Residential Mobility, Brownfield Remediation and Environmental Gentrification in Chicago

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Abstract

We examine whether moving behavior contributes to the correlation between race and pollution using a residential sorting model and data on neighborhood demographics in Chicago. We find that black residents are less likely to stay and thus more likely to be displaced compared with white residents in neighborhoods after brownfields are cleaned up, contributing to environmental gentrification. This provides evidence that race and pollution become increasingly correlated because of moving behavior, with people of color less likely to move toward cleaner neighborhoods. Cleaning up pollution without a policy that acknowledges residential mobility may thus fail to correct environmental injustice.

Keywords
Sorting, housing market, environmental justice, land use

JEL codes
Q53, Q58, R21, R23

1.   Introduction

Seminal work by the U.S. General Accounting Office (GAO 1983) and the United Church of Christ's Commission on Racial Justice (UCC 1987) shows that people of color and low-income individuals are disproportionally exposed to environmental hazards in the United States. This has led to concerns that the siting of hazards and cleanup of polluted areas is unjust and driven by racism and economic inequality (Been and Gupta 1997, Mohai and Saha 2007). Environmental justice advocates have responded to these concerns by working to influence the siting of environmental hazards. Yet research has yielded mixed evidence that siting is discriminatory. While race, income and pollution are often correlated, these correlations can be contemporaneous and disappear when examined at the time of siting (Baden and Coursey 2002, Wolverton 2009), particularly for hazards sited before the 1970s (Saha and Mohai 2005). This begs the question: how do race and pollution become correlated over time? One explanation is that environmental regulators tend to neglect minority and low-income communities, allowing pollution to linger in these communities (Lavelle and Coyle 1992, Viscusi and Hamilton 1999). Another explanation is that people of color and low-income individuals are "coming to the nuisance" because housing prices tend to be lower near environmental hazards (Been 1994, Pastor et al. 2001).

The evidence, however, for "coming to the nuisance" is mixed (Mohai and Saha 2015). Several studies find no significant change in the percentage of minority residents after the siting of a hazard (Been and Gupta 1997, Pastor et al. 2001), nor a significant change in the propensity of white residents to move out (Hunter et al. 2003). Other studies, however, find evidence that the share of minorities increases in neighborhoods with hazards after siting (Stretesky and Hogan 1998, Saha and Mohai 2005), and that people of color are more likely to move to neighborhoods with hazards (Crowder and Downey 2010). An important caveat of these studies, though, is that they usually focus on only one aspect of the moving process—move-ins, move-outs, or overall neighborhood demographic change—which can make finding conclusive evidence of "coming to

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the nuisance" challenging. This caveat could explain the mixed evidence in the literature because one needs information about both individual movers and alternative residential locations to determine whether people of color or low-income individuals move to polluted neighborhoods from relatively unpolluted areas (Depro et al. 2015). For example, move-in data could capture that a neighborhood experiences an influx of minority residents after the siting of a hazard yet mask that these individuals moved from less polluted neighborhoods. Thus, there is a crucial need for research that looks for "coming to the nuisance" by examining all aspects of the moving process, using information on residential mobility and demographic change in neighborhoods with and without environmental hazards.

In this paper, we look for evidence that people of color "come to the nuisance" using a model of residential mobility and longitudinal data on neighborhood demographics. We focus on the move decisions of black and white persons in Chicago, Illinois between 2000 and 2010 in response to brownfield cleanups earlier in that decade. Brownfields are properties with known or suspected environmental hazards that reduce the potential for redevelopment. The Illinois Environmental Protection Agency (IEPA) has assisted with and certified brownfield cleanups through the Illinois Site Remediation Program (SRP) since 1989. By combining data on SRP properties with move predictions separated by race group generated from the mobility model, we can test for race-specific differences in Chicago residents' tendency to move into neighborhoods with and without brownfield cleanup. Given the black-white income gap, we hypothesize that black residents are likely to less stay in or move toward areas with cleanup.

Our work produces several important contributions to research on environmental justice and neighborhood change. First, ours is one of the first studies to look for evidence of "coming to the nuisance" using a residential sorting model that combines longitudinal demographic data with information on moving costs in a way that simulates move-in, move-out, and overall neighborhood demographic change. This approach makes our results more definitive on the mobility hypothesis

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than prior work that relies on one measure of change. Second, we use the siting of cleanup rather than pollution per se to test for post-siting demographic change. This approach is important because "coming to the nuisance" implies that when pollution is located in minority and low-income communities—where cleanup has the potential to reduce injustice—post-cleanup move-in by higher-income white residents will push poor, predominantly minority residents away, maintaining disparities in pollution exposure.[1] Third, our study complements existing hedonic research measuring the welfare effects of hazardous site cleanup (Linn 2013, Haninger et al. 2017, Savchenko and Braden 2019), which warns that while the economic benefits of cleanup may be substantial, these benefits may not be spread equitably. Our research shines additional light on this inequity by quantifying the disparity in willingness to pay for cleanup between black and white residents.

Our results show that black residents in Chicago are significantly less likely to move to neighborhoods with cleanup and less willing to pay for cleanup relative to white residents, consistent with the mobility hypothesis. We find the disparity in willingness to pay is about $20 per cleanup or nearly $150 per cleanup per square kilometer, on average, which is robust to changes in key modeling assumptions, including the amount of moving cost and the size of the migration system. These results indicate that post-cleanup demographic change in Chicago neighborhoods disproportionately provides white residents access to quality improvements. Thus, our results help confirm that residential mobility and "coming to the nuisance" offer at least a partial explanation of why people of color are disproportionately exposed to pollution.

The remainder of our paper is organized as follows. Section 2 describes the geographic setting in Chicago and the datasets. Section 3 presents the model of residential mobility and then describes how we use regression analysis to test the hypothesis that mobility explains the correlation between race and cleanup. Section 4 briefly summarizes the output of the residential mobility

model, which is separated by race group, before describing and discussing the estimated disparity in willingness to pay for cleanup. Section 5 concludes.

