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Inter-Neighborhood Migration, Race, and Environmental Hazards: Modeling Micro-Level Processes of Environmental Inequality

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Abstract

This study combines data from the Panel Study of Income Dynamics with neighborhood-level industrial hazard data from the Environmental Protection Agency to examine the extent and sources of environmental inequality at the individual level. Results indicate that profound racial and ethnic differences in proximity to industrial pollution persist when differences in individual education, household income, and other micro-level characteristics are controlled. Examination of underlying migration patterns further reveals that black and Latino householders move into neighborhoods with significantly higher hazard levels than do comparable whites, and that racial differences in proximity to neighborhood pollution are maintained more by these disparate mobility destinations than by differential effects of pollution on the decision to move.

A burgeoning body of literature demonstrates that in U.S. urban areas, concentrations of pollution and industrial hazards tend to be highest in neighborhoods with large populations of African American and Hispanic residents (Ash and Fetter 2004; Brulle and Pellow 2005; Downey 2005, 2007; Pastor, Sadd, and Hipp 2001). Moreover, evidence suggests that this racial inequality in exposure to environmental hazards may contribute to significant racial disparities in a variety of outcomes, including physical and psychological health, educational success, and perceptions of social order (Downey and Van Willigen 2005; Evans and Kantrowitz 2002; Pastor, Sadd, and Morello-Frosch 2002, 2004; Ross, Reynolds, and Geis 2000; Sadd, Pastor, Boer, and Snyder 1999). Given these potential repercussions, developing an understanding of the extent of the magnitude of racial and ethnic differences in location near high levels of pollution and assessing the causes of this environmental inequality are clearly important endeavors.

Yet, while there is some consensus that racial and ethnic disparities in exposure to industrial hazards exist in the aggregate (Ash and Fetter 2004; Derezinski, Lacy, and Stretesky 2003, Downey 2003; Morello-Frosch, Pastor, and Sadd 2001), we currently have very little information about the extent of racial and ethnic differences in proximity and exposure to environmental hazards at the individual level or about the individual- and household-level characteristics that help determine who lives near environmental hazards. As a result, the

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available evidence leaves unanswered several important theoretical questions about the extent to which racial and ethnic differences in exposure to environmental hazards can be explained by group differences in economic resources or other sociodemographic characteristics. Moreover, despite assertions that the overrepresentation of minority families in hazardous neighborhoods likely reflects racially differentiated patterns of mobility and immobility between neighborhoods with varying levels of pollution (Hunter, White, Little, and Sutton 2003; Mitchell, Thomas, and Cutter 1999), past research provides almost no direct insights into these underlying micro-level mobility processes.

The current study addresses these significant gaps in the existing literature on environmental racial inequality by employing multilevel data to examine patterns and determinants of individual proximity to industrial pollution. Specifically, individual-level data from the nationally representative Panel Study of Income Dynamics (PSID) are merged with neighborhood-level environmental hazard data derived from the Environmental Protection Agency's (EPA) Toxics Release Inventory (TRI) to provide a first individual-level analysis of racial and ethnic differences in proximity to neighborhood hazards and an assessment of the racially-differentiated patterns of inter-neighborhood migration that shape this environmental inequality.

Although these data do not allow us to test hypotheses concerning hazardous facility siting patterns, they do allow us to directly address a number of theoretically important questions that have not been satisfactorily addressed in the literature: Are there significant racial and ethnic differences in the level of pollution faced by individual householders and their families? Can these differences be explained by household economic resources and other individual- and household-level sociodemographic characteristics? Are there racial and ethnic differences in the effects of household economic resources on proximity and exposure to environmental hazards? To what extent are racial and ethnic differences in neighborhood hazard levels reflective of group differences in mobility away from environmentally hazardous neighborhoods? And for those who move, are there significant racial and ethnic differences in destination-neighborhood hazard levels that cannot be explained by differences in household socioeconomic resources and other theoretically relevant factors?

Past Research

Academic interest in environmental inequality has grown dramatically over the past twenty years, with researchers in fields as diverse as sociology, economics, epidemiology, geography, and legal studies attempting to determine whether minority and low income neighborhoods are disproportionately burdened by environmental hazards (Anderton, Anderson, Oakes, and Fraser 1994; Anderton, Anderson, Rossi, Oakes, Fraser, Weber, and Calabrese 1994; Been 1994; Bowen, Salling, Haynes, and Cyran 1995; Chakraborty and Armstrong 1997; Hamilton 1995; Liu 2001; Pastor et al.2002; Szasz and Meuser 1997). Using tract, block group, county, and zip code-level demographic data, environmental inequality researchers have studied the distribution of social groups around a variety of environmental hazards, including hazardous waste sites, manufacturing facilities, superfund sites, and chemical accidents (Bowen 2002; Derezinski, Lacy, and Stretesky 2003; Morello-Frosch et al.2001; Szasz and Meuser 1997). But while this past research provides substantial insight into racial and ethnic disparities in exposure and proximity to environmental hazards, a number of important questions still remain unanswered.

