675	8.233	0.157
Charlotte, NC	-9.865	8.591	0.252
Columbus, OH	0.826	8.011	0.918
Portland, OR	-2.887	10.873	0.791
Pittsburgh, PA	-9.434	7.814	0.228
Norfolk, VA	NA	NA	NA

SE = 7.68 on 371 degrees of freedom. *Adj.* $R^2 = 0.167$. $F = 5.33$ on 18 and 371 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Tables B25064 and B25071 [20].

HOLC Rating and Job Accessibility. A one-point decrease in HOLC rating corresponds to 25,185 additional jobs accessible within a 30-minute commute via transit. This is likely because most of the low-rated HOLC neighborhoods were located in the urban core, where we also observe higher job and transit density.

Table 6: Multilevel Model: Number of Jobs Accessible via Transit, 1000s

Variable	β	SE	p
Intercept	65.063	41.055	0.114
HOLC Rating	-25.185	3.229	0.001***
Birmingham, AL	9.755	43.499	0.823
San Diego, CA	26.425	40.884	0.518
Tampa, FL	12.812	43.692	0.770
Atlanta, GA	86.118	46.616	0.065*
St. Louis, MO	26.354	40.693	0.518
Indianapolis, IN	5.317	40.667	0.896
Kansas City, MO	21.970	40.915	0.592
Louisville, KY	17.992	41.678	0.666
New Orleans, LA	10.574	41.064	0.797
Baltimore, MD	95.251	40.674	0.020**
Minneapolis, MN	109.502	40.659	0.007***
Buffalo, NY	46.962	43.033	0.276
Charlotte, NC	92.656	45.025	0.040**
Columbus, OH	59.141	41.904	0.159
Portland, OR	149.996	56.950	0.009***
Pittsburgh, PA	76.705	40.882	0.061*
Norfolk, VA	NA	NA	NA

$SE = 40.25$ on 375 degrees of freedom. *Adj.* $R^2 = 0.502$. $F = 24.22$ on 17 and 375 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* Owen & Levinson (2014) [16].

HOLC Rating and Zero-Car Households. A one-point decrease in HOLC rating corresponds to a 10.869% increase in zero-car households. One way to read this is that these households have better transit access, making it unnecessary to own a car. Another way to read this is these residents are transit-dependent and would prefer a car if they could afford one. The correlation between income and zero-car households for the study area (-0.631), and Table 2, *Summary of Census Tract Characteristics by HOLC Rating*, both demonstrate that zero-car households are often poorer households.

Table 7: Multilevel Model: Percentage Zero-Car Households

Intercept	32.628	11.661	0.005***
HOLC Rating	-10.869	0.919	0.001***
Birmingham, AL	7.746	12.354	0.531
San Diego, CA	-0.551	11.611	0.962
Tampa, FL	6.001	12.409	0.629
Atlanta, GA	17.195	13.239	0.195
St. Louis, MO	22.151	11.557	0.056*
Indianapolis, IN	3.959	11.549	0.732
Kansas City, MO	6.970	11.620	0.549
Louisville, KY	9.383	11.837	0.428
New Orleans, LA	7.178	11.662	0.539
Baltimore, MD	27.875	11.553	0.016**
Minneapolis, MN	11.929	11.547	0.302
Buffalo, NY	17.558	12.221	0.152
Charlotte, NC	3.423	12.787	0.789
Columbus, OH	10.786	11.901	0.365
Portland, OR	41.854	16.174	0.010***
Pittsburgh, PA	19.499	11.611	0.094*
Norfolk, VA	NA	NA	NA

SE = 11.43 on 374 degrees of freedom. *Adj.* $R^2 = 0.489$. $F = 22.97$ on 17 and 374 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Table B08201 [20].

HOLC Rating and Unemployment. There is no statistically significant relationship between HOLC rating and unemployment when controlling for education levels. A one-percent increase in residents with a high school degree corresponds to a 0.15% increase in unemployment; A one-percent increase in residents with a four-year degree corresponds to a 0.25% decrease in unemployment.