2. Data

The primary datasets used in our analysis are neighborhood-level demographic summaries constructed from decennial census records and the list of SRP properties maintained by the IEPA. The demographic summaries provide information on the number of black and white persons living in each of Chicago's 77 community areas in 2000 and 2010.[2] These groups include Hispanic residents who self-identify as black or white in the census.[3] From these data, Panel A of Table 1 shows that about 1.1 million and 1.2 million black and white persons, respectively, lived in Chicago in 2000. We do not distinguish individuals in these groups by housing tenure, although later in the analysis we account for differences between renters and owners when we estimate moving costs between community areas.

We track post-cleanup demographic change in Chicago by measuring the population share for each race group living in each community area plus an outside alternative. These community areas are city-defined neighborhoods (Irwin 2019) with boundaries established in the 1920s to facilitate longitudinal comparisons of demographic characteristics, based on "(a) settlement, growth and history of the area; (b) local identification with the area; (c) the local trade area; (d) distribution of membership of local institutions; [and] (e) natural and artificial barriers, such as the Chicago River, railroad lines, parks and boulevards" (Northeastern Illinois Planning Commission 1999). Chicago's community area boundaries have not changed since the 1980 census (Keating 2008), and residents commonly refer to parts of the city by community area names (McMillen 2008), which makes them well suited to track neighborhood preferences and residential sorting over time. Census tracts are a smaller spatial unit than community areas, however, it is not always clear which tracts are practical location alternatives (i.e. tracts with only a few residents), a potential complication

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community areas avoid by aggregating tracts into grouped alternatives.[4] Another potential complication when working with spatial units is the "ecological fallacy," which arises when trying to infer individual disparities from neighborhood-level demographic summaries. Research finds that the ecological fallacy tends to mask environmental injustice in more aggregated data (Banzhaf et al. 2019). Our research avoids committing the ecological fallacy with respect to race and pollution, though, by disaggregating and modeling separately the mobility of black and white residents.

The other primary dataset records the location and timing of brownfield cleanups. The state of Illinois defines brownfields as "abandoned or under-used industrial and commercial properties with actual or perceived contamination and an active potential for redevelopment" (Illinois Environmental Protection Agency 2020). The presence of hazards makes brownfields a threat to human and environmental health. To address this threat, the IEPA has operated the SRP since 1989, which documents contaminants and provides technical assistance for remediation. If no contamination is found, or if the property owner undertakes remedial actions directed by the IEPA, then the owner receives a No Further Remediation (NFR) letter, which certifies that the property is no longer a threat to human and environmental health. NFR letters are often necessary to sell, resolve litigation, and secure financing and insurance for remediated properties (Illinois Environmental Protection Agency 2001).

We use the date and locations of NFR letters to determine when and where property owners cleaned up brownfields. All things equal, black and white residents may prefer to stay in their neighborhoods after cleanup. But because things are not equal, black residents may have more difficulty staying in cleaned-up neighborhoods—for example, because their rent increased after the improvement—and thus cleaning up brownfields may affect the residential sorting behavior of black and white residents differently. The modeling assumption we make below is that residents move between 2000 and 2010 based on the intensity of cleanups they observe between 2000 and

2005.[5] Figure 1 presents a map of community areas, cleanups and the number of black residents in 2010 in Chicago.

It should be noted that we do not observe the locations of existing brownfields or cleanups not processed through the SRP program. This is not a problem under certain assumptions. Our analysis explicitly controls for the influence of brownfields not cleaned up during the period of interest by employing fixed effects, i.e. location-specific constants in the regression model, discussed below. Our analysis also estimates an unbiased effect of cleanups if the sites that participate in the SRP program are uncorrelated with the locations of other cleanups. To control for active commercial and industrial facilities with environmental hazards, we include the number of Toxic Release Inventory (TRI) facilities documented in 2005 by the U.S. Environmental Protect Agency. TRI facilities in Chicago are clustered around densely populated, residential and industrial corridors west of the central business district.

We also collect data on community areas characteristics besides brownfield cleanups and TRI facilities. These data include two measures of school quality because schools are likely to be important in move decisions. The first is the percent of elementary schools in 2003-2004 with at least 40% of the student body testing at or above the Illinois Standards Achievement Test (ISAT) or the Iowa Test of Basic Skills (ITBS). The second is a dummy variable that equals one if a majority of schools in 2003-2004 were overcrowded based on current enrollment and capacity. Both measures are published by the Illinois Facilities Fund (IFF), which assists Chicago Public Schools with operational and capital planning (Kneebone et al. 2004). Next, we include the number of index crimes in 2005, including homicide, rape, robbery, assault and battery, human trafficking, burglary, theft, and arson. The Chicago Police Department publishes these data in summaries through annual reports (Chicago Police Department 2005). Additionally, we include an indicator for community areas transected by the Chicago Transit Authority's rapid transit Pink Line, which received a route update and increased service in 2006. Finally, we include the percent change in the number of black

residents in each community area between 1990 and 2000 to control for pretrends. We present

statistical summaries of these variables in Panel B of Table 1.