First, because most research on the topic examines the distribution of environmental hazards within a single or small number of metropolitan areas, and because the hazard examined often varies from one study to another (Downey 2008), existing studies leave open questions about the overall magnitude of environmental racial inequality, providing dramatically different estimates of racial/ethnic disparities in proximity and exposure to environmental hazards (Bowen 2002; Downey 2007). For example, many studies provide strong evidence of environmental racial inequality (Ash and Fetter 2004; Been 1994; Brulle and Pellow 2005; Downey 1998, [2003], [2006], [2007]; Hamilton 1995; Kreig and Faber 2004; Mohai and Bryant 1992; Morello-Frosch et al. 2001; Ringquist 1997; Stretesky and Lynch 2002), some find evidence of greater proximity to environmental hazards for some minority groups but not others (Brown et al. 1997; Mennis and Jordon 2005; Pastor et al. 2002; Sadd et al. 1999), and some find, at best, only weak evidence of environmental racial inequality (Anderton et al. 1994a, 1994b; Atlas 2002; Bowen et al. 1995; Clark et al. 1995; Derezinski et al. 2003; Oakes et al. 1996; Yandle and Burton 1996). These uneven findings not only raise questions about methodological inconsistencies across studies, they also make it difficult to assess the actual scale and pervasiveness of environmental racial inequality in urban America and, by extension, the potential impact that this inequality has on racial differences in individual well-being.

Second, and perhaps more importantly, virtually all past research relies on aggregate-level data to assess the correspondence between *neighborhood* sociodemographic composition (e.g., percentages made up of particular racial groups) and *neighborhood* hazard levels. These aggregate-level studies provide researchers with important information about the broad distribution of environmental hazards. However, they do not allow researchers to adequately test many of the key theoretical arguments informing the environmental inequality literature because most of the mechanisms proposed in these theoretical arguments operate at the individual or household levels. Most notably, aggregate-level studies are unable to resolve ongoing debates about the relative effects of race and household socioeconomic status in the determination of proximity and exposure to environmental hazards. While some authors attempt to test these arguments with aggregate-level data (Been and Gupta 1997; Downey 2003, 2005; Hamilton 1995; Hunter et al. 2003; Oakes, Anderton, and Anderson 1996; Pastor, Sadd and Hipp 2001; Shaikh and Loomis 1999), it is impossible to know whether or not conclusions drawn from these studies reflect ecological fallacy. For example, some aggregate-level studies attempt to assess the relative effects of race and socioeconomic resources on exposure to pollution by regressing neighborhood hazard levels on average neighborhood income levels and the percentage of minorities living in the neighborhood. Any conclusions drawn from such tests, however, are based on the questionable assumption that higher neighborhood incomes necessarily reflect higher levels of income among individual minority residents of the area. Moreover, evidence suggests that neighborhood characteristics may have important influences on family socioeconomic resources (c.f., Cutler and Glaeser 1997), raising questions about the direction of causality in the cross-sectional association between neighborhood socioeconomic conditions and local levels of pollution. Thus, using aggregate-level cross-sectional data is problematic because it prevents researchers from determining the extent to which household-level resources affect proximity and exposure to pollution and the degree to which racial disparities in family level resources contribute to racial/ethnic differences in pollution exposure and proximity.

Third, despite the plethora of environmental inequality research, only a handful of studies have attempted to isolate the mechanisms through which aggregate patterns of environmental racial inequality develop and are maintained (exceptions include Been and Gupta 1997; Downey 2005; Hamilton 1995; Hunter et al. 2003; Oakes, Anderton, and Anderson 1996; Pastor, Sadd, and Hipp 2001; Shaikh and Loomis 1999). Some of these studies have assessed the argument that environmental racial inequality emerges because environmental hazards are disproportionately sited in minority neighborhoods (Been and Gupta 1997; Downey 2005; Hamilton 1995; Pastor, Sadd, and Hipp 2001; Shaikh and Loomis 1999). However, other studies have pointed out that in the context of high levels of residential mobility, initial siting decisions may have relatively little influence on patterns of proximity and exposure to environmental hazards, as individual householders may simply move away from these hazards. According to this argument, racial differences in exposure to environmental hazards may develop and persist because minority households are less likely than white households to move away from, and more likely to move into, areas containing environmental hazards (Boer, Pastor, Sadd, and Snyder 1997; Brooks and Sethi 1997; Downey 2005; Hamilton 1995; Hunter et al. 2003; Mohai and Bryant 1992; Oakes, Anderton, and Anderson 1996). As Hunter and her colleagues (2003:24) point out, “selective migration is often implied to be a key dynamic leading to differential exposure to proximate environmental hazards” (2003: 24).