Table 8: Multilevel Model: Percentage Unemployed Individuals in the Labor Force

Variable	β	SE	p
(Intercept)	8.957	5.924	0.131
quantScore	-0.656	0.463	0.158
High School Diploma or Equivalent	0.153	0.054	0.005***
Some College	0.031	0.052	0.552
Four-Year Degree	-0.253	0.046	0.001***
Graduate or Professional Degree	-0.060	0.052	0.251
Birmingham, AL	4.201	5.433	0.439
San Diego, CA	3.091	5.174	0.551
Tampa, FL	9.151	5.482	0.096*
Atlanta, GA	6.781	5.837	0.246
St. Louis, MO	7.965	5.095	0.119
Indianapolis, IN	5.263	5.095	0.302
Kansas City, MO	3.705	5.123	0.471
Louisville, KY	3.932	5.214	0.451
New Orleans, LA	5.106	5.156	0.323
Baltimore, MD	5.482	5.102	0.283
Minneapolis, MN	4.990	5.120	0.330
Buffalo, NY	1.819	5.419	0.737
Charlotte, NC	9.263	5.645	0.102
Columbus, OH	5.336	5.247	0.310
Portland, OR	13.431	7.120	0.060*
Pittsburgh, PA	5.493	5.129	0.285
Norfolk, VA	NA	NA	NA

$SE = 5.003$ on 370 degrees of freedom. *Adj.* $R^2 = 0.588$. $F = 27.51$ on 21 and 370 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Tables B15003 and B23025 [20].

HOLC Rating and Income. A one-point decrease in HOLC rating corresponds to a \$3,107 decrease in annual median household income, controlling for education levels. While the education coefficients appear small, they make a big difference in income: for example, if a census tract has 10% more residents with four-year degrees, that tract is expected to have a \$4,420 increase in annual median household income. This table, and Table 8, *Multilevel Model: Percentage Unemployed Individuals in the Labor Force*, indicate a possibility that higher education can boost incomes and reduce unemployment beyond any residual effects of HOLC rating.

Table 9: Multilevel Model: Annual Median Household Income, \$1000s

Variable	β	SE	p
Intercept	5.843	6.809	0.391
HOLC Rating	3.107	0.532	0.001***
High School Diploma or Equivalent	0.130	0.063	0.039**
Some College	0.081	0.059	0.174
Four-Year Degree	0.442	0.052	0.001***
Graduate or Professional Degree	0.423	0.060	0.001***
Birmingham, AL	-8.156	6.247	0.193
San Diego, CA	-1.987	5.950	0.739
Tampa, FL	-5.009	6.304	0.427
Atlanta, GA	-11.799	6.712	0.080*
St. Louis, MO	-7.597	5.859	0.196
Indianapolis, IN	-4.665	5.859	0.426
Kansas City, MO	-4.769	5.899	0.419
Louisville, KY	-6.618	5.996	0.270
New Orleans, LA	-4.219	5.929	0.477
Baltimore, MD	-4.887	5.867	0.405
Minneapolis, MN	-6.210	5.888	0.292
Buffalo, NY	-8.037	6.230	0.198
Charlotte, NC	-1.343	6.491	0.836
Columbus, OH	-16.189	6.033	0.008**
Portland, OR	-23.340	8.188	0.005**
Pittsburgh, PA	-8.306	5.898	0.160
Norfolk, VA	NA	NA	NA

$SE = 5.754$ on 371 degrees of freedom. *Adj.* $R^2 = 0.741$. $F = 54.58$ on 21 and 371 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. DEGREES.
Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Tables B15003 and B06001 [20].

HOLC Rating and Poverty. A one-point decrease in HOLC rating corresponds to a 10.659% increase in households in poverty. Here, poverty is defined as households making less than 150% of the Federal Poverty Level, or an annual household income below $36,450 for a family of four in 2016.

