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Examining discrimination in home improvement financing (Home Mortgage Disclosure Act 2012–2016) and neighborhood health in the United States

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ABSTRACT

Institutional racism by financial institutions historically denied Black homeowners access to home mortgage loans. An understudied aspect of the homeownership continuum is home repair and maintenance, with few studies assessing discrimination in access to funding for home improvement. Using US Home Mortgage Disclosure Act data between 2012 and 2016, we assess individual and census-tract level predictors of applying to, and being denied home improvement loans. We find non-Hispanic Black applicants are significantly more likely to be denied loans (OR: 2.28 $p < 0.01$), and that loans for areas with a high proportion of non-Hispanic Black residents (OR: 1.09, $p < 0.01$) are most likely to be denied, while applications in tracts with the highest proportion of non-Hispanic white residents (OR: 0.90, $p < 0.01$) are least likely to be denied. We find that white ($r = 0.203$), but not Black ($r = 0.02$) home improvement applications are correlated with the proportion of Black residents currently residing in the census tract. Additionally, at the census tract level, home improvement loan denial rates are associated with usually getting less than 7 hours of sleep, which is associated with adverse health outcomes. Future research on institutional racism should consider the social and health impacts of discrimination in home improvement loan financing for Black applicants and within Black communities.

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Institutional racism; housing; contextual effects

Introduction

The role of racism in the creation of neighborhoods in the United States is well documented (Rothstein 2017, Metzger and Webber 2018, Taylor 2019). Access to housing in neighborhoods with desirable resources is a key avenue of analysis in the study of racism and health, much of which has focused on discrimination affecting homeownership, and the denial of home purchase loans (Groos *et al.* 2018). However, few studies have assessed discrimination in relation to another important aspect of housing: repairs and home improvement (Harris 2009). To date, no study has assessed home improvement loans nationwide, and no epidemiologic study using the US Home Mortgage Disclosure Act (HMDA) data has included home improvement loan data. In this study, we examine access to home improvement loans as a potentially valuable resource for neighborhoods and explore the potential health impacts.

Racially discriminatory actions by the U.S. federal government, state and local governments, real estate agents, city planners, financial institutions, and white homeowners have ensured people of color, particularly Black people, will be sequestered into neighborhoods lacking necessary resources such as quality schools, jobs, political power, city services, and housing stock – all of which influence the health of residents (Williams *et al.* 2019). Importantly, the policies and practices which have created segregated neighborhoods were intentional decisions reinforced through racial terrorism and deception to ensure the most desirable resources remained in white communities – actively preventing Black and other minoritized families from moving there (Rothstein 2017, Taylor 2019, Williams *et al.* 2019). These desired resources are differentially allocated through bureaucratic and private institutions, are inextricably linked, resistant to change, and are examples of opportunity hoarding (Gee and Ford 2011, Gee and Hicken 2021, Cashin 2021).

Attempts to address how institutions differentially allocate housing resources lead to the Home Mortgage Disclosure Act (HMDA) of 1975 (McCoy 2007). HMDA was one of several pieces of legislation designed to address the concentration of poverty and disinvestment in urban cores, and specifically how lending institutions contribute. HMDA was initially developed to provide oversight and ultimately prevent discrimination such as that perpetrated by the infamous Home Owners Loan Corporation (HOLC),

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known for their color-coded risk maps which designated poor, non-white communities as 'high risk' and colored them red. However, in the 1990s, HMDA began requiring the reporting of race and gender of the applicant as well, not just racial makeup of the census tract for the loan (McCoy 2007).

Racial discrimination, either by individuals or institutions, whether intentional or not, create and maintain disparities [Supplementary Box 1]. Though individual, interpersonal racial bias is typically well defined and understood, it has been more difficult to reach a consensus on the definition of structural, systemic, and institutional racism (Lett *et al.* 2022). In this study, we assess institutional racism as policies and practices within an institution which create disparities in the allocation of resources, even if race is not explicitly named in the policy. For instance, though individual appraisers undervaluing homes of Black homeowners based on their own stereotypes is considered interpersonal racism, the fact that home appraisal values are used to determine if and for how much one can refinance their home is considered institutional racism, since Black homes are systematically more likely to be undervalued. Structural racism refers to how these institutions interact and reinforce one other, such as how property taxes based on home valuation are used to fund public school and services, resulting in lower quality education and resources for residents (Gee and Ford 2011). The fact that lower educational attainment influences future employment, income, and ability to obtain a home shunts the myriad of racial disadvantages into the next generation, ensuring the racial hierarchy will be preserved. The individual and structural elements of racism are constantly being reinforced over space and time, thus making it systemic (Lett *et al.* 2022). HMDA data is used by researchers and advocacy groups to assess institutional racism by financial institutions, with the acknowledgement that it has the potential to reflect, create, and reinforce additional disadvantages by race in housing as well as other domains such as health and wealth in our society.

Among health researchers, the bulk of studies on the relationship between racial discrimination in housing and health has focused on area-level racial disparities in home ownership or the ability to obtain a home loan. These studies theorize that racially patterned, community-level divestment is an example of institutional racism, and thus would result in worse health outcomes in that community, particularly Black residents. However, the results of these studies have produced contradictory results. Contemporary measures of redlining, usually operationalized as racial disparities in home mortgage approval rates, have yielded results that suggest a *protective* impact of mortgage discrimination for residents, including improved mental health (Gee 2008), improved birth outcomes (Mendez *et al.* 2014), and improved cancer survival (Beyer *et al.* 2016, Collin *et al.* 2021). Other studies have used historic HOLC redlining maps as an exposure and example of institutional racism in housing, rather than contemporary mortgage disparities. These studies typically produce results consistent with the hypothesis that racism in housing is harmful, predicting worse birth outcomes (Krieger *et al.* 2020), greater exposure to community violence (Jacoby *et al.* 2018), worse self-reported health (McClure *et al.* 2019), and adverse cancer outcomes (Beyer *et al.* 2016).

That contemporary measures of mortgage discrimination have produced contrary results may be due to the fact that the population used to operationalize institutional racism – individuals hoping to obtain a home purchase loan – may not be the same population as those assessed as the outcome (i.e. current residents of the tract in which the loan was intended). For instance, Mendez et al. found that preterm birth rates among Black mothers were lower in areas with the greatest disparities in Black-white home mortgage approvals (i.e. contemporary redlining). In addition to increased social and political support, and differences in tenure as proposed by the authors, it is possible that since those experiencing the discrimination do not currently live in the neighborhood, that the operationalization of the exposure is not capturing an aspect relevant for those being assessed in the outcomes. It is possible that current Black residents in tracts where white potential homeowners are approved and Black potential homeowners are denied, are more resilient in withstanding displacement, while those more vulnerable residents have already gone. In this case, the experience of discrimination impacting future Black residents would not necessarily be impactful for current residents. However, when examining historic redlining, the persistence of past institutional racism is an indicator for current forms of racism and divestment, thus closer to experiences to current residents. As such, contemporary disparities in mortgage lending may not be the most effectual way to assess how these institutionally racist actions impact the health of the current population.

An understudied aspect of the housing market, and racism in housing, however, is that for repairs and maintenance (Harris 2009). Home maintenance is a necessary component of home ownership, following the acquisition of property – whether new or existing – and lies on the continuum between occupancy, resale and potentially foreclosure if repair and other housing expenditures create financial strains (Van Zandt and Rohe 2011). This becomes particularly important as housing stock ages and repairs become necessary for the physical integrity of the building, and potentially the health of occupants. Empirical studies on the impact of housing improvements have shown that

addressing specific structural needs in housing, particularly chemical, pest, warmth/energy, and accessibility needs, improve the health of residents – particularly children and the elderly (Ige *et al.* 2019). Lower income homeowners often face unexpected costs related to unavoidable repairs due to the age or quality of the housing, as well as unpredictable changes in mortgage costs due to predatory lending or unstable incomes (Van Zandt and Rohe 2011). As such, delays in necessary repairs, or inability to upgrade to keep up with expected home valuation trends, leads to a depreciation in home value, and the reduced ability to benefit from the perks of home ownership such as home equity, home value appreciation, and tax benefits (Van Zandt and Rohe 2011). These depreciations also influence neighboring home values. Not being able to keep up with repairs also places homeowners at risk for code violations which are additional costs through fees & fines, or may be weaponized to encourage displacement in gentrifying neighborhoods. Cities across the United States have selectively enforced building code violations in order to obtain funds or land, often at the detriment of vulnerable occupants, rather than for their benefit (Dorsey 2005). A recent study in Austin, Texas, found that in areas vulnerable to gentrification or currently gentrifying that there were substantially higher rates of code complaints than in places where gentrification was not taking place (Martin 2019). Most existing research on structural deficits of housing and the health of residents has focused on the health of tenants in subsidized housing and long-term care facilities, and rarely focus on owner-occupied repairs (Thomson *et al.* 2013, Ige *et al.* 2019).