However, to date, the absence of appropriate multi-level data related to the mobility behaviors of individual householders has prevented researchers from directly testing environmental inequality hypotheses related to racially-differentiated patterns of residential mobility. Moreover, those aggregate-level studies that have attempted to identify the ways in which mobility patterns shape environmental inequality have produced contradictory results. For example, while most environmental inequality research shows that whites live further from environmental hazards than do members of minority groups, only one study (Shaikh and Loomis 1999) has found evidence of a disproportionate flow of white population out of hazardous neighborhoods and none have observed that environmentally hazardous neighborhoods receive disproportionately large in-flows of minority residents (Been and Gupta 1997; Downey 2005; Hamilton 1995; Pastor, Sadd, and Hipp 2001; Shaikh and Loomis 1999). Similarly, Hunter et al’s (2003) comprehensive study of inter-county migration flows found no evidence of racial differences in migration away from counties containing hazardous facilities. Thus, if racially-differentiated mobility processes are responsible for maintaining racial differences in exposure to environmental hazards, aggregate-level studies appear to be inadequate for uncovering these dynamics. Instead, as Hunter and her colleagues (2003) conclude, building a fuller understanding of racial differences in proximity and exposure to environmental hazards requires that attention be paid to patterns of individual mobility between small geographic units.

In sum, past research provides several important insights into racial and ethnic disparities in proximity and exposure to environmental hazards. However, reliance on aggregate-level demographic data and the existence of only a few national environmental inequality studies has made it difficult for researchers to (a) ascertain the overall magnitude of environmental inequality at the individual level in the U.S., (b) adequately test theoretical arguments related to the relative effects of race and socioeconomic resources on racial disparities in exposure and proximity to environmental hazards, and (c) isolate the micro-level mechanisms through which aggregate patterns of environmental racial inequality develop and are maintained. This paper begins to fill these gaps in the literature by employing multilevel data drawn from two nationally representative datasets and theoretical arguments and analytic techniques drawn from the environmental inequality and residential attainment literatures. In drawing upon the data, theories, and analytic techniques of these two literatures, this study provides the first national comparison of racial and ethnic differences in *household* proximity to urban industrial hazards and the first individual-level examination of racial and ethnic differences in household mobility into and out of environmentally hazardous neighborhoods. In addition, this paper utilizes an innovative Geographic Information Systems (GIS) technique that weights the potential impact of each industrial facility in the dataset inversely according to geographic distance from the facility, allowing us to measure hazard proximity more precisely for each neighborhood than has been possible in prior research.

Theoretical Perspectives

Evidence that racial/ethnic minorities are disproportionately concentrated in environmentally hazardous neighborhoods has given rise to a number of competing theoretical arguments within the environmental inequality literature. These theoretical arguments highlight the importance of racially differentiated patterns of residential mobility and reflect a strident debate about the relative effects of individual socioeconomic characteristics and race in determining patterns of pollution exposure and proximity. According to the ***racial income inequality thesis*** (Downey 2005; Oakes, Anderton, and Anderson 1996), racial differences in exposure and proximity to environmental hazards largely reflect group differences in socioeconomic resources. More specifically, this thesis holds that property values and rents tend to be relatively low in environmentally hazardous neighborhoods, making such neighborhoods more accessible to lower-income families, among which non-white families are overrepresented, and less attractive to higher income families, among which white families are overrepresented. This argument is consistent with the more general *spatial assimilation model* (Alba, Logan, Stults, Marzan, and Zhang 1999; Massey 1985) that informs much of the research on residential attainment by emphasizing socioeconomic characteristics as the main predictors of access to higher-quality neighborhoods.

The income-inequality and spatial assimilation perspectives hold strong implications for racial differences in mobility between lesser- and higher-quality neighborhoods (c.f., Crowder and South 2005; Crowder, South, and Chavez 2006; Quillian 1999; South, Crowder, and Chavez 2005), and thus offer a key argument regarding the micro-level processes that affect environmental inequality. Specifically, these perspectives assume that racial differences in the likelihood of moving into and out of environmentally hazardous neighborhoods emerge largely as a function of group differences in socioeconomic resources. Accordingly, white and Asian householders should be best able to avoid highly polluted neighborhoods, owing largely to their relatively high average levels of income and education (U.S. Census Bureau 2008). In contrast, relatively low average socioeconomic resources among Latino and African American families likely limit opportunities for members of these groups to move out of, or avoid moving into, neighborhoods with high levels of pollution, thereby increasing their overall proximity and exposure to pollution. Of course, the implication of these arguments is that racial/ethnic differences in exposure and proximity to local pollution, and in the mobility patterns that affect this exposure and proximity, will be attenuated by controls for group differences in household socioeconomic resources.