Table 10: Multilevel Model: Percentage Households Below 150% FPL

Variable	β	SE	p
Intercept	41.370	12.329	0.001***
HOLC Rating	-10.659	0.971	0.001***
Birmingham, AL	9.146	13.062	0.484
San Diego, CA	3.814	12.277	0.756
Tampa, FL	2.880	13.120	0.826
Atlanta, GA	-4.891	13.999	0.727
St. Louis, MO	9.839	12.22	0.421
Indianapolis, IN	4.492	12.212	0.713
Kansas City, MO	6.814	12.286	0.579
Louisville, KY	6.798	12.515	0.587
New Orleans, LA	-2.250	12.331	0.855
Baltimore, MD	-3.269	12.215	0.789
Minneapolis, MN	6.650	12.209	0.586
Buffalo, NY	8.259	12.922	0.523
Charlotte, NC	9.159	13.521	0.499
Columbus, OH	21.443	12.583	0.090*
Portland, OR	17.923	17.101	0.295
Pittsburgh, PA	2.726	12.276	0.824
Norfolk, VA	NA	NA	NA

$SE = 12.09$ on 374 degrees of freedom. *Adj.* $R^2 = 0.275$. $F = 9.742$ on 17 and 374 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Table B15003 [20].

HOLC Rating and Black Residents. A one-point decrease in HOLC rating corresponds to a 15.153% increase in the percentage of Black residents at the census tract level.

Table 11: Multilevel Model: Percentage Black Residents

Variable	β	SE	p
Intercept	56.889	29.401	0.054*
HOLC Rating	-15.153	2.313	0.001***
Birmingham, AL	39.635	31.151	0.204
San Diego, CA	-19.943	29.278	0.496
Tampa, FL	28.447	31.289	0.364
Atlanta, GA	21.870	33.383	0.513
St. Louis, MO	47.433	29.141	0.104
Indianapolis, IN	16.762	29.122	0.565
Kansas City, MO	15.074	29.300	0.607
Louisville, KY	17.361	29.847	0.561
New Orleans, LA	17.895	29.407	0.543
Baltimore, MD	42.800	29.128	0.143
Minneapolis, MN	1.187	29.117	0.968
Buffalo, NY	3.093	30.817	0.920
Charlotte, NC	12.750	32.244	0.693
Columbus, OH	16.690	30.009	0.578
Portland, OR	-22.307	40.783	0.585
Pittsburgh, PA	17.037	29.277	0.561
Norfolk, VA	NA	NA	NA

$SE = 28.83$ on 375 degrees of freedom. *Adj.* $R^2 = 0.352$. $F = 13.5$ on 17 and 375 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Table B02001 [20].

HOLC Rating and White Residents. On the contrary, a one-point decrease in HOLC rating corresponds to a 16.806% decrease in the percentage of white residents at the census tract level. This table and the prior table (Table 11, *Multilevel Model: Percentage Black Residents*) indicate that HOLC policies may relate to the persistence of racial segregation in U.S. neighborhoods.

Table 12: Multilevel Model: Percentage White Residents

Variable	β	SE	p
Intercept	26.399	28.136	0.349
HOLC Rating	16.806	2.213	0.001***
Birmingham, AL	-27.670	29.811	0.354
San Diego, CA	7.354	28.019	0.793
Tampa, FL	-19.937	29.943	0.506
Atlanta, GA	-13.836	31.948	0.665
St. Louis, MO	-40.524	27.888	0.147
Indianapolis, IN	-10.391	27.870	0.709
Kansas City, MO	-13.872	28.040	0.621
Louisville, KY	-8.516	28.563	0.766
New Orleans, LA	-8.538	28.143	0.762
Baltimore, MD	-34.355	27.875	0.219
Minneapolis, MN	-7.382	27.865	0.791
Buffalo, NY	-10.496	29.492	0.722
Charlotte, NC	-12.704	30.857	0.681
Columbus, OH	-12.093	28.719	0.674
Portland, OR	9.904	39.03	0.800
Pittsburgh, PA	-12.822	28.018	0.647
Norfolk, VA	NA	NA	NA

$SE = 27.59$ on 375 degrees of freedom. *Adj.* $R^2 = 0.272$. $F = 9.618$ on 17 and 375 degrees of freedom, $p = 0.001$. Norfolk, VA Boolean variable is removed because of multicollinearity. Author's calculations from the following: *(1)* Nelson et al. (2018) [14] *(2)* 2016 ACS 5-Year Estimates, Table B02001 [20].