Similar to the case of home mortgage loans, there is also historical evidence of racism related to home improvement. In the late 1960s and early 1970s, financial institutions began to target low income families, particularly Black mothers, for provision of federal and local home-ownership programs designed to 'improve' the lives and communities of Black people (Taylor 2019). Due to existing discrimination in where Black would-be homeowners were allowed to purchase homes, and due to their current income status, these programs often led eligible applicants into existing, often distressed housing in lower income areas of the city. Appraisers and real estate agents colluded to sell existing homes by ignoring significant repair needs such as broken furnaces, rat infestations, and lack of plumbing, often deceiving would-be home owners and federal officials about passing inspections (Taylor 2019). Often on a fixed income and newly responsible for the conditions, new homeowners could not afford the massive repair costs – leading to fines from the city, health problems for their children, and often to foreclosure. Successful home ownership has consistently been tied to morality and 'The American Dream' ideology. As such, the dilapidated homes and divested neighborhoods were used to justify many stereotypes of Black people and Black neighborhoods that persist today. These stereotypes include Black women as having low domestic skills, unfit to be mothers and homemakers (despite conflicting narratives of Black women as servants), of Black people as harbingers of falling property values, and of Black neighborhoods as full of slothful residents in need of 'broken windows' policing (Taylor 2019). These examples of cultural racism, which use imagery and racist ideologies to reinforce Black people as lower caste, create a feedback loop which supports further barriers to housing for Black families which persist today (Williams *et al.* 2019).

To date, few studies have explicitly examined discrimination in ability to obtain funding for home improvement tasks. A 1984 study by Ryker, Pol, and Guy used HMDA home improvement lending data from 1977-1979 to determine if there was evidence of racial discrimination by financial institutions in Memphis, Tennessee (Ryker *et al.* 1984). In this study, authors found home improvement lending rates were negatively correlated with the percentage of Black residents in the tract. More recently, a Philadelphia Federal Reserve study, also using HMDA data, found that Black applicants, and applicants in communities of color where more likely to be denied a home improvement loan, controlling for applicant characteristics such applicant income and coapplicant status (Carlin 2018). Credit history – also a function of structural racism – appears to explain some, but not all of this disparity. Nevertheless, applicant race and neighborhood composition remain significant predictors of home improvement loan denial.

Discrimination in the ability to improve one's home may be another mechanism through which racism in housing impacts health inequities. In addition to housing repair needs influencing surrounding home valuation, personally living in households with disrepair (Burdette *et al.* 2011), and living in subjectively lower quality neighborhoods (Weden *et al.* 2008), with higher levels of disrepair and vacancy (Sivak *et al.* 2021) is associated with greater reports of psychological distress, depression symptomology, and worse sleep quality (Hale *et al.* 2013). Poor sleep quality and shorter sleep duration are associated with adverse physical and mental health outcomes, which has led the American Academy of Sleep Medicine and the Sleep Research Society to recommend getting 7 hours or more per night to maintain health (Panel *et al.* 2015, Itani *et al.* 2017). Participants in a qualitative study from Philadelphia, Pennsylvania reported that homes falling into disrepair is a cause for vacancy, which in turn influences mental health

through anxiety, stigma, and the potential attraction for crime (Garvin *et al.* 2013).

Noting apparent disparities in structural repair needs among lower income homeowners, and possibility to improve health, several US cities have made efforts to provide financial support specifically for home improvements. In Philadelphia, the Basic Systems Repair program (BSRP) supports low-income homeowners with grants to repair structural damage. A recent evaluation of community impacts of this program found a decrease in police-reported crimes in neighborhoods with access to this program (South *et al.* 2021). In Detroit, the 'Make it Home Repair Program' provided grants and homeowner education to low-income eligible home owners (Eisenberg *et al.* 2021). Qualitative reports from participants support reduced stress related to housing expenditure and safety concerns – highlighting the ongoing burden caused by the inability to address major housing needs which are often addressed through small-sum grants (median $6,000). The implication is that home improvement loans and grants provide an opportunity to address necessary repairs, when liquid assets and home equity are low, with the potential to improve the health and financial stability of homeowners, as well as increasing home values within the neighborhood.

Motivated by the evidence gaps regarding discrimination and home improvement loans and its potential impacts on homeowners and community health, we investigate the US population distribution and health impacts of the gap between the desire to improve and repair one's home, and the financial resources to do so. Specifically, in this study using US national data, we aim to 1) assess applicant and neighborhood-level predictors of Home Improvement Loan application and approval status, and 2) assess associations, at the census tract level, between home improvement loan denial rates and population data on residents' mental health and sleep duration. By assessing home improvement loan disparities, rather than home purchase loan disparities, we may be able to better assess how discriminatory divestment among current residents is related to the health of current residents.

We used Drs. Ford & Airhihenbuwa's Public Health Critical Race Praxis (PHCRP) to guide the assessment of racial disparities in where and for whom home improvement loan applications were completed and approved. PHCRP describes the principle of structural determinism, which posits that macro-level decisions of dominant institutions maintain and reinforce a racial hierarchy which creates racial disparities (Ford and Airhihenbuwa 2010). In this study, financial institutions reporting loan-level data to HMDA. Dr Nancy Krieger's Ecosocial theory of disease distribution links macro-level decisions to physiologic harm within a population through the tenet of embodiment, which becomes evident in observed differences in health outcomes (Krieger 2012). Using these frameworks, we hypothesized that Black applicants would be more likely to be denied home improvement loans than white applicants, and that in census tracts with higher denials, people will report worse health.

Methods

Population, exposure, and outcome data

We used publicly available, loan-level data from the Consumer Financial Protection Bureau, made available through the Home Mortgage Disclosure Act (HMDA) (Consumer Financial Protection Bureau 2019). We restricted the data to Loan Applicant Records (LAR) whose designated purpose was 'Home Improvement Loans' between 2012 and 2016. LAR data were further restricted to properties listed as 'owner-occupied as principal dwelling', 'one- to-four-family homes'. Records were excluded if the applications were withdrawn by the applicant, incomplete, or purchased by the institution. We abstracted primary applicant self-reported race, ethnicity, and gender, applicant income (in thousands), requested loan amount (in thousands), and whether the loan includes a coapplicant. Neither the value of the target property, nor the loan-to-value ratio were available. Loan records in the HMDA dataset are linked to the census tract of the property for which the loan was requested. Applications where the census tract is missing were excluded (1.14%).

In these analyses, our geographic unit of analysis is the census tract. We obtained census tract data on sociodemographic characteristics, and selected housing characteristics using the American Community Survey (ACS) 5-year estimates (2012–2016). Population and sociodemographic characteristics obtained from the ACS include population density, percent non-Hispanic Black, percent non-Hispanic white, total number of households in the tract, percent of households headed by Black (Hispanic and non-Hispanic) and non-Hispanic white residents, percent of families reporting income below poverty level in the last 12 months, median household income, and percent renting in the tract. ACS does not provide head of household data disaggregated by Hispanic ethnicity for Black households. Additionally, we determine the age distribution in the tract (<18, 18–24, 25–44, 45–64, <65). We calculated the racial-economic Index of Concentrations at the Extreme (ICE) as a measure of spatial social segregation (Krieger *et al.* 2016). ICE was measured within the census tract as

$$\frac{\#\ NHW\ Head\ of\ Households\ earning > \$100k\ in\ last\ 12\ mos\ -\ \#\ Black\ Head\ of\ Households\ making < \$25k\ in\ last\ 12\ mos}{Total\ Households\ in\ Census\ Tract}$$

More positive numbers indicate a greater concentration of wealthy non-Hispanic white residents within the tract, while negative numbers indicate greater concentration of low-income Black residents within the tract.