In contrast to the racial income-inequality thesis, the ***residential discrimination thesis*** (Bullard 1993; Godsil 1991; Mohai and Bryant 1992) suggests that racial and ethnic differences in exposure and proximity to environmental hazards, and in the mobility patterns that shape this proximity, result from housing market discrimination that restricts the housing options available to members of at least some minority groups. Consistent with the broader *place stratification perspective* that informs research on residential attainment and mobility (Alba et al.1999; Crowder and South 2005), the residential discrimination thesis assumes that discriminatory actions by real estate agents (Pearce 1979; Yinger 1995), local governments (Shlay and Rossi 1981), and mortgage lenders (Ross and Yinger 2002; Shlay 1988; Squires and Kim 1995) create barriers to residential attainment for minority homeseekers (Galster 1991; Galster and Keeney 1988; Massey and Denton 1993). These barriers are assumed to reduce the ability of minority families to move out of, or avoid moving into, hazardous neighborhoods, thereby creating or maintaining environmental racial inequality.

While the discrimination/stratification perspective was developed to apply to racial and ethnic minority groups in general (Alba and Logan 1993), discriminatory barriers to mobility may be especially restrictive for African Americans (Massey and Denton 1993). Paired discrimination tests suggest that Black, Asian, and Latino auditors all tend to experience negative treatment at the hands of realtors (Turner and Ross 2003; Turner et al. 2002). However, data on racial attitudes point to a distinct queue of residential preferences among survey respondents, with Asians ranked as the most desirable minority neighbors, African Americans as the least desirable, and Hispanics falling in between these extremes (Charles 2000). According to the stratification perspective, these preferences likely affect the residential opportunities available to members of each of these groups, with the most restrictive barriers to residential opportunities erected for those groups deemed least desirable.

Consistent with this argument, cross-sectional studies of residential attainment (e.g., Alba, Logan, and Stults 2000; Logan and Alba 1995; Logan et al. 1996) show that relative to both Whites and members of other minority groups, African Americans face disadvantages in access to high-status neighborhoods that cannot be explained by group differences in socioeconomic resources. In contrast, Asians appear to be much more likely than Blacks to gain access to suburban areas and neighborhoods with greater locational amenities, even in the absence of high levels of family resources or cultural assimilation (Alba et al. 1999). And, while Latinos are less likely than non-Latino whites to live in higher-status neighborhoods, much of this difference can be explained by lower levels of education and income among most Latino groups (Alba, Logan, and Stults 2000; Logan and Alba 1995; Logan et al. 1996). While these patterns of residential attainment do not necessarily point to the absence of discrimination towards Latino and Asian homeseekers, they are suggestive of unique barriers to residential mobility for African Americans. This relative disadvantage of African Americans is also reflected in aggregate population patterns. While high-income racial and ethnic minority groups are less segregated than low-income minority groups from non-Hispanic whites, this income effect is weaker among African Americans than among Asians and Latinos (Iceland and Wilkes 2006; St. John and Clymer 2000).

Overall, the discrimination thesis implies that minority group members will be more likely than whites to live in environmentally hazardous neighborhoods, with African Americans more likely than Latinos and, especially, Asians to live in such neighborhoods. These disparities are assumed to arise out of discriminatory barriers that limit opportunities for minorities, but especially African Americans, to escape highly polluted areas or avoid them as destinations. Moreover, unlike the income-inequality/assimilation thesis, the discrimination/stratification argument suggests that racial and ethnic differences in proximity to neighborhood hazards, and in patterns of mobility into and out of highly polluted areas, will persist even after controlling for household differences in socioeconomic resources such as income and education.

The discrimination/stratification perspective also suggests that due to discriminatory practices against minority homeseekers, the *effects* of socioeconomic characteristics on both pollution proximity and related mobility outcomes might vary across racial and ethnic groups. Specifically, in what Logan and Alba (1993) refer to as the “strong version” of the stratification perspective, discrimination in housing markets limits the ability of minority householders to translate their socioeconomic resources into more desirable residential outcomes to such a degree that even resource-rich members of minority groups are likely to end up in relatively less advantageous neighborhoods than are lower income whites. Thus, this argument holds that the effects of income and education on access to less polluted neighborhoods should be stronger for white than for minority householders. In contrast, the “weak version” of the stratification perspective (Logan and Alba 1993) suggests that while even relatively low-status white householders are able to gain access to fairly advantageous neighborhoods, only the highest-status minority householders are able to achieve similar residential outcomes. Thus, the effects of income and education on residential mobility into low-hazard areas should be stronger for minority householders than for white householders. Given evidence of the unique barriers to neighborhood attainment faced by blacks, these differences from white householders in the effect of socioeconomic status are likely to be more pronounced for black householders than for Latinos or Asians.