3.   Methods

In this section, we develop a sorting model that uses neighborhood demographic change between

2000 and 2010 to learn about the differences in black and white residents' values for Chicago

community area attributes, including brownfield cleanups. Estimation follows the two-step

procedure developed by Depro et al. (2015). We first set-up and solve a system of equations for

each race group that calculates the probability that an individual in location b moves to location a,

which allows us to estimate the mean utility in each location for each group. We then carry out a

regression using the mean utilities to estimate the black-white difference in willingness to pay for

cleanup.[6]

3.1   Calculating move probabilities and mean utilities

We model the probability of a move by measuring the share of individuals living in location b in

2000 who move to location a by 2010, which we denote $s_{a,b}$. The choice set includes the option to

stay in location b; we denote this stay probability by $s_{b,b}$. The mean utility from living in location b,

δ_b, is a function of observable location attributes X_b, parameters β, and unobservable attributes ξ_b:

(1) $\delta_b = f(X_b, \xi_b; \beta).$

Imbedded in the mean utilities is the information we need to determine how brownfield cleanup

affects mobility, and whether black residents are disproportionately excluded from cleanup and

exposed to pollution. For each individual i, the utility received from living in b is the sum of the

mean utility and an idiosyncratic component $\eta_{i,b}$:

(2) $U_{i,b} = \delta_b + \eta_{i,b}$

Each individual knows that if they move from b to a, their utility changes by

(3) $$U_{i,a} - U_{i,b} = (\delta_a - \delta_b) - \mu MC_{a,b} + (\eta_{i,a} - \eta_{i,b})$$

where $MC_{a,b}$ is the cost of moving from b to a and μ is a parameter measuring the effect of moving

cost on utility, which measures the marginal utility of income. For residents who stay rather than

move, there is no change in utility and no moving cost, $MC_{b,b} = 0$. Assuming that $\eta_{i,b}$ is i.i.d. Type

I extreme value, then we can express the share of individuals who move from b to a as

(4) $$s_{a,b} = \frac{e^{(\delta_a - \delta_b - \mu MC_{a,b})}}{\sum_{l=1}^{N+1} e^{(\delta_l - \delta_b - \mu MC_{l,b})}}$$

where l is one of the location alternatives, N is the number of community areas, and $N + 1$ is the

number of community areas plus the outside "catch-all" alternative. To account for residents

moving to or away from Chicago, the population of the catch-all alternative in our model equals the

net change in the city's black/white population between 2000 and 2010. We explore the sensitivity

of the results to this assumption in one of our robustness checks, in which we re-estimate the model

using much larger populations in the catch-all alternative.

We estimate the mean utilities by solving an exactly identified system of equations that

calculates the move shares $s_{a,b}$ from statistics on community area populations and city-level

moves.[7] This is accomplished by defining the population living in location a in 2010 as:

(5) $$pop_a^{2010} = \sum_{b=1}^{N+1} s_{a,b} pop_b^{2000}.$$

Divide both sides of equation (5) by $TOTPOP = \sum_{b=1}^{N+1} pop_b^{2000} = \sum_{b=1}^{N+1} pop_b^{2010}$ to get:

(6) $$\sigma_a^{2010} = \sum_{b=1}^{N+1} \left[\frac{e^{(\delta_a - \delta_b - \mu MC_{a,b})}}{\sum_{l=1}^{N+1} e^{(\delta_l - \delta_b - \mu MC_{l,b})}} \right] \sigma_b^{2000}$$

where σ_l^t is the percent of the population in location l in period t, $\sigma_l^t = \frac{pop_l^t}{TOTPOP}$.

Equation (6) is a system of $N + 1$ equations, but with $N + 2$ parameters, including the mean

utilities δ_l and the marginal utility of income μ, the system is underidentified. In other words, there

is more than one set of shares that can explain the change in community area demographics between 2000 and 2010. To solve this identification problem, therefore, we add an equation for the percentage of Chicago residents who did not move between 2000 and 2010. The percentage of stays is

$$(7) \qquad \%Stay = \frac{\sum_{b=1}^{N} s_{b,b} pop_b^{2000}}{\sum_{b=1}^{N} pop_b^{2010}}.$$

We find this percentage for each race group using public microdata from the 2010 American Community Survey 5-year sample. We base the %Stay on the share of individuals who moved into their 2010 residences before 2000. We present these statistics in Panel A of Table 1, which shows that a slightly higher percentage of black residents than white residents reported moving into their current residence before 2000.

Solving the system of equations requires finding the mean utilities δ_l and marginal utility of income μ that satisfy equations (6) and (7). After the equations have been filled out with the statistics on population shares in each location and the percentage of city-level stays, we solve for the unknowns δ_l and μ by minimizing the sum of squared residuals between the observed population shares in 2010 $\bar{\sigma}_l^{2010}$ and the predicted shares $\hat{\sigma}_l^{2010}$, as well as the squared residual between the actual and predicted percentage of stays, $\overline{\%Stay}$ and $\widehat{\%Stay}$. We can generate predicted values $\hat{\sigma}_l^{2010}$ and $\widehat{\%Stay}$ using the right-hand sides of equations (6) and (7) for any combination of δ_l and μ. To find the combination of δ_l and μ that minimizes the residuals, we use the generalized reduced gradient method in Excel Solver. We constrain the utility of one location to zero, which does not affect the results because only the relative level of the mean utilities affects the move shares, not the absolute level.[8]

3.2   Moving costs

This section details how we calculate the moving costs that appear in the mobility model. We measure moving costs as the sum of physical costs, financial costs and search costs. Physical costs include transporting home contents, vehicles, and the value of time spent moving. Financial costs include closing costs and non-refundable deposits. Search costs include the cost of learning about and securing a new residence. We calculate these costs separately for homeowners and renters to account for the fact that homeowners tend to have larger and more expensive moves, as explained below.