Distribution of the age of housing stock within the census tract was obtained by the ACS (built between 2016–2014; 2013–2000; 1999–1980; 1979–1960; 1959–1940; before 1940). We used Zillow's proprietary Zillow Home Valuation Index (ZHVI) to determine 'typical' home value within the census tract (Zillow 2016). The ZHVI is a 'smoothed, seasonally adjusted measure of typical home value', reflecting homes at the 35th to 65th percentile (Zillow 2021). We selected the single-family homes time-series dataset at the Zip Code level, then using the Missouri Census Data Center's Geographic Correspondence Engine (GeoCorr 2014), allocated zip codes to census tracts (Geocorr 2014). For zip codes in multiple census tracts, we created a weighted average of the ZVHI based on the proportion of *households* within the zip code in each census tract.

To assess census tract level health status, we draw from the CDC's PLACES/500 Cities 'Local Data for Better Health' initiative, which is a recently developed unique resource providing estimates of population health at the census tract level in the US (Centers for Disease Control and Prevention). We use the 2019 release as it contains the 2017 measurements of reporting 14 days or more poor mental health days in the past month, and usually getting less than 7 hours of sleep; these data are provided only for the total population and are not stratified by race/ethnicity. Census tract home improvement loan denial rates were linked to the 28,830 census tracts included in the 500 Cities project.

Analyses

First, we assessed census tract-level predictors of applying for a home improvement loan through financial institutions reporting via HMDA. For each census tract, we assessed the average number of applications submitted per-year between 2012 and 2016, divided by the total number of owner-occupied households in the census tract, first for all residents, then stratified by non-Hispanic white, and Black owner-occupied households. Next, we calculated simple correlations between the overall and race-stratified application rates, and census tract characteristics.

Next, we assessed the odds of having the home improvement loan application denied using a generalized estimating equation (GEE) with a binary distribution and logit link, clustering at the census tract and county-levels with robust standard errors (Hubbard *et al.* 2010). First, we assessed odds of denial accounting for loan-level financial information, next we added applicant gender and coapplicant status, and finally, we included primary applicant race-ethnicity and census-tract level characteristics. Our final analysis was restricted only to non-Hispanic Black and non-Hispanic white applicants, and included an interaction term for applicant race. Our analyses found a significant interaction between race and all loan- and tract-level characteristics, thus our final models stratify by race, as the main effects models are not appropriate. To improve model fit of our binomial outcome, we rank all census tract covariates within the county into tertiles: highest, middle, and low. This produces a within-county estimate likely most appropriate for this national-level assessment given the wide variation in home valuation, cost of living, and income across the United States. We interpreted these disparate home improvement denial odds as evidence of institutional racism, which is consistent with previous literature (Gee 2008, Mendez *et al.* 2014).

Finally, we assess associations, at the census tract level, between home improvement loan denial rates (categorized into tertiles) and (1) population and housing characteristics; and (2) rates of adults reporting poor mental health for greater than or equal to 14 days in the past month, and reporting regularly getting less than 7 hours of sleep. For these analyses, we employed a generalized estimating equation with a Poisson link and log-(population) offset (Hubbard *et al.* 2010). Our model accounts for clustering at the city-level. To obtain an approximate number of respondents per measure, we back-transformed the rates available in the 500 Cities dataset by multiplying the rate and the provided census tract population. Missingness was addressed through complete case analyses.

All analyses were performed in SAS 9.4. Harvard University IRB approved this protocol as exempt, non-Human subjects research.

Results

There were 3,429,779 owner-occupied single-family Home Improvements loans completed for approval in the HMDA dataset between 2012 and 2016. Non-Hispanic Black primary applicants accounted for 9.5% ($n = 327{,}028$) applications, and non-Hispanic white primary applicants accounted for 65.4% of total applications ($n = 2{,}243{,}443$).

Applications were successfully matched to 71,731 census tracts (98.2%). The remaining 1.8% of census tracts did not have home improvement loan applications that met inclusion criteria during this time period.

Who applies for home improvement loans?

Between 2012 and 2016, approximately 9.68 (SD: 8.15) home improvement loan applications per 1,000 owner-occupied households were completed, per year, per census tract. The application rate among non-Hispanic Black primary applicants was 12.23 per 1,000 Black-head households (SD: 23.08), while the application rate among non-Hispanic white primary applicants per 1,000 non-Hispanic white-head households was 8.31 (SD: 8.59) (Table 1). There was a moderately strong, positive correlation between overall home improvement loan application rate and the percentage of Black residents in the census tract ($r = 0.223$, $p < 0.001$). This observed pattern is driven primarily by non-Hispanic white ($r = 0.20$, $p < 0.01$) rather than non-Hispanic Black ($r = 0.02$, $p < 0.001$) applicants. This pattern of application rates and census tract characteristics was also found when examining social segregation. Overall, the correlation between home improvement application rates ($r = -0.182$, $p < 0.001$) and non-Hispanic white application rates ($r = -0.16$, $p < 0.001$) were negatively correlated with census tracts with greater high-income white households compared to low-income Black households. The proportion of Black households making less than $25,000 in the past 12 months had a similar correlation with application rate ($r = 0.181$, $p < 0.001$) and was largely driven by white applicants, where the correlation between lower income Black household and white Home Improvement applicants was moderate and positive ($r = 0.140$, $p < 0.001$), and relationship between lower income Black households and Black applicants was weak ($r = 0.02$, $p < 0.001$). Notably, among non-Hispanic Black applicants, the proportion of white residents in the census tract was positive, though weakly correlated application rates ($r = 0.031$, $p < 0.01$), while among non-Hispanic white applicants, the application rate was negative ($r = -0.103$; $p < 0.01$ (Table 1)).

Home improvement application rates were also positively correlated with the proportion of people renting the census tract ($r = 0.142$, $p < 0.01$), and poverty levels within the tract ($r = 0.157$, $p < 0.01$). The age distribution of tract residents was weakly correlated for most age groups, except for the proportion of residents over 65 years of age ($r = -0.145$), which was negatively correlated. As expected, distribution in the age of housing stock was correlated with application rate in the census tract, with the strongest correlations between the proportion of homes built before 1940 ($r = 0.117$, $p < 0.01$), and the proportion of homes built between 1980 and 1990 ($r = -0.105$, $p < 0.001$).

Table 1. Census-tract level correlates of census tract home improvement loan application rates overall, and stratified by non-Hispanic Black and non-Hispanic white primary applicant race (HMDA 2012–2016; American community survey 2016 5-year estimates; Zillow 2012–2016).