In summary, both the income-inequality/assimilation perspective and the discrimination/stratification perspective predict that in comparison to whites, members of minority groups will be less likely to leave, and more likely to enter, polluted neighborhoods, thereby increasing their overall proximity and exposure to environmental hazards. Furthermore, both theoretical arguments suggest that among minority groups, Asians will be best able, and African Americans least able, to gain access to low-pollution neighborhoods, with Latinos occupying an intermediate position with regard to both pollution proximity and it's underlying mobility patterns.

However, these theoretical perspectives offer very different expectations regarding the underlying mechanisms that shape racial/ethnic disparities in pollution exposure and proximity. While the income-inequality/assimilation perspective assumes that these disparities will be explained by racial/ethnic differences in socioeconomic resources, the discrimination/stratification perspective assumes that these racial disparities will persist even after individual education, income, and other factors are controlled. In addition, the discrimination/stratification perspective suggests that discriminatory housing market dynamics will produce racial/ethnic differences in the effects of economic resources on both the ability to move into neighborhoods with lower levels of environmental hazards and overall proximity to these hazards.

Finally, residential attainment research suggests that these mobility patterns are likely to be complicated by the effects of a wide range of additional individual- and household-level factors that also play important roles in shaping mobility decisions. For example, past research indicates that inter-neighborhood migration is significantly shaped by the age, sex, and marital status of the householder, the number of children in the household, housing tenure, and the level of residential crowding in the household (Crowder and South 2005; Deane 1990; McHugh, Gober, and Reid 1990; South and Crowder 1997; South and Deane 1993). In contrast to existing environmental inequality research, we directly control for these factors to better isolate racial and ethnic differences in hazard proximity and mobility between less- and more-hazardous neighborhoods and to adequately test predictions made by the inequality/assimilation and discrimination/stratification perspectives.

Data and Methods

Sources

In order to test these predictions we rely on data from the Panel Study of Income Dynamics (PSID) linked to neighborhood-level environmental hazard data based on the Environmental Protection Agency's (EPA) Toxics Release Inventory (TRI). The PSID is a well-known longitudinal survey of U.S. residents and their families begun in 1968 with approximately 5,000 families (about 18,000 individuals). Members of panel families were interviewed annually between 1968 and 1997 and every two years thereafter. New families have been added to the panel as children and other members of original panel families form their own households.

For several reasons, the PSID is uniquely suited to examining environmental racial stratification and underlying mobility patterns. First, the PSID data are collected for a diverse national sample and contain rich information on a variety of individual- and household-level characteristics that are central to the study of residential attainment.[1] Second, the longitudinal nature of the PSID data makes it possible to assess, prospectively, the effects of micro-level and contextual conditions on residential mobility. Third, and most importantly, the PSID's supplemental Geocode Match Files allow us to link the addresses of individual respondents at each interview to their corresponding census tract identifiers.[2] These identifiers make it possible to trace the mobility of PSID respondents across neighborhoods between successive interviews. They also enable us to attach detailed environmental data about the neighborhoods occupied by PSID respondents at each interview.

For this study, the individual- and household-level data provided by the PSID are attached to information on neighborhood proximity to environmental hazards constructed from the EPA's TRI dataset. Although TRI data do not provide researchers with information about facility siting decisions,[3] they are still the most comprehensive and detailed, publicly available national record of industrial facility activity available to researchers. The TRI records the number of pounds of specified toxic chemicals released into the environment each year by industrial facilities that fall into one of seven industrial categories (manufacturing, metal mining, coal mining, electric generating facilities that combust coal or oil, chemical wholesale distributors, petroleum terminals, and bulk storage), employ the equivalent of ten or more full-time workers, and manufacture, process, or otherwise use the specified chemicals in specified quantities. TRI data were first collected in 1987, but because there are some questions about the accuracy of the first few years of TRI data, our study utilizes only 1990–2000 TRI data.[4] In addition, in order to improve the accuracy of our hazard estimates, we include only those facilities that the EPA estimates were located within 200 meters of the latitude and longitude coordinates provided in the TRI data. Thus, our data incorporate information from a total of 30,309 facilities in the continental United States between 1990 and 2000, with facility counts ranging from 14,506 to 17,581 per year.