The typical home for sale and rental unit have three and two bedrooms, respectively (Zillow 2016). Thus, for homeowners, we use a physical cost of $2,194, which is the mid-point of the range provided by moving.com for a Chicago move with partial packing services for a three-bedroom household. For renters, we use a physical cost of $1,416, which is the mid-point of the range provided by moving.com for a Chicago move with partial packing services for a two-bedroom household. To these costs we add the value of the moving household's time, using the average hourly wage in the Chicago metropolitan area in 2005, $28 (all dollar amounts are adjusted to 2020$), assuming two adults in the household and 8 moving hours, plus the time spent driving from the old community area to the new community area assuming a driving speed of 20 miles per hour. For moves between a community area and the catch-all alternative, we assume a fixed cost of $5,000 for homeowners and $4,000 for renters, based on the range of values presented in Bieri et al. (2014) for intercity moves.[9]

For financial costs, we assume homeowners pay 3.75% and 3.3% of the 2000 median housing value in the old and new community area, respectively, which includes splitting a 6% realtor commission evenly between the buyer and the seller, plus transfer taxes that buyers and sellers pay in Chicago. Renters do not pay this cost, but we assume renters have to pay a non-refundable deposit equal to half of one month's rent in the new community area. We assume a house value of $211,318 and an apartment rent of $804 for moves into the catch-all alternative, which are

the median values in Cook County. For search costs, we assume a flat $20/mile between the old and new community area. Later, we perform several robustness checks to probe the sensitivity of the results to different assumptions about search costs.

Finally, we sum up the physical, financial and search costs, weighting the physical and financial costs for owners and renters by the percentage of residents in each community area who are owners and renters, respectively. We input the annualized value of these moving costs in the model, using a time horizon of 37 years and a discount rate of 2.5%. Using this methodology, the average annualized moving cost between two community areas is $435, and the average cost of a move between a community area and the catch-all is $823.

3.3 Regression analysis

After using the mobility model to estimate the mean utilities for black and white residents, we can measure disparities in marginal willingness to pay for cleanup using a linear specification of equation (1). First, however, we must convert the utilities into comparable dollar values by dividing the race group-specific estimates of $\delta_{l,r}$ by race group-specific estimates of μ_r, where $r = black,$ $white$. Let $\hat{\delta}_{l,r} = \delta_{l,r}/\mu_r$. Then we can decompose the mean utility for each location l and race group r into

(8) $$\hat{\delta}_{l,black} = \psi_{black} + \varphi_l + \beta_{black}X_l + \varepsilon_{l,black}$$

(9) $$\hat{\delta}_{l,white} = \psi_{white} + \varphi_l + \beta_{white}X_l + \varepsilon_{l,white}$$

where ψ_r is a group-specific constant, φ_l captures the effect of location-specific attributes, and X_l includes location attributes that may or may not affect black and white residents differently, such as brownfield cleanups. Equations (8) and (9) can be stacked into a single equation

(10) $$\hat{\delta}_{l,r} = \theta_l + \pi X_l B_r + \lambda B_r + B_r \varepsilon_{l,black} + (1 - B_r)\varepsilon_{l,white}$$

where $\theta_l = \psi_{white} + \varphi_l + \beta_{white} X_l$ is a location-specific constant, $\pi = \beta_{black} - \beta_{white}$ measures the difference in mean willingness to pay for attributes on the margin, $\lambda = \psi_{black} - \psi_{white}$ measures the difference in mean willingness to pay between black and white residents conditional on the attributes, and $B_r = 1$ for black residents and $B_r = 0$ for white residents. We estimate equation (10) using the XTREG command in Stata.

We consider three different measures of brownfield cleanups in the regression. Our first measure is the number of brownfields cleaned up in each community area between 2000 and 2005. This is the same measure that some studies in the hedonics literature have used to measure the effect of cleanup on nearby property values (Mastromonaco 2014). Another approach in the brownfield hedonics literature is to use an inverse distance index to measure the density of cleanups within a certain distance of individual properties (Linn 2013, Savchenko and Braden 2019). To measure the density of cleanups in Chicago neighborhoods, therefore, we also estimate a regression that uses the number of cleanups per square kilometer. Finally, our third measure is the number of acres cleaned up in a neighborhood. We expect that if cleanup affects moving behavior, then individuals who move to neighborhoods with more acres cleaned up should experience a greater change in utility.

To the extent that cleanup creates a ripple effect on neighborhood attributes not in the model, then the regression will of course attribute these additional changes to cleanup. This ripple effect can take different forms; for example, if cleanup induces redevelopment among surrounding properties or alters a neighborhood's identity (Bryson 2012). It also includes changes in racial composition that residents may derive utility from, i.e. living with neighbors of the same race. For a sorting model that explicitly examines preferences for neighborhood racial composition, see Bayer et al. (2007). We do not attempt to partial out these additional changes because they are part of the gentrification process induced by cleanup and thus part of the effect of interest.

4.   Results

4.1   Residential sorting model

We use the sorting model to calculate the mean utilities $\left\{\delta_{l,r}\right\}_{l=1}^{N+1}$ and the marginal utility of income μ_r for black and white residents separately. The solution has a marginal utility of income of 0.00767 for black residents and 0.00748 for white residents. Figure 2 presents the mean utilities in a scatter plot. There is a modest negative correlation (the correlation coefficient is -0.239) between the two sets of utilities, which indicates that community areas of high utility for black residents tend to have low utility for white residents and vice versa. The mean utility of the catch-all alternative, shown in the figure as a filled circle, is considerably higher than the utility of any community area for black residents, which suggests that locations outside Chicago are among the most desirable for black movers. The catch-all alternative is far less desirable to white movers in relative terms. This result indicates that between 2000 and 2010 white residents preferred to stay in the city while black residents preferred to leave, essentially reversing the pattern of white flight that occurred in previous decades.[10] This signals an important shift in black and white residents' urban experiences, which continue to be unequal. Note that we are far from the first to make such a claim; prior research has documented the outmigration of black residents from major metropolitan areas, including Chicago, since the late 1990s (Frey 2004), as well as racial differences in the effects of urban redevelopment and urban amenity values (Essoka 2010, Baum-Snow and Hartley 2020).