	Overall Application Rate (n = 71,468)		Non-Hispanic Black Application Rate (n = 47,509)		Non-Hispanic White Application Rate (n = 69,833)		
Average Application Rate in Census Tract (per 1,000 households) (SD)	9.68 (8.15)		12.23 (23.08)		8.31 (8.59)		White-Black Difference in Correlations
Correlations with Application Rates	Correlation	p-value	Correlation	p-value	Correlation	p-value	
Percent Black in Tract	0.223	<0.01	0.020	<0.01	0.204	<0.01	0.184
Percent White in Tract	−0.116	<0.01	0.031	<0.01	−0.103	<0.01	−0.134
Race-Economic ICE	−0.182	<0.01	−0.023	<0.01	−0.161	<0.01	−0.138
Median Income in Tract	−0.097	<0.01	−0.034	<0.01	−0.078	<0.01	−0.044
Poverty Rate in Tract	0.157	<0.01	0.033	<0.01	0.120	<0.01	0.087
Percent Renting	0.142	<0.01	0.029	<0.01	0.067	<0.01	0.038
Black Households earning Less than $25,000	0.181	<0.01	0.022	<0.01	0.140	<0.01	0.118
Black Households earning More than $100,000	0.072	<0.01	−0.034	<0.01	0.074	<0.01	0.108
White Households earning Less than $25,000	−0.089	<0.01	0.015	0.0011	−0.073	<0.01	−0.088
White Households earning More than $100,000	−0.092	<0.01	−0.016	0.0006	−0.083	<0.01	−0.067
Distribution of Residents in tract by age							
<18 years of age	0.094	<0.01	0.015	0.0015	0.071	<0.01	0.056
18–24 years old	0.080	<0.01	0.008	0.0846	0.046	<0.01	0.038
25–44 years old	0.048	<0.01	0.008	0.0919	0.016	<0.01	0.008
45–64 years old	−0.069	<0.01	−0.013	0.0033	−0.025	<0.01	−0.012
Over 65 years old	−0.145	<0.01	−0.016	0.0003	−0.096	<0.01	−0.08
Median Zillow Home Valuation Index	−0.103	<0.01	−0.071	<0.01	−0.088	<0.01	−0.017
Distribution of Homes by year built							
2014–2016	0.015	<0.01	0.004	0.3459	0.005	0.1508	0.001
2000–2013	−0.028	<0.01	−0.020	<0.01	−0.029	<0.01	−0.009
1980–1999	−0.105	<0.01	−0.036	<0.01	−0.091	<0.01	−0.055
1960–1979	−0.045	<0.01	−0.005	0.2511	−0.044	<0.01	−0.039
1940–1959	0.058	<0.01	0.022	<0.01	0.059	<0.01	0.037
Before 1940	0.117	<0.01	0.040	<0.01	0.103	<0.01	0.063

We assessed the difference (Δ) between the correlations between non-Hispanic Black and non-Hispanic white primary applicants and found that the strongest absolute difference was between the non-Hispanic Black and non-Hispanic white application rates and the percent of non-Hispanic Black residents in tract (Δ = 0.184). The second greatest difference was racial-economic social segregation as assessed by the ICE measure (Δ = 0.138), and finally the percentage of non-Hispanic white residents in the census tract (Δ = 0.134) (Table 1). We encourage the interpretation of these correlations and differences with caution, as it is intended to quickly display general differences, by race/ethnicity, of where applicants are attempting to obtain a home improvement loan.

Predictors of denial

Of the 3,429,779 home improvement loan applications included in this analysis, 39.4% were denied (n = 1,350,885). We found that non-Hispanic Black primary applicants (61.3%), and other applicants of color (51.2% were significantly more likely to have their application denied than non-Hispanic white primary applicants (31.8%, $p < 0.001$)). Women (44.0%) and applicants where gender was missing (54.0%) were more likely than men to have the application rejected (34.6%). Having a coapplicant decreased the likelihood of denial (46.9% vs. 28.8%, $p < 0.001$). The average applicant income (in thousands) among those who had their applications approved was significantly greater than the income of those denied (98.1 [SD:113.1] vs. 74.5 [SD:124.2]), and the average requested loan amount was also greater among those approved than denied (96.8 [SD:206.6] vs. 49.2 [SD:128.2]).

Among census tract characteristics, we found denial rates increased as the percentage of non-Hispanic Black residents increased, as poverty rate increased, as percentage renting increased, and the proportion of housing stock built before 1960 increased. We found that denial rates decreased as proportion of white residents increased, as the typical home value (ZHVI) increased, as racial-economic social segregation increased.

Accounting for clustering at the census tract and county, and controlling for applicant and census tract characteristics, having a coapplicant, applicant gender, and applicant race and ethnicity remained significant predictors of odds of loan application denial (Table 2). Applications with a co-applicant were less likely to be denied (OR: 0.842, 0.840-0.845). Women (OR: 1.142, 1.136-1.149) and applicants with gender unknown (OR: 1.528, 1.517-1.560) were significantly more likely to be denied than men. Primary applicants who were non-Hispanic Black had 2.279 times the odds of being denied a home improvement loan compared to their white counterparts, while other people of color had 1.685 times the odds of being denied, and where race was unknown, 2.072 times the odds of denial compared to white applicants (Table 2).

To assess racial disparities in likelihood of application denial, accounting for differences across census tracts, we examined the odds of denial based on applicant and census-tract level characteristics. We included an interaction term for applicant race-ethnicity (non-Hispanic Black vs. non-Hispanic white) for all characteristics and found all to be statistically significant for at least one level, suggesting that the relationship between the selected covariates and applicant denial rates varies by race-ethnicity (S1). As such, we primarily report stratified results (Table 2).

The baseline probability of being denied a home improvement loan is significantly greater for non-Hispanic Black compared to non-Hispanic white primary applicants. Across levels of applicant income, and requested loan amounts, holding all covariates constant, the predicted probability of denial never converges (Figure 1). For each additional $1,000 dollars in applicant income, the denial odds went down by roughly 25% (OR: 0.763, 95% CI: 0.753-0.774) for non-Hispanic Black applicants, and 30% for non-Hispanic white applicants (OR: 0.715, 95% CI: 0.710, 0.719) (Table 2). Similarly, across all strata of applicant and census tract covariates, Black applicants had higher probability of being denied the home improvement loan (Figure 2). Controlling for all applicant and census tract characteristics, among Black applicants, having a coapplicant was associated with 9% lower odds of denial (OR: 0.916, 95% CI: 0.908-0.923), while among white applicants, a coapplicant was associated with 15% lower odds of denial (OR:0.858, 95% CI: 0.855-0.861). Additionally, both Black (OR: 1.162, 95% CI: 1.144-1.182) and white (OR: 1.136, 95% CI: 1.128-1.144) women had significantly higher odds of denial compared to their male counterparts (Figure 3).

Across tertiles of typical home valuation (ZHVI), both non-Hispanic Black and non-Hispanic white applicants saw a significant decrease in denial odds, however applying for loans in census tracts with the highest home values was more protective for non-Hispanic Black (OR: 0.784, 95% CI: 0.756, 0.814) compared to non-Hispanic white (OR 0.897, 95% CI: 0.882, 0.911) applicants. As percent poverty in the tract increased, both non-Hispanic Black and non-Hispanic white applicants had greater odds of denial, with non-Hispanic Black applicants having 1.159 (95% CI: 1.113, 1.208) times the odds of denial when applying in the highest tertile of poverty in tract, compared to the lowest, while non-Hispanic white applicants had 1.096 (95% CI: 1.076, 1.117) times the odds of being denied. Applying for home improvement loans for properties in the highest tertile of percent renting was not associated with denial for non-Hispanic white applicants (OR: 1.004, 95% CI: 0.985, 1.022); however, it was associated with increased

Table 2. Odds ratio of home improvement loan denial by applicant- and census-tract level characteristics (HMDA 2012–2016; American community survey 2016 5-year estimates; Zillow 2012–2016).