Sample

Our effective sample consists of 12,763 PSID household heads, including 2,636 Latinos, 3,951 non-Latino blacks, 130 Asians, and 6,046 non-Latino whites who were interviewed between 1990 and 2003 and resided in a census-defined Metropolitan Statistical Area (MSA) at the time of the interview. One key drawback of the PSID data is that Asians and Latinos are substantially underrepresented since the original panel was selected in 1968, just

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[1] While PSID sample weights are designed to improve the generalizability of the data they are not used here because no weights were assigned for a significant number of PSID householders and because the PSID sample weights are primarily a function of independent variables included in our analyses (Winship and Radbill 1994). Weighted results based on the subsample for which sample weights are available do not change the central conclusions of the analysis.

[2] We use census tracts to represent neighborhoods because they come the closest of any commonly available spatial entity in approximating the usual conception of a neighborhood (Hill 1992; Jargowsky 1997; White 1987). Although the PSID Geocode provide geographic codes defined at several census we use 2000 geographic codes for addresses at all interview years in order to maintain consistency and to accurately detect changes in tract location.

[3] TRI data do not provide information on facility age or why facilities are added to or dropped from the list each year. As a result, it is impossible to tell whether facilities that move onto or off of the TRI list do so because they have been newly sited or newly closed or because their emissions patterns have changed.

[4] One potential problem with the TRI is that the guidelines used to determine which facilities and emissions are included in the database have changed over time, with chemicals being added to and dropped from the list in various years, and new industries being included in its reporting requirements at various points in time. However, this is unlikely to affect our results since there is no reason to believe that these changes have impacted the neighborhoods occupied by some racial and ethnic groups more than the neighborhoods occupied by other racial and ethnic groups. Moreover, the impact of possible changes in the TRI measure are minimized by the fact that we use these data to compare hazard levels at one conceptual point in time rather than inferring changes from one point in time to another.

prior to the rapid increase in the populations of these groups. This underrepresentation was partially remedied in 1997 and 1999 with the addition to the panel of 511 families headed by post-1968 immigrants or their adult children. In addition, the representation of Latinos was increased between 1990 and 1995 with the incorporation of members from the Latino National Political Survey (LNPS). We include Latinos and Asians that were incorporated as part of these sample additions as well as those who were part of, or married into, original PSID panel families. Nevertheless, given the small size and questionable representativeness of the samples of Latinos and especially Asians, inferences drawn about the residential experiences of these groups should be made with caution.

We include in our sample only respondents who were classified as heads of the household either at the beginning *or* the end of an annual mobility interval (i.e., the period between annual interviews) because the residential experiences of the household head typically determine those of other members of the household. Imposing this selection criterion avoids counting as unique and distinct those moves made by members of the same family (e.g., children and spouses) since only moves by the head of the household are included. At the same time, moves by family members who were not the household head at the beginning of the interval but became a household head by the end of the interval (e.g., when a child leaves the parental home or when an ex-husband or ex-wife establishes a new residence) are included in our effective sample.

Finally, we include observations beginning in 1990 because this is the first year in which reliable TRI data are available, and we focus on metropolitan residents in order to enhance comparability with past environmental inequality research, much of which focuses on aggregate population patterns within metropolitan areas. Focusing on metropolitan residents also allows us to calculate more precise environmental hazard estimates because metropolitan area census tracts tend to be smaller than non-metropolitan area census tracts. Given these restrictions, our analyses include data drawn from 302 of the 329 metropolitan areas in the continental U.S.

We take full advantage of the longitudinal nature of the PSID by segmenting each respondent's data record into a series of person-period observations, with each observation referring to the two-year period between PSID interviews.[5] This strategy avoids the need to focus on proximity to pollution at any single point in time and allows us to examine multiple residential moves that may affect this proximity. On average, the individuals in the sample contribute just fewer than four person-period observations for a total sample size of 46,470 observations.

Dependent variables

We test hypotheses related to three separate dependent variables. First, in order to assess the overall level of environmental inequality in metropolitan America, we examine *proximate industrial pollution* in the tract occupied by each PSID householder at the end of each observational interval (time t+2). Second, in order to model the residential mobility processes that likely shape overall environmental inequality, we treat inter-neighborhood residential mobility as a two-stage process involving, first, the decision to move and, second, the choice of destination neighborhood (c.f., Massey, Gross, and Shibuya 1994). Accordingly, the second dependent variable in our analysis is a dichotomous variable indicating whether the respondent *moved out of the census tract of origin* between PSID interviews (a value of "1" for those who moved during the mobility interval and "0" for

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[5] The use of a two-year interval is necessitated by the adoption of a biennial interview schedule in the PSID after 1997.

those who remained in the same tract), and the third dependent variable is *proximate industrial pollution* in the *destination tracts* of mobile PSID householders.