4.2 Regression analysis

We present the regression estimates in Table 2. Column (1) shows the parameters when cleanup is measured as a count variable. These estimates provide significant evidence of a disparity in black and white residents' willingness to pay to live in neighborhoods with more cleanup, i.e. fewer

brownfields. This specification implies that black residents are willing to pay $20 less per year for an additional cleanup compared to white residents. There are also important differences in the willingness to pay for other attributes. Relative to white residents, black residents have a lower willingness to pay to live in neighborhoods with more performing schools, and a lower willingness to pay to live in neighborhoods that receive upgraded rapid transit service.

Column (2) presents the results when the count of cleanups is standardized by square kilometers. These results also provide evidence that black residents have a lower willingness to pay to live in neighborhoods with more cleanup. We estimate that black residents are willing to pay $148 less per year for an additional cleanup per square kilometer compared to white residents. Community areas average 7.9 square kilometers, so this estimate implies a difference in willingness to pay of about $19 per year for a single cleanup, which is very close to the effect reported in column (1).

In contrast, the results in column (3) fail to provide evidence that black residents' willingness to pay for cleanup is less than white residents'. The difference in willingness to pay for an acre of cleanup is negative but not significantly different from zero. Why would significant differences arise for the first two cleanup measures but not the third? One explanation is that people value small cleanups differently from large cleanups. Large brownfields can be dozens or hundreds of acres while small brownfields tend to be about an acre—the difference, for example, between a closed steel mill and a gas station. Small brownfields are far more common in our data. The median Chicago brownfield participating in the SRP program is 0.9 acres and 95% of participating properties are smaller than 15 acres. Differences in the amount and area of cleanup could also contribute to measurement error, which would attenuate the cleanup effect. When we exclude the community areas where average cleanup exceeds 15 acres, the difference in willingness to pay per acre of cleanup jumps to $1980 per 100 acres per year (s.e. = 857, $N = 126$), or about $20 per acre per year, which is significant at the 5% level. This result suggests that redevelopment associated

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with smaller as opposed to larger brownfields tends to drive the difference in black and white residents' willingness to pay for cleanup.

We can use the results in column (2) to simulate what the correlation between the locations of black residents and cleanup would look like if black and white residents had the same willingness to pay for cleanup after 2000. The correlation between the actual black population in 2010 and the number of cleanups per square kilometer between 2000 and 2010 is -0.232, which indicates a modest negative association between the locations of black residents and cleanup in 2010. We then simulate the black population using the counterfactual mean utility

(10) $$\delta_{l,black} = \mu_{black}(\psi_{black} + \varphi_l + \beta_{black}X_l + \varepsilon_{l,black} - \pi cleanup_l)$$

where $cleanup_l$ is the number of cleanups per square kilometer. When we do this, we find the simulated black population and the number of cleanups per square kilometer is 0.017. In other words, achieving parity in willingness to pay for cleanup eliminates the negative correlation between black residential locations and cleanup. This result is consistent with the hypothesis that residential mobility and "coming to the nuisance" drive the correlation between race and pollution.

4.3 Robustness checks

In this section, we examine the sensitivity of the results to variation in moving costs and the size of the catch-all alternative. First, we revise moving costs by assuming that black residents pay 10 percent more for housing. Prior research estimates that black residents pay a premium for housing ranging from two to ten percent (Myers 2004, Bayer et al. 2017) due to supplier price discrimination, exclusion or racial prejudice. We present the revised estimates in Table 3, column (1), when the number of cleanups is measured per square kilometer. The coefficient of interest is still negative, and, in fact, little changed from its counterpart in Table 2, column (2). This suggests that the disparity between black and white residents' willingness to pay for cleanups is not due to

differences in housing costs. Next, we replace the $20/mile search cost with a $90/mile search cost

for black residents, who could face higher search costs if brokers or sellers are averse to working

with people of color, increasing the difficulty of finding new housing (Courant 1978).[11] Again, this

adjustment has little effect on the estimates, which we present in column (2) of Table 3. Finally, we

equate the population of the catch-all alternative to the population of Cook County excluding

Chicago, rather than the net change in the city's population between 2000 and 2010, which

essentially doubles the size of the catch-all for black residents and triples the catch-all for white

residents. Column (3) of Table 3 shows that this adjustment increases the disparity in willingness

to pay by 26%.

What if residents decided to move based on cleanups performed before 2000? When we use

the number of cleanups between 1995 and 2000 rather than between 2000 and 2005, the disparity

in willingness to pay roughly doubles. We find the difference in willingness to pay is $53 (s.e. =

14) and $222 (s.e. = 88) for an additional cleanup per community area and per square kilometer,

respectively, and $20 (s.e. = 40) per 100 acres of cleanup. If we allow for nonlinearity in the effect

by including the number of cleanups as a quadratic polynomial, the second-degree coefficient is

positive but not significantly different from zero and the other estimates are qualitatively unchanged

from those reported above. For brevity, we do not present these results, but they are available upon

request.

4.4   Additional discussion

Our result that black residents are willing to pay less than white residents for cleanup is consistent

with the hypothesis that race and pollution are correlated in part because people of color move to

the nuisance or, in the context of this study, move away from cleanup. This does not mean that

black residents or, more generally, people of color dislike cleanup; rather, the disparity we find in

willingness to pay suggests that, on average, white residents outcompete black residents for housing

in neighborhoods with more cleanup. As black and white residents adjust their location choices and housing prices increase after cleanup, over time, environmental hazards will tend to become associated with poor, black communities and cleanup with relatively affluent, white communities. Though a $20 per cleanup per year difference in willingness to pay may appear small, the importance of our research lies in showing the existence of a disparity between black and white residents' responses.[12]

Our results are consistent with Depro et al.'s (2015) study of residential mobility and coming to the nuisance. They estimate that Hispanic and non-Hispanic white residents' willingness to pay differs by about 30¢ for a unit reduction in cancer risk in Los Angeles. When they simulate how residential locations would change if Hispanic and non-Hispanic white residents had the same willingness to pay to avoid cancer risk, they find that the correlation between the percentage of Hispanic residents and cancer risk would fall from 0.368 to -0.079. We find a shift of similar magnitude would occur between black residential locations and brownfield cleanups in Chicago if black and white residents had the same willingness to pay for cleanup.