	Overall (*n*= 3,429,779)	Among Non-Hispanic Black Applicants (*n*=327,028)	Among Non-Hispanic White Applicants (*n*=2,243,443)
	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)
Intercept	1.272 (1.242, 1.301)	1.558 (1.483, 1.633)	1.252 (1.218, 1.285)
(log)Applicant Income	0.718 (0.714, 0.722)	0.763 (0.753, 0.774)	0.715 (0.710, 0.719)
(log) Loan Amount	0.842 (0.840, 0.845)	0.916 (0.908, 0.923)	0.858 (0.855, 0.861)
Co-applicant	0.723 (0.718, 0.727)	0.873 (0.854, 0.891)	0.723 (0.717, 0.728)
Applicant Gender			
Male	Reference	Reference	Reference
Female	1.142 (1.136, 1.149)	1.162 (1.144, 1.182)	1.136 (1.128, 1.144)
Gender Unknown	1.538 (1.517, 1.560)	1.434 (1.158, 1.776)	1.491 (1.360, 1.634)
Applicant Race/Ethnicity			
Non-Hispanic Black	2.279 (2.249, 2.309)		
Other People of Color	1.685 (1.664, 1.707)		
Race Unknown	2.072 (2.050, 2.095)		
Non-Hispanic white	Reference	Reference	Reference
Zillow Home Valuation Index (Tertiles)			
Lowest	Reference	Reference	Reference
Middle	0.912 (0.901, 0.924)	0.867 (0.842, 0.893)	0.934 (0.919, 0.948)
Highest	0.861 (0.849, 0.873)	0.784 (0.756, 0.814)	0.897 (0.882, 0.911)
Percent Poverty in Tract (Tertiles)			
Lowest	Reference	Reference	Reference
Middle	1.029 (1.017, 1.042)	1.075 (1.039, 1.111)	1.015 (1.001, 1.029)
Highest	1.128 (1.111, 1.146)	1.159 (1.113, 1.208)	1.096 (1.076, 1.117)
Percent Renting in Tract (Tertiles)			
Lowest	Reference	Reference	Reference
Middle	0.997 (0.984, 1.009)	1.014 (0.982, 1.047)	0.987 (0.973, 1.001)
Highest	1.016 (1.000, 1.032)	1.045 (1.006, 1.085)	1.004 (0.985, 1.022)
Population Density of Tract (Tertiles)			
Lowest	Reference	Reference	Reference
Middle	0.959 (0.947, 0.971)	0.972 (0.942, 1.003)	0.959 (0.946, 0.973)
Highest	0.972 (0.959, 0.986)	0.959 (0.927, 0.993)	0.976 (0.959, 0.992)
Percent of Housing Stock Built before 1960 (Tertiles)			
Lowest	Reference	Reference	Reference
Middle	1.007 (0.994, 1.019)	1.013 (0.982, 1.045)	1.000 (0.986, 1.014)
Highest	1.015 (1.002, 1.029)	1.064 (1.030, 1.099)	1.014 (0.998, 1.029)
Year of Application			
2012	1.136 (1.127, 1.146)	1.203 (1.173, 1.233)	1.027 (1.017, 1.038)
2013	1.083 (1.075, 1.092)	1.149 (1.121, 1.176)	1.059 (1.048, 1.069)
2014	1.139 (1.130, 1.148)	1.108 (1.082, 1.134)	1.142 (1.131, 1.153)
2015	1.074 (1.066, 1.082)	1.073 (1.049, 1.098)	1.074 (1.064, 1.084)
2016	Lowest	Reference	Reference
Neighborhood Racial Composition and Racial/Economic Social Segregation[a]			
Percent Non-Hispanic Black in Tract			
Lowest	Reference	Reference	Reference
Middle	1.037 (1.025, 1.050)	1.064 (1.024, 1.106)	1.031 (1.017, 1.046)
Highest	1.093 (1.078, 1.109)	1.143 (1.099, 1.189)	1.058 (1.040, 1.076)
Percent Non-Hispanic White in Tract			
Lowest	Reference	Reference	Reference
Middle	0.931 (0.918, 0.944)	0.931 (0.903, 0.961)	0.955 (0.939, 0.971)
Highest	0.904 (0.889, 0.918)	0.862 (0.827, 0.899)	0.942 (0.925, 0.960)
Racial Economic ICE			
Lowest	Reference	Reference	Reference
Middle	0.914 (0.901, 0.928)	0.904 (0.874, 0.936)	0.940 (0.923, 0.958)
Highest	0.883 (0.867, 0.900)	0.838 (0.800, 0.878)	0.919 (0.899, 0.939)

Odds of home improvement loan denial were obtained using generalized estimating equations with robust standard errors accounting for clustering at the census tract and in the county. [a]Estimates for relationship between neighborhood racial composition, and social segregation were obtained separately, controlling for applicant and other neighborhood sociodemographic and housing characteristics.

odds of denial for non-Hispanic Black applicants (OR: 1.045, 95% CI: 1.006, 1.085). Similarly, applying for home improvement loans for properties in tracts with the highest concentration of older (i.e. pre-1960) housing was not associated with the odds of denial among non-Hispanic white applicants (OR: 1.014, 0.998, 1.029), but did predict higher odds denial for non-Hispanic Black applicants (OR: 1.064, 1.030, 1.099).

Finally, we assessed the impact of neighborhood racial composition, and racial-economic segregation on the odds of home improvement denial for individuals. Overall, percent non-Hispanic Black in the census tract was associated with increased odds of loan application denial, with applicants applying in tracts with the highest proportion of non-Hispanic Black residents having 1.093 times the odds (95% CI: 1.078, 1.109) of being denied compared to those with the lowest proportion of non-Hispanic Black residents. For non-Hispanic Black applicants, the odds of denial when applying in a primarily non-Hispanic Black tract were significantly higher (OR: 1.143, 95% CI: (1.099, 1.189)) than for non-Hispanic white applicants (OR: 1.058 95% CI: 1.040, 1.076)

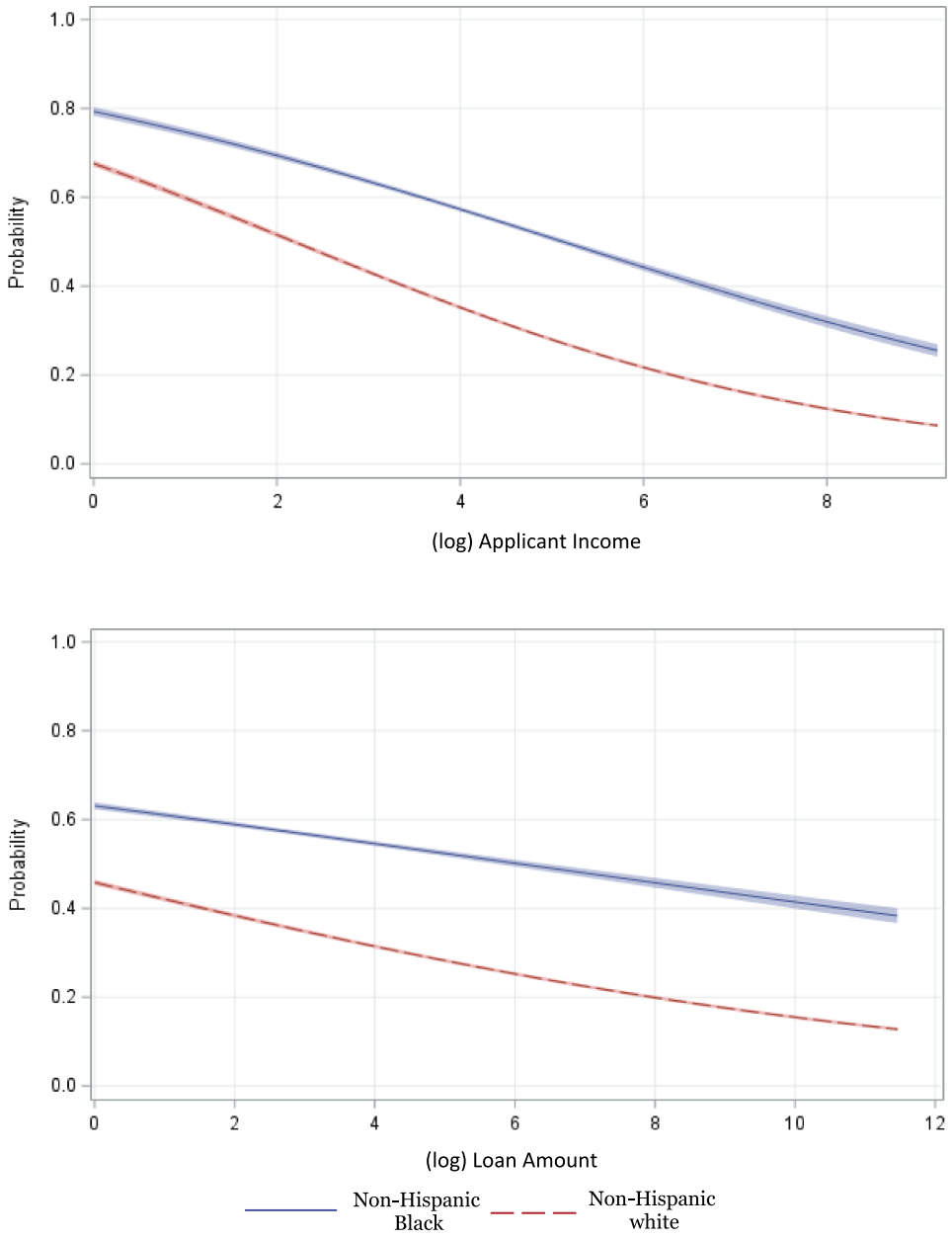

Figure 1. Predicted probability of home improvement loan denial for applicant income (log 1,000s) and loan amount (log 1,000s), stratified by primary applicant race/ethnicity. Probabilities predicted where year = 2016, home valuation, poverty rate, percent renting, population density, and percent of housing built before 1960 is set to the lowest tertile, log Applicant income = 4.193, and log Loan Amount = 3.321, coapplicant = 0 and sex="Male".