Proximate industrial pollution is a continuous, tract-level measure of neighborhood proximity to TRI facility air pollution that weights the potential effect of each TRI facility inversely according to geographic distance from the facility, thereby incorporating both the level of toxic air emissions produced by each TRI facility[6] and facility proximity to the center of each respondent's census tract. The variable is calculated as follows. First, for each year of TRI data, we locate each TRI facility on a census tract map of the continental U.S., using latitude-longitude coordinates provided by the EPA to locate each facility. This map is then overlaid with a rectangular grid made up of 400-foot square grid cells. For each grid cell we calculate a distance-weighted sum of the pounds of air pollutants emitted that year by all TRI facilities located within 1.5 miles of that grid cell.[7] For example, if two TRI facilities, emitting 10,000 and 2,000 pounds of air pollutants per year respectively, are located within 1.5 miles of grid cell A, and the distance-based weights for these facilities are .8 and .15 respectively, then grid cell A receives a *proximate industrial pollution* value of (.8 * 10,000) + (.15 * 2000), or 8300. Finally, we use these grid cell values to calculate an average grid cell value for each census tract in the country. The resulting tract-level, hazard-proximity score provides a more precise estimate of the level of proximate industrial pollution in and around U.S. census tracts than has been utilized in past research.

Because researchers have yet to develop a commonly accepted spatial weighting scheme for the measurement of neighborhood hazards, we experimented with several distance-decay functions to estimate proximity to industrial hazards. Specifically, in order to assess the robustness of our results, we constructed alternative versions of the hazard variables by altering both the size of the grid-cells and the distance at which industrial sites are considered influential (i.e., the distance at which the distance decay weights reach zero). Except where noted in the text, the results of the analyses using these alternative procedures lead to substantive conclusions identical to those reported below.

It is important to keep in mind that this *proximate industrial pollution* measure cannot be interpreted in absolute terms. Because the measure incorporates distance-weighted information about pollution from TRI facilities located not only inside, but also outside (but within 1.5 miles) of the tract, the scores on this variable do not refer to the total pounds of air pollutants emitted in each census tract in each year or to the pounds of pollutants emitted in the average census tract grid cell each year. Instead, they are estimates of the relative, non-exposure-related influence of all nearby TRI facilities on each census tract and must be interpreted relative to one another. For example, a score of 1,000 on this variable indicates twice the estimated proximate industrial pollution in and around the tract as a score of 500 (see Downey 2006). It is also important to note that these are proximity estimates, not pollution concentration or exposure estimates. While many researchers consider proximity estimates to be inferior to concentration and exposure estimates (see Downey 2006), a proximity measure is most appropriate for the purposes of this study because it likely approximates more closely than concentration and exposure estimates the sensory cues (e.g.,

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[6] An alternative to measuring the level of emissions produced by TRI facilities would be to measure the physical size of the facilities. This would be especially appropriate if individual home seekers use facility size as their primary indicator of industrial pollution. Unfortunately, the TRI provides no direct measure of facility size and such measures are unavailable from other sources (Dun and Bradstreet provide square footage data for many industrial facilities, but for only a small subset of the facilities included in our database). Nevertheless, TRI facility air emissions are strongly correlated with facility size (r = .71, p < .0001) for a subset of facilities for which facility size data are available.

[7] The distance-weights used to calculate the weighted-sum grid cell values decline from one to zero as distance from the grid cell increases (until distance reaches 1.5 miles, after which the weight remains constant at zero). The average number of grid cells per tract is 54 with a minimum of 1 and a maximum of 1,176.

visibility of factories and smell of emissions) that individuals and families consider when making decisions to move to or from specific neighborhoods.[8]

Explanatory variables

As a key component of our effort to investigate how patterns of inter-tract mobility shape overall patterns of environmental inequality, we examine the decision to move to a different tract as a function of the level of *proximate industrial pollution*, as measured above, in and around the tract at the beginning of the observation interval (time t). The race/ethnicity of the respondents is indicated with a set of dummy variables differentiating between those reporting a Latino ethnicity, non-Latino respondents reporting white race (hereafter “whites”), non-Latino respondents reporting black or African-American race (hereafter “blacks”), and non-Latino respondents self-reporting as Asian or Pacific Islander (hereafter “Asian”). Other explanatory variables, which follow closely from those examined in past studies (c.f., Crowder and South 2005), allow us to control for established life-cycle, demographic, and socioeconomic characteristics that affect residential attainment and migration. Our primary indicators of socioeconomic status are *education*, measured by years of school completed, and total family (husband and wife) taxable *income*, measured in thousands of constant 2000 dollars. Key demographic and life-cycle predictors of residential mobility include *age* and, to capture the non-monotonic dependence of migration on age (Long 1988), age-squared. The *sex* of the household head is captured by a dummy variable scored 1 for females and 0 for males. *Marital status* is a dummy variable taking a value of 1 for respondents who were married or permanently cohabiting at the beginning of the migration interval. The generally negative effect of *children* on migration propensity is tapped with a variable indicating the total number of people under age 18 in the family unit at the beginning of the migration interval. *Home ownership* is measured with a dummy variable scored 1 for those living in an owner-occupied housing unit at the beginning of the interval and 0 for non-owners. *Household crowding* is measured by the number of persons per room and *length of residence* is indicated with a dummy variable taking a value of 1 for those respondents who had lived in their current home for at least three years at the beginning of the mobility interval. In all models we control for the *year of observation* to account for both temporal changes in mobility and pollution levels[9] and the uneven distribution of observations for Latino and Asian householders across the years of the PSID data. All of these variables, except gender and race/ethnicity, are considered time-varying and refer to conditions at the beginning of the observation interval (time t).