5 Results and Interpretation

5.1 Lessons Learned

Hypotheses and Results. For the most part, expectations and results align relatively closely. Table 13, *Hypotheses and Results*, lists the expectations correlating with a decrease in HOLC rating and the evidence from multilevel models.

Table 13: Hypotheses and Results

Variable	Expectation	Result
Educational Attainment		
Pct. HS Degree or Equivalent	Positive	Positive
Pct. Some College, No Degree	Positive	Positive
Pct. 4-Year College Degree	Negative	Negative
Pct. Grad./Prof. Degree	Negative	Negative
Access to Jobs via Transit		
No. Jobs Accessible by Transit	Positive	Positive
Income and Wealth		
Annual Median Household Income	Negative	Negative
Pct. Owner-Occupied Housing Units	Negative	Negative
Median Home Value	Negative	Negative
Pct. Households below 150% FPL	Positive	Positive
Pct. Unemployed in Labor Force	Positive	No Relationship
Median Gross Rent as % of Ann. Inc	Positive	Positive

This is population-weighted mean education levels. We can see a stark divergence. So there's really an uphill climb here. When you look at things in the aggregate, it doesn't look so good. However, what can we do on the smaller level?

Table 14: Mean Education Levels by Race and HOLC Rating

	Pct. Black Residents			Pct. White Residents		
	High School Diploma	Some College	College Diploma	High School Diploma	Some College	College Diploma
Class A	18.875	36.479	37.205	6.381	16.455	75.668
Class B	34.596	29.147	17.344	12.134	21.415	62.350
Class C	34.474	32.801	12.580	19.504	24.781	45.126
Class D	34.552	29.007	11.195	23.163	21.901	33.798

Author's calculations from 2016 ACS 5-Year Estimates, Tables C15002A and C15002B [20]. All means are weighted by the total number of observations.

5.2 Policy Implications

Lessons from the Fair Housing Act of 1968. FIRST, what values and principles did the Fair Housing Act ensconce? However, the iteration of the Fair Housing Act passed by the Senate notoriously conferred no "teeth" in enforcement to its administering agency, the U.S. Department of Housing and Urban Development.

LOCAL ENFORCEMENT rolf pendall BLACK METROPOLIS IN 21ST CEN john a powell

5.3 Proposed Alterations and Additions

Disregard transit accessibility files to expand the potential study area. This study rests on the cusp of statistical invalidity; while it has a decent total sample size ($n = 395$ census tracts), some individual MSAs have a paltry number of observations. A more robust study would encompass as many MSAs as possible but only keep those with a relatively large number of observations after spatial overlay with HOLC files. A larger within-MSA sample size would enable the use of more robust statistical techniques such as a random effects multilevel model.

Use raster methods to overlay HOLC shapefiles with census tract shapefiles. When multiple HOLC neighborhoods intersect with a single census tract, the current overlay method, discussed in §3.2, simply takes the mean of the HOLC ratings and assigns this value to the tract. This method assumes an equal contribution of each HOLC rating when it is plausible that a census tract could share 90% of its area with a HOLC neighborhood in "Class B" and only 10% of its area with a HOLC neighborhood in "Class A." Rasterizing both spatial layers and computing the zonal mean, where the zone is the census tract, would account for the percentage areal contribution of each HOLC rating to the census tract.

Control for housing amenities and compute a spatial overlay with HOLC shapefiles at the parcel level. Another way to circumvent the problem of spatial overlay mentioned above is to disregard census units altogether. County appraisal shapefiles contain rich information about the amenities and condition of every housing unit at the parcel level. Using appraisal data would confer two benefits: 1) Controlling for more variables and analyzing appraised values at the parcel level would enable a more reliable reading of the influence of HOLC rating than is possible in this project; and 2) With only a small percentage of exceptions, housing parcels will definitively lie within or outside of a HOLC neighborhood.

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