(Table 2 and S1). Alternatively, the proportion of non-Hispanic white residents in the tract was associated with a decreased odds of home improvement loan denial (OR: 0.904, 95% CI: 0.889, 0.918) compared to tracts with the smallest proportion of non-Hispanic white residents. Among non-Hispanic Black applicants, the protection afforded by applying in tracts with the highest proportion of non-Hispanic white residents was greater than that of non-Hispanic white applicants (S1), with non-Hispanic Black applicants in the highest tertile of white residents having 0.86 times the odds of denial, compared to white applicants in the highest tertile of white residents having 0.94 times the odds of denial, compared to the lowest tertile. The impact of racial-economic segregation was similar, with the odds of denial decreasing significantly as the ICE measure increased (p-value for trend < 0.001). Among non-Hispanic Black applicants, living in an area with the greatest stratification of wealthy non-Hispanic white households compared to poor non-Hispanic Black households, the odds of being denied a home improvement loan was reduced by 16.2% (OR: 0.838, 95% CI: 0.800-0.878), while non-Hispanic white applicants in this highest ICE tertile odds denial were reduced 8.9% (OR: 0.919, 95% CI: 0.899, 0.939)

Census-tract predictors of census-tract home owner improvement loan denial rates

Next, we assessed if census tract racial composition and social segregation influenced likelihood of census tract

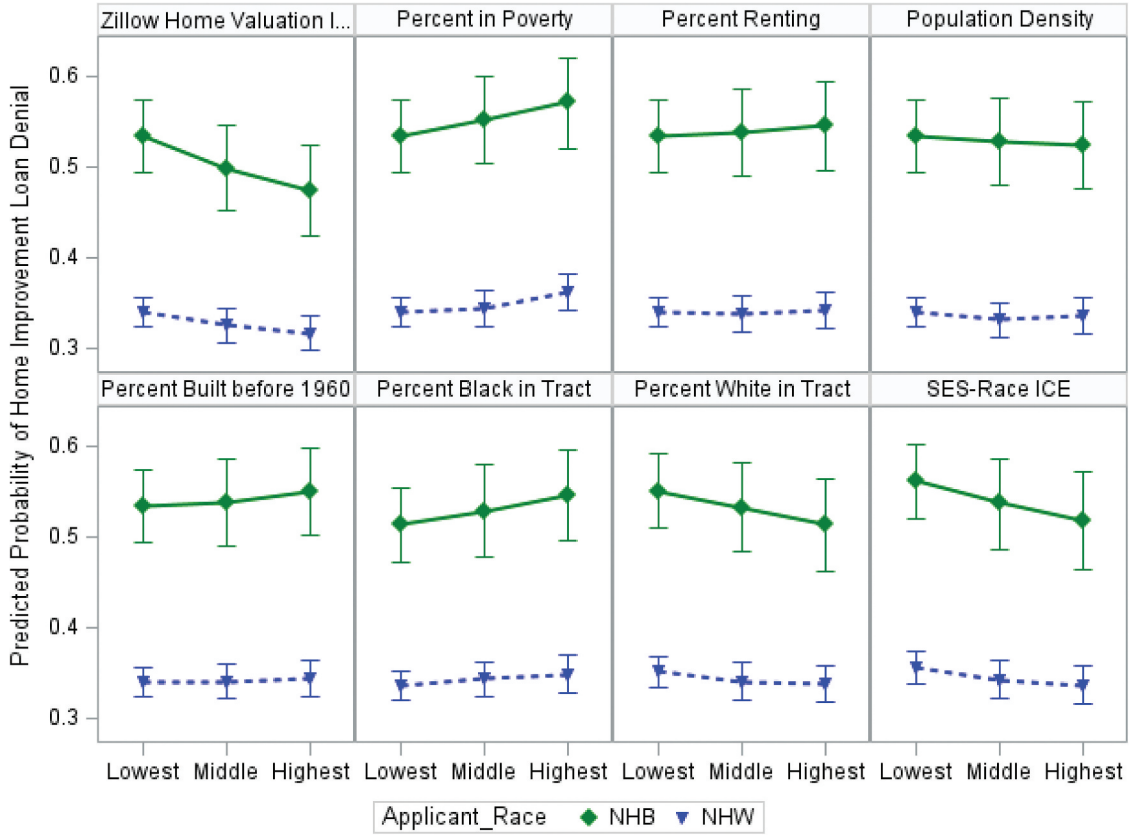

Figure 2. Predicted probability of home improvement loan denial by census tract characteristics, stratified by applicant race/ethnicity. Predicted probabilities for Percent non-Hispanic Black, Percent non-Hispanic White, and SES-Race ICE were calculated separately. Probabilities predicted where year = 2016, home valuation, poverty rate, percent renting, population density, and percent of housing built before 1960 is set to the lowest tertile, log Applicant income = 4.193, and log Loan Amount = 3.321, coapplicant = 0 and sex = "Male".

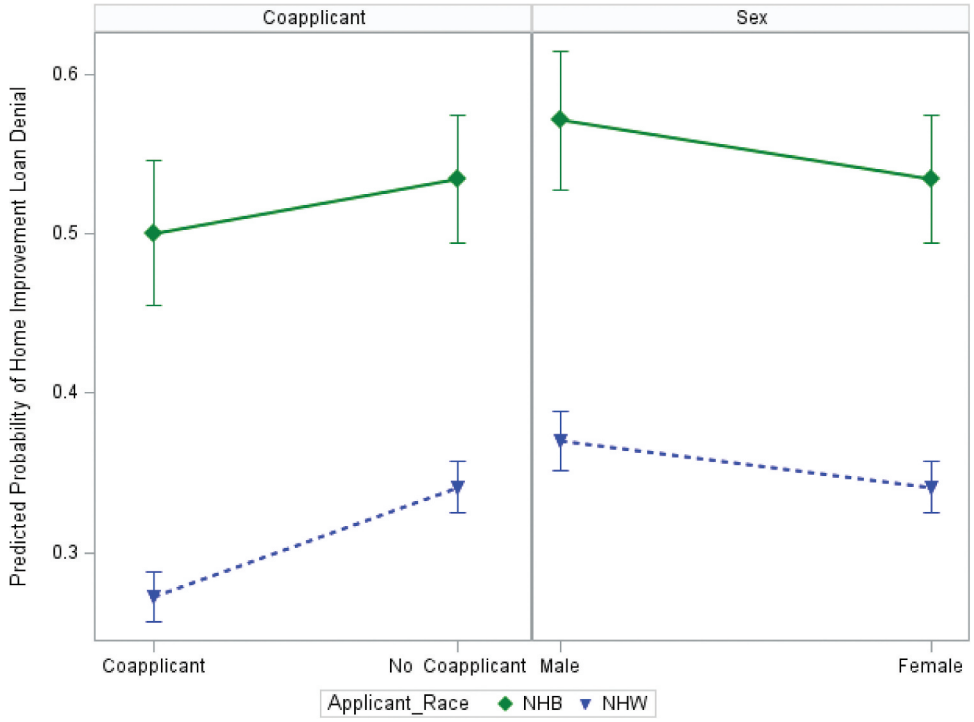

Figure 3. Predicted probability of home improvement loan denial by coapplicant status and applicant sex, stratified by applicant race/ethnicity. NHB=Non-Hispanic Black, NHW = Non-Hispanic white. Predicted probabilities predicted where year = 2016, home valuation, poverty rate, percent renting, population density, and percent of housing built before 1960 is set to the lowest tertile, log Applicant income = 4.193, and log Loan Amount = 3.321.

home improvement loan denial rates. We found that among the census tracts with the lowest denial rates, 50.15% of tracts also had the lowest proportion of non-Hispanic Black residents (Table 3). Alternatively, among census tracts with the highest denial rates, 58.9% also had the greatest proportion of non-Hispanic Black residents ($p < 0.001$) and 63.5% had the lowest proportion of non-Hispanic white residents. Among census tracts with the lowest denial rates, 51.15% had the greatest proportion of non-Hispanic white residents, and only 12.8% had the lowest proportion of white residents. Among the census tracts with the lowest denial rates, over half (55%) had the greatest extreme concentration of white higher income households (as measured by the racial-economic ICE), while among census tracts with the highest denial rates, two-thirds (65%) had the greatest concentration of low-income Black households (Table 3).