Analytic strategy

We begin our analysis with an assessment of overall racial differences in proximity to industrial pollution at the household level and then test theoretical arguments about the extent to which these differences can be explained by group differences in socioeconomic resources. To do this, we first model the level of proximate industrial pollution for

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[8] The claim that many individuals are concerned about residing near environmental hazards is supported by the drastic growth in recent years in the number of community-based environmental justice organizations dedicated to removing or banning industrial hazards from their neighborhoods (Downey and Van Willigen 2005: 291). It is also supported by recent research that suggests that residential proximity to industrial activity, industrial pollution, and other environmental hazards (a) increases psychological distress, feelings of personal powerlessness, perceptions of neighborhood disorder and beliefs about local health risks and (b) reduces property values and local economic activity (Downey 2006; Downey and Van Willigen 2005; Liu 2001; Sadd et al. 1999). This research and the growing environmental justice movement suggest that residential proximity to environmental hazards is likely to be both an important indicator of individual, family, and neighborhood well-being and an important cue used by individuals and families to rank neighborhood desirability.

[9] It is possible that individuals’ reactions to local environmental conditions might be affected by periodic media coverage or other events that raise awareness of the presence of, or dangers related to, local environmental hazards. We tested for basic period effects by re-estimating key models for three different time periods: 1990–1993, 1994–1997, and 1999–2003. The pattern of racial disparities in overall exposure to environmental hazards, the effects of local hazards on out-mobility, and the hazard level in destination tracts were very similar across these periods.

household heads at the end of the observation interval (time t+2) as a function of individual and family characteristics at the beginning of the interval (time t), allowing us to ascertain the overall racial/ethnic differences in proximity and exposure to pollution in the U.S. both before and after controlling for socioeconomic resources and other relevant predictors of residential attainment..

We then assess racial/ethnic differences in patterns of mobility and immobility that may shape overall levels of environmental inequality. Here we employ a two-stage modeling strategy consistent with the assumption of a sequential mobility decision-making process (Frey 1979; Massey et al. 1994). In the first stage of the mobility analysis we include the entire sample of PSID household heads and use logistic regression to examine the additive and interactive effects of proximate industrial pollution, respondent race/ethnicity, and other individual- and household-level characteristics on the odds of moving to a different census tract between successive interviews. Here our central focus is on whether there are significant racial/ethnic differences in the effects of local industrial pollution on the likelihood of leaving the neighborhood.

In the second stage of the mobility analysis we select those household heads that left their census tract of origin during the mobility interval and estimate linear regression models in which the dependent variable is the proximate industrial pollution in the census tract to which the householder relocated. Our primary goal in these models is to assess racial/ethnic differences in the level of proximate industrial pollution in the destination tracts of mobile householders and to investigate whether these differences can be explained by group differences in socioeconomic resources or other individual- and household-level characteristics.

Because movers do not represent a random sample of householders, we correct for selection bias using a maximum-likelihood Heckman procedure (Heckman 1979). This procedure involves a two stage process: 1) a selection stage in which a set of variables are used to predict the probability of moving and 2) a substantive model stage in which a set of theoretically relevant predictors and the latent probability of selection to mobility (estimated in stage 1) are used to predict proximate industrial pollution levels in the destination tracts of those who move. Thus, the central goal of the procedure is to assess the influence of theoretically important predictors of mobility destinations while controlling for the latent probability of becoming a mover in the first place. In our application of the Heckman procedure, the “selection” equation includes all of the regressors described above, while the “substantive” equation (predicting proximate industrial pollution in the destination tract) omits the sociodemographic predictors (age, sex, marital status, number of children, duration of residence, and household crowding) because their influence is restricted largely to the likelihood of moving out of the origin tract.

Because the same PSID respondent can