Our results are also consistent with claims that removing environmental hazards helps gentrify neighborhoods by making it harder for low-income individuals and people of color to stay in their homes relative to white persons. A growing body of research shows that property values increase after removing hazards (Braden et al. 2011, Sigmund and Stafford 2011), up to as much as 15% following brownfield cleanup, depending on the measure of surplus and coverage of spatial spillovers (Haninger et al. 2017). More specifically, prior research finds that remediating a brownfield in Chicago increases nearby property values 1-2% (Linn 2013). Higher prices like these have led to concerns about environmental gentrification—which occurs when wealthy households move to communities with previously high levels of pollution, changing socioeconomic and demographic characteristics (Sieg et al. 2004)—and the impact of cleanup on environmental equity. Our results show that neighborhood demographics do indeed change after cleanup, with larger

changes in the turnover of black residents, and welfare gains disproportionately flowing to white residents. This outcome confirms claims by community advocates and some scholars in the environmental justice literature (Taylor 2014) but has yet to receive much study in economics (Banzhaf and McCormick 2012, Eckerd 2011).

Our results also provide empirical support for Banzhaf and Walsh (2013), who find that tastes for public goods, including environmental quality, can produce sorting on race and segregation when there is a substantial income difference between race groups. The black-white disparity in willingness to pay for cleanup that we find in Chicago is evidence that cleanup may in fact induce sorting on race. Banzhaf and Walsh (2013) also find that segregation worsens when there are racial preferences or prejudice. Our results are mute on the effect of racial preferences, although we acknowledge that these preferences could be important and should be investigated in future research.

The disparity in willingness to pay and racial sorting is likely explained by income inequality. As measured in the 2010 ACS, the median household income of non-Hispanic white residents is $77,906 (65,842 2010$) compared to $34,752 (29,371 2010$) for black residents. This income disparity leaves black residents less able to afford housing in cleaner neighborhoods. Because they have lower incomes, black persons may be prioritizing the consumption of goods that white persons derive little utility from on the margin—e.g. food, transportation and utilities—rather than neighborhood amenities. Another explanation is that awareness of environmental hazards is higher among white residents than black residents, although ultimately this explanation may be driven by income or educational inequalities.

Although our estimates are not sensitive to assumptions about additional moving costs for black residents due to discrimination, recent research finds that discrimination does affect black individuals' ability to move to cleaner communities. Christensen and Timmins (2019) find experimental evidence that real estate agents steer black homebuyers toward neighborhoods with

higher concentrations of Superfund sites and TRI releases. And Christensen et al. (2020) report that black renters are significantly less likely than white renters to receive responses to inquiries about properties in low-exposure locations but not in high-exposure locations. These two papers provide evidence that discrimination in the housing market can block people of color from cleaner neighborhoods. This form of discrimination could have important implications for our model, which assumes residential location choices are unconstrained. Part of the disparity we measure could therefore be due to constraints imposed in the search process that steer black movers away from communities with cleanup.

Some may reject our results because we do not condition differences in willingness to pay on socioeconomic variables, e.g. income. This criticism misinterprets the goal of our study, which is to uncover differences between race groups. Not controlling for variables such as income is deliberate because we are interested in explaining the importance of residential mobility to the correlation between race and pollution, rather than the correlation between race and pollution conditional on income. This analysis is consistent with an environmental justice movement focused on evidence of racial inequities while being fully aware of the role that income and wealth play in these inequities. Nevertheless, we agree that information about the effects of potential mediating variables, such as income and homeownership, is important and should be examined in future research.

5.   Conclusion

We examined the correlation between race and pollution through the lens of residential sorting and whether people of color are less likely to live in a community following a brownfield cleanup. Using Chicago as our study area, we built residential sorting models for black and white residents and used regression analysis to find that black residents are less likely to stay in their neighborhood following a cleanup or move to other neighborhoods with cleanup. The higher willingness to pay

for cleanup among white residents sheds light on the observed differences in pollution exposure between race groups.

Our results highlight an important issue in metropolitan environmental policy. As environmental justice initiatives increasingly push for the removal of environmental hazards, policymakers must be cognizant of the potentially counterproductive impacts of these efforts due to post-cleanup demographic change. To achieve an equitable distribution of environmental quality, therefore, it seems likely that pollution remediation will have to be paired with programs that eliminate group-based mobility differences.