Census tract denial rates and health outcomes

Finally, we examined associations between census tract home improvement loan denial rates and census-tract level rates of poor mental health for ≥14 days in the past month, and reporting regularly getting less than 7 hours of sleep.

In crude, unadjusted analysis, only accounting for loan application rate, log average loan amount, and log average applicant income, census tracts with the highest denial rates had, on average 8% higher rates of reporting poor mental health for at least half the

Table 3. Sociodemographic characteristics (ACS 2016 5-year estimates) across tertiles of home improvement denial rates (HMDA 2012–2016).

	All Census Tracts		Lowest Denial Rate		Moderate Denial Rate		Highest Denial Rate		
	n	%	n	%	n	%	n	%	p
Number of Census Tracts	71731	100	23916	33.34%	23665	32.99%	24150	33.67%	
Denial Rate Range (min, max)	0.00%	100.00%	0.00%	32.43%	32.45%	49.81%	50.00%	100.00%	
Average Denial Rate (SD)	0.00%	0.00%	22.70%	7.30%	40.30%	4.76%	64.97%	12.88%	
Average Applicant Rate (per 1000 households) (SD)	9.68	8.15	9.35	4.97	9.23	5.57	10.44	11.91	
Average Loan Amount (in 000)	87.83	62.54	109.31	70.64	87.65	51.32	66.71	56.49	
Average Applicant Income (in 000)	86.15	116.04	131.60	155.32	79.54	94.66	47.62	61.26	
Zillow Home Valuation Index									<0.001
Lowest	22680	31.81%	5612	23.59%	7219	30.63%	10934	45.68%	
Middle	25035	35.11%	7274	30.58%	8835	37.48%	7654	31.98%	
Highest	23581	33.07%	10902	45.83%	7517	31.89%	5349	22.35%	
Percent Poverty in Tract									<0.001
Lowest	22680	31.71%	12385	51.89%	8355	35.31%	3141	13.03%	
Middle	24951	34.89%	8195	34.33%	9123	38.56%	6564	27.22%	
Highest	23881	33.39%	3289	13.78%	6184	26.13%	14408	59.75%	
Unemployment Rate									<0.001
Lowest	22680	31.71%	12119	50.75%	8020	33.89%	3748	15.54%	
Middle	24965	34.90%	8043	33.68%	8960	37.86%	6885	28.55%	
Highest	23881	33.39%	3718	15.57%	6684	28.25%	13486	55.91%	
Percent Renting in Tract									<0.001
Lowest	22680	31.71%	10844	45.42%	9092	38.42%	3949	16.37%	
Middle	24958	34.90%	7810	32.71%	8475	35.82%	7600	31.51%	
Highest	23882	33.39%	5219	21.86%	6095	25.76%	12571	52.12%	
Population Density in Tract									<0.001
Lowest	22680	31.69%	9611	40.19%	9135	38.61%	5159	21.37%	
Middle	24981	34.91%	8113	33.93%	8120	34.32%	7673	31.78%	
Highest	23899	33.40%	6188	25.88%	6407	27.08%	11310	46.85%	
% Homes built before 1960									<0.001
Lowest	22680	31.73%	7822	32.77%	8706	36.79%	7357	30.50%	
Middle	24922	34.86%	9034	37.84%	8280	34.99%	6571	27.24%	
Highest	23883	33.41%	7017	29.39%	6676	28.21%	10192	42.26%	
Percent non-Hispanic Black in Tract									<0.001
Lowest	22680	31.81%	11978	50.15%	7898	33.38%	4015	16.64%	
Middle	24782	34.76%	9034	37.82%	8958	37.85%	5900	24.46%	
Highest	23839	33.43%	2873	12.03%	6808	28.77%	14210	58.90%	
Percent non-Hispanic White in Tract									<0.001
Lowest	22680	31.71%	3064	12.83%	5517	23.31%	15310	63.46%	
Middle	24965	34.90%	8517	35.66%	9385	39.66%	5990	24.83%	
Highest	23885	33.39%	12304	51.51%	8762	37.03%	2825	11.71%	
Racial/Economic ICE									<0.001
Lowest	22680	31.70%	2404	10.07%	5508	23.28%	15973	66.22%	
Middle	24992	34.93%	8230	34.47%	9701	41.00%	5954	24.68%	
Highest	23883	33.38%	13239	55.46%	8453	35.72%	2193	9.09%	
Age Distribution of Tract									
Percent Less than 18 years	22.53%	6.48%	21.53%	6.00%	22.13%	5.86%	23.91%	7.25%	
Percent 18–24 years	9.53%	7.16%	9.00%	8.01%	8.96%	5.68%	10.62%	7.43%	
Percent 25–44 years	26.04%	7.29%	25.01%	7.74%	25.85%	6.97%	27.24%	6.96%	
Percent 45–64 years	26.64%	5.82%	27.93%	5.84%	27.22%	5.31%	24.81%	5.81%	
Percent over 65 years	15.26%	7.74%	16.54%	7.62%	15.84%	7.56%	13.43%	7.70%	

days in the past month compared to the lowest tertile (RR: 1.084; 95% CI: 1.069-1.099, $p < 0.001$ (Table 4)). Census tracts in the middle tertile had 3.3% higher rates of reporting poor mental health compared to the lowest quintile (RR: 1.033; 95% CI: 1.024-1.042, $p < 0.001$ (Table 4)). In adjusted analyses, accounting for average loan, and neighborhood characteristics, these associations were reduced to null (RR: 0.998; $p = 0.5$, RR: 1.00; $p = 0.6$, respectively (Table 4)).

Next, we assessed the association between home improvement denial rates and reporting regularly getting less than 7 hours of sleep. In crude analysis, census tracts with the highest denial rates had a 3.2% higher population average rate of reporting regularly getting inadequate sleep compared to census tracts with the lowest denial rates (RR: 1.032; 95% CI: 1.02-1.05, $p < 0.001$), while census tracts with denial rates in the middle tertile had a 2.1% higher average rate of residents reporting inadequate sleep (1.021; 95% CI: 1.01-1.03 $p < 0.001$ (Table 4)). In adjusted analyses, these relationships were attenuated and were marginally significant at $\alpha = 0.05$levels. Census tracts with the highest rates of home improvement loan denials had 0.8% higher population average of inadequate sleep (RR: 1.008; 95% CI: 0.99-1.016; $p = 0.06$), while census tracts with middling loan denial rates had 0.6% higher rates of reporting inadequate sleep (RR: 1.008; 95% CI: 1.00-1.012; $p = 0.04$ (Table 4)).

Discussion

Repairs, maintenance, and other home improvement projects are a necessary component of homeownership. However, few studies have assessed institutional racism in home improvement loan financing, and its impact on health. Financial constraints that prevent or delay necessary repairs lead to the degradation of the property itself, a depreciation in home and neighborhood value, and can impact the health of residents through increased stress or physical exposure to environmental harms. Researchers aiming to understand how racism in housing influences health should examine the role of home improvements and the ability to afford them.

Table 4. Census-tract level associations between 2012 and 2016 average home improvement loan denial rates and relative risk of reporting poor mental health (>14 days in past month) or usually sleeping less than 7 hours per night in the census tract in 2017 (2017 CDC 500 cities initiative) ($n = 26,830$).