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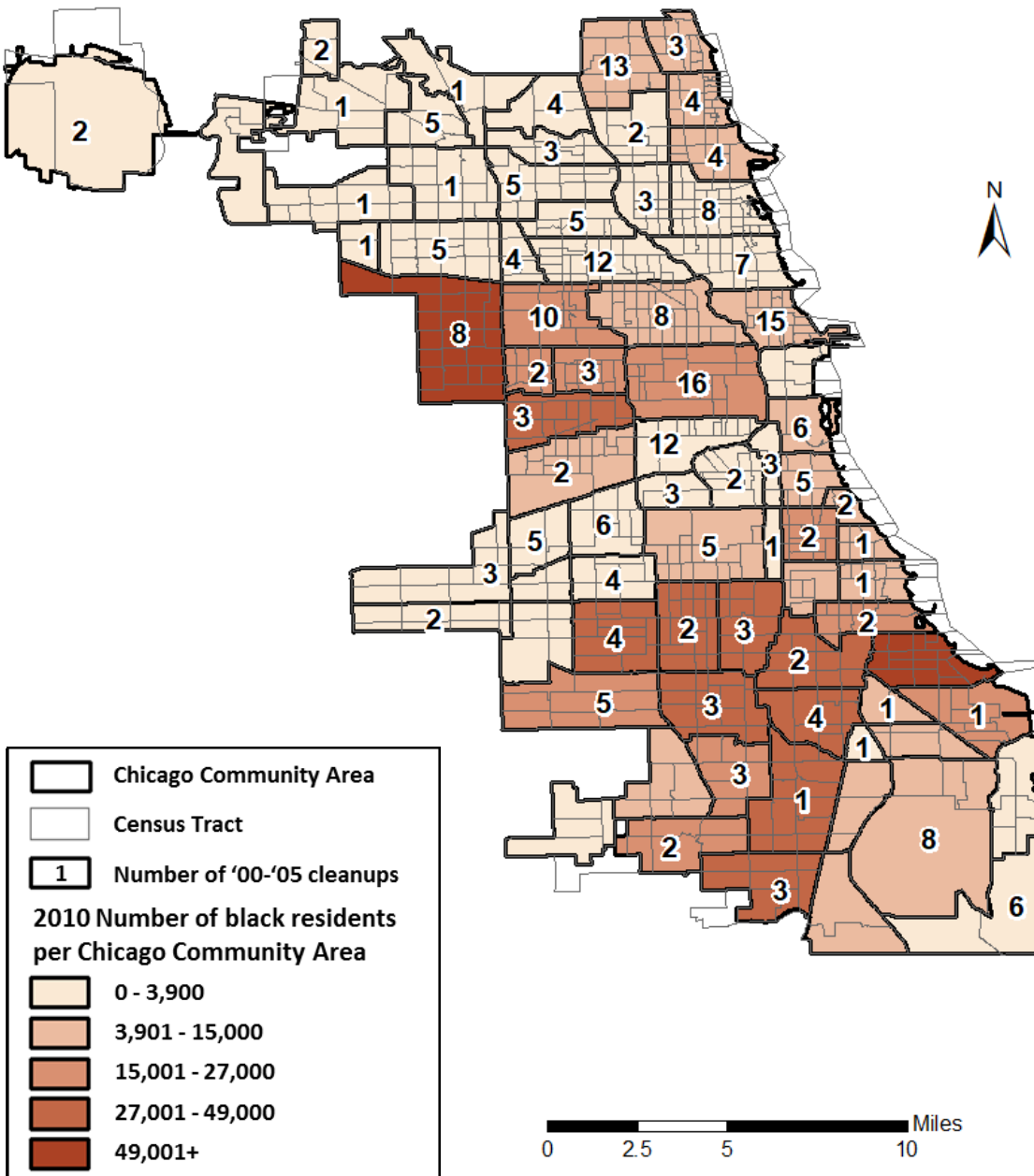
Figure 1. Map of the number of brownfield cleanups between 2000 and 2005, and black residents in 2010 by Chicago community area.
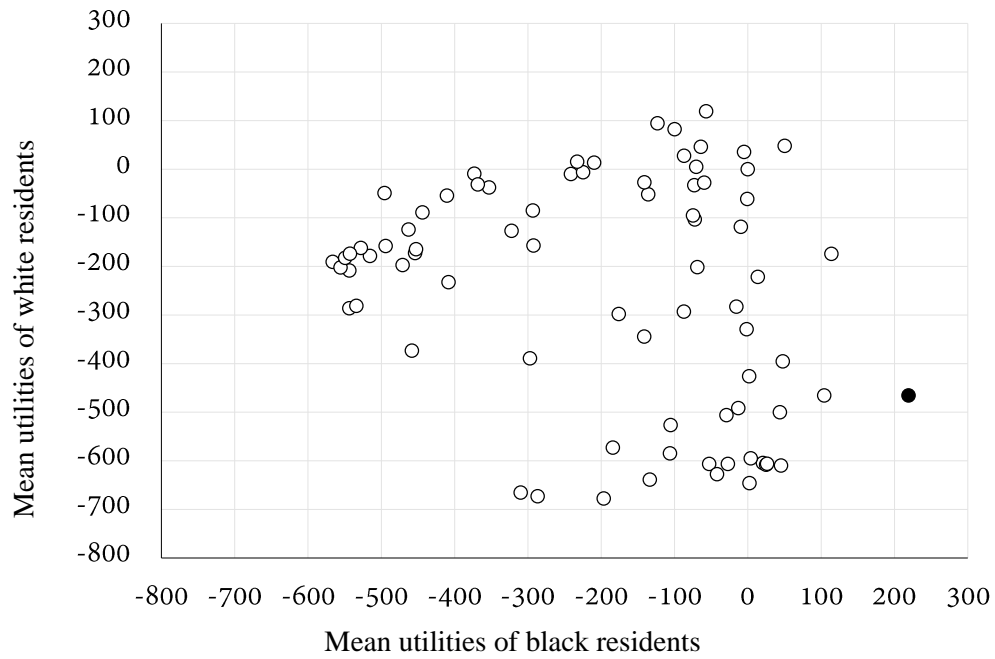
Figure 2. Scatter plot of black and white residents' mean utilities in Chicago community areas. The filled circle shows the mean utilities of the catch-all alternative.