	Mental Health		Sleep	
	Model 1	Model 2	Model 1	Model 2
	Relative Risk (95% CI)	Relative Risk (95% CI)	Relative Risk (95% CI)	Relative Risk (95% CI)
Denial Rate				
Lowest	Ref	Ref	Ref	Ref
Middle	1.033 (1.024, 1.042)	1.003 (0.996, 1.009)	1.021 (1.011, 1.032)	1.006 (1.000, 1.012)
Highest	1.084 (1.069, 1.099)	0.998 (0.990, 1.006)	1.032 (1.016, 1.048)	1.008 (0.999, 1.016)
Zillow Home Value				
Lowest		Ref		Ref
Middle		0.983 (0.976, 0.989)		1.000 (0.995, 1.006)
Highest		0.979 (0.968, 0.991)		1.004 (0.996, 1.012)
Poverty				
Lowest		Ref		Ref
Middle		1.046 (1.037, 1.055)		0.997 (0.990, 1.005)
Highest		1.109 (1.090, 1.128)		0.982 (0.969, 0.996)
Unemployment Rate				
Lowest		Ref		Ref
Middle		1.017 (1.012, 1.022)		1.003 (0.999, 1.008)
Highest		1.031 (1.025, 1.038)		1.005 (0.999, 1.011)
Percent Renting				
Lowest		Ref		Ref
Middle		1.032 (1.025, 1.040)		0.989 (0.974, 1.005)
Highest		1.057 (1.044, 1.070)		0.982 (0.953, 1.012)
Built Before 1960				
Lowest		Ref		Ref
Middle		1.023 (1.017, 1.029)		0.989 (0.984, 0.994)
Highest		1.036 (1.028, 1.044)		0.983 (0.976, 0.989)
Percent non-Hispanic Black				
Lowest		Ref		Ref
Middle		1.002 (0.995, 1.009)		1.013 (1.003, 1.023)
Highest		1.002 (0.994, 1.009)		1.041 (1.032, 1.051)
Percent non-Hispanic White				
Lowest		Ref		Ref
Middle		1.003 (0.996, 1.009)		0.982 (0.977, 0.988)
Highest		1.020 (1.006, 1.034)		0.957 (0.945, 0.970)
Racial-Economic ICE				
Lowest		Ref		Ref
Middle		0.982 (0.976, 0.989)		0.991 (0.984, 0.999)
Highest		0.961 (0.946, 0.976)		0.978 (0.961, 0.994)

Estimates were produced using Poisson general estimating equation models, clustering census tracts (level 1) within cities (level 2) to produce population average estimates. Model 1 included average application rate, loan amount, and applicant income in the census tract. Model 2 estimating suboptimal sleep additionally controls for mental health rate.

We found that the overall application rates – and notably non-Hispanic white application rates – were correlated with the proportion of non-Hispanic Black residents in the tract, the poverty rate in the tract, and the proportion of low-income Black households in the tract. Though correlation cannot and should not be used on its own, we found these patterns to be striking as it may be an indicator of incipient or ongoing neighborhood change. Gentrification has largely been defined by its effects on neighborhoods, primarily by changes in the housing market, increases in the areas economic status, and changes in the demographics of residents such that the neighborhood's 'character' changes (Bates 2013). Though the debate on the process of gentrification, and how best to measure it is ongoing (Bates 2013), our novel findings suggest the publicly available data on home improvement loan interest and approval may provide insight on lower-income and predominantly Black and brown areas where there is an interest and action towards structural home rehabilitation among white people. Future studies should examine disparities in the desire to obtain home improvement loans longitudinally in relation to neighborhood change.

When assessing determinants of individual odds of home improvement loan denial, we found that Black applicants were significantly more likely to be denied, and that the boost in approval odds provided by having higher income, higher requested loan amount, and having a coapplicant was greater for non-Hispanic white compared to non-Hispanic Black applicants. Conversely, the penalty assigned to census tracts with a greater proportion of non-Hispanic Black residents, with older housing stock, and higher poverty and rental rates, is greater for non-Hispanic Black compared to non-Hispanic white applicants. This is particularly important given that there appears to be a disproportionate desire for applications in these areas. These findings suggest that in lower income and non-Hispanic Black communities, non-Hispanic white applicants are favored to non-Hispanic Black applicants. Though not assessed directly in this study, there is evidence that unmet housing expenditures such as repairs and maintenance lead to foreclosure, or potentially can lead to home loss through eminent domain or code violation enforcement (Dorsey 2005). These are also important precursors to neighborhood change which, as a type of structural racism, should continue to be examined empirically.

Our preliminary analysis of census tract level associations indicates that overall home improvement loan denial rates are associated with higher census tract rates of poor mental health and short sleep durations, however tract-level sociodemographic characteristic account for these associations. The strongest association is for reporting less than 7 hours of sleep, aligning with previous research on subjective neighborhood quality. Taken together, not only is there evidence of discrimination in repair financing, there is also a potential impact on the health of residents. While studies have assessed the health effects of renovations and repairs in subsidized and public housing (Ellen *et al.* 2020), we are only aware of one study that has looked at potentially health-relevant implications of repairs for home owners, which reported that in areas where home owners could access home improvement funds, there was a significant decrease in reported crime (South *et al.* 2021). With 'broken windows' policing designed to target neighborhoods in physical disrepair, and given the negative impact of policing on Black health (Sewell and Jefferson 2016, Alang *et al.* 2017, Jackson *et al.* 2017, Bor *et al.* 2018), it is possible that both a reduction in crime, and a reduction in police presence, could improve the mental health and well-being of residents.

Strengths and limitations

This study had several limitations which should be noted. First, these data do not include critical information also likely to impact denial odds, including information about the value of the target property, or additional information about the applicant's financial status such as credit score. Both home appraisal and credit scores, however, are subject to structural racism and are thus part-and-parcel of what we have aimed to assess. Additionally, the data pertain solely to home improvement loans provided specifically though funding institutions reporting through the HMDA, and thus is limited to this specific mechanism. We were not able to assess other ways in which households identify funding, particularly when there are barriers to access through traditional mechanisms. For example, wealthier, more established homeowners may choose mortgage refinance, which was not included in this analysis, while lower income homes may access local grants, microfinancing, or small as-needed loans provided through community-led organizations such as Voices of Women in St. Louis, Missouri (Voices of Women VOW 2021) – or may work collectively with neighbor and family resources to crowdsource funds. As such, the interpretation of these findings is limited to denied access to home improvement loans reportable through the HMDA. Nevertheless, bank-provided home improvement lines of credit remain a notable avenue to access necessary funds for households with repair needs. Institutional discrimination in home improvement financing stands to compound upon discrimination in home purchases. Additionally, we were limited by available census-tract level data to assess health outcomes. The association with sleep was very weak, however this should not discourage future research on other potentially related health outcomes.

A major strength of this study is our novel, systematic, national examination of home improvement loan applications and patterns of approval versus denial. Particularly in the study of racism, housing, and health, home improvement has been neglected despite its important role in the maintenance and sustainability of owner-occupied homes. As the first study of institutional racism and health to utilize HMDA data to assess access to home improvement financing, we believe this study supports additional work calling for new data, and novel measures of structural racism to complement our growing understanding of how racism, particularly anti-Black racism, operates to produce health disparities. Furthermore, this study should be used to inform local policy and support advocacy work on fair lending practices. Beyond the initial purchase loan, homeowners can face disparate trajectories in their journeys which could be the difference between homeownership as wealth generation or as a substantial financial burden. That there are gaps in the desire to, and ability to, structurally repair ones' home, and that this mismatch is greater for Black residents should encourage local entities to assess their constituency's needs and potentially fill these gaps through grant programs such as those in Detroit and Philadelphia (South *et al.* 2021, Eisenberg *et al.* 2021).

Conclusions

The study of the impact of institutional and structural racism requires understanding the mechanisms and potential leverage points for change. Given the complexities of the various actors in maintaining structural racism, it will be critical to continue to explore untapped data sources and research questions to meet this goal. By examining an underutilized variable – home improvement loans – in a publicly available, well-established data source, we believe this study does exactly this. Furthermore, we have expanded the study of housing discrimination beyond the application for mortgage loans, and potentially identified early indicators of neighborhood change and its implications for current health of residents

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Author Contributions

This paper is part of a larger dissertation submission to complete the requirements to receive a doctoral degree. Krieger, Arcaya, and Williams served on the dissertation committee and contributed significantly to the research and development of this manuscript. Metzger contributed significantly to the conceptualization of this project and development of the manuscript.

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