Table 1. Summary statistics of Chicago and its community areas

Panel A. Chicago	Black residents	White residents
Population (2000)	1,065,000	1,215,018
Percent stay between 2000 and 2010	38.57	36.98

Panel B. Community areas	Mean	St. Dev.
Brownfields cleaned up - count	3.61	3.49
Brownfields cleaned up - per sq km	0.52	0.44
Brownfields cleaned up - acres	12.12	34.24
TRI facilities per sq km	0.21	0.32
Index crimes per 10000 persons	620.55	406.11
Percent performing schools	0.58	0.35
Overcrowded schools	0.35	0.48
Rapid transit (Pink Line) update	0.06	0.25
% change in 1990-2000 black population	2.55	6.48

Table 2. Race group differences from the sorting model

Attribute	(1)	(2)	(3)
Cleanups - count × black	-19.688**		
	(8.687)		
Cleanups - count per sq km × black		-147.805**	
		(69.414)	
Cleanups - 100 acres × black			-28.087
			(86.225)
TRI facilities × black	-157.692	-150.213	-223.019**
	(96.125)	(98.304)	(94.926)
Index crimes × black	0.132	0.152*	0.152*
	(0.087)	(0.087)	(0.090)
Percent performing schools × black	-431.387***	-401.519***	-444.984***
	(110.927)	(113.163)	(114.773)
Overcrowded schools × black	-114.694	-128.593*	-105.416
	(70.424)	(71.310)	(73.291)
Rapid transit (Pink Line) update × black	-215.898*	-266.183**	-264.462**
	(124.547)	(122.733)	(127.816)
Black	406.594***	388.311***	344.845***
	(108.471)	(107.304)	(108.816)
% change in 1990-2000 black population × black	-11.363**	-10.887**	-10.029**
	(4.796)	(4.793)	(4.968)
N	154	154	154

Standard errors in parentheses below coefficients. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 3. Sorting model robustness checks

Attribute	10% housing cost premium for black residents (1)	$90 search cost for black residents (2)	Increase catch-all population to Cook County (3)
Cleanups - per sq km × black	-143.807**	-146.268**	-186.022**
	(70.753)	(71.623)	(82.406)
TRI facilities × black	-161.799	-167.052	-151.430
	(100.201)	(101.432)	(116.703)
Index crimes × black	0.154*	0.150*	0.170
	(0.089)	(0.090)	(0.103)
Percent performing schools × black	-418.282***	-429.677***	-509.415***
	(115.347)	(116.765)	(134.344)
Percent overcrowded schools × black	-135.171*	-134.221*	-120.253
	(72.686)	(73.580)	(84.657)
Rapid transit (Pink Line) update × black	-264.108**	-266.228**	-308.768**
	(125.102)	(126.639)	(145.705)
Black	386.342***	384.445***	463.935***
	(109.375)	(110.719)	(127.388)
% change in 1990-2000 black population × black	-11.567**	-12.265**	-12.083**
	(4.885)	(4.945)	(5.690)
N	154	154	154

Standard errors in parentheses below coefficients. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

[1] This process is referred to as "environmental gentrification." See Sieg et al. (2004), Banzhaf and McCormick (2007) and Eckerd (2011).

[2] This data is publically available at the City of Chicago's Department of Planning and Development (https://www.chicago.gov/city/en/depts/dcd/supp_info/community_area_2000censusprofiles.html) and the Chicago Metropolitan Agency for Planning (https://datahub.cmap.illinois.gov/dataset/2010-census-data-summarized-to-chicago-community-areas).

[3] Hispanic residents across all race groups make up 29% of residents.

[4] There are 860 census tracts in Chicago, or about 11 tracts per community area. Readers familiar with aggregating alternatives in choice modeling (e.g. Parsons and Needelman (1992)) will recognize that this level of aggregation is relatively low. Spatial aggregation does not necessarily combine heterogeneous alternatives; for example, basing neighborhoods on similar housing characteristics produces units larger than census tracts (Clapp and Wang 2006).

[5] Our results are qualitatively robust if we assume that residents decide to move based on cleanups entirely before the period of demographic change, between 1995 and 2000.

[6] Note that the estimation technique is different in the two stages: in the first stage, we use a mathematical procedure to solve the system of move equations and, in the second stage, we use an econometric procedure to estimate the difference in willingness to pay.

[7] To be clear, there are other approaches to estimating neighborhood mean utilities (Kuminoff et al. 2013). For example, Bayer et al. (2007) use a cross section of restricted-access census data in a sorting model to measure preferences for neighborhood attributes while allowing for preference heterogeneity in observable characteristics, such as race and education. For applications in environmental economics, see Klaiber and Phaneuf (2010), Hamilton and Phaneuf (2015), and Bakkensen and Ma (2020).

[8] Note that Depro et al. (2015) use a contraction mapping procedure to solve a similar system of equations and normalize the utilities in their model to be mean zero. As a check on the suitability of our Solver-based method, we calculated the mean utilities for the same set of stylized examples examined by Depro et al. (2015). We found the mean utilities from our method to be the same as those in Depro et al. (2015).

[9] Our physical moving costs is based on the low end of the distance scale in Bieri et al. (2014) because the largest portion of moves to and from Chicago will be to locations in the same or adjacent counties (e.g. Cook County).

[10] This prediction reflects the loss of nearly 200,000 black residents in Chicago over the same period as documented in the census.

[11] We use $90/mile so that the average move cost between community areas equals the average move cost when we assume black residents pay 10 percent more for housing.

[12] To put this result in context, note that Bayer et al. (2007) estimate a difference between black and white residents' willingness to pay for a one standard deviation increase in average test scores of $341 per year (in 2020$). Furthermore, back-of-the-envelope calculations using the result in Depro et al. (2015) indicate that the difference between Hispanic and white willingness to pay for a one standard deviation reduction in cancer risk is about $14 per year. In contrast, we estimate a willingness to pay disparity of $70 for a one standard deviation increase in cleanups. As pointed out by a reviewer, though, small differences imply that as a fraction of income black residents may value environmental quality relatively more on the margin. For example, suppose black and white residents' willingness to pay for a one standard deviation increase in cleanups is $130 and $200 (matching the real $70 difference above), respectively. Given black and white household incomes average about $35,000 and $78,000, respectively, black residents in this example are devoting a greater fraction of income to live in areas with cleanup (0.37% vs 0.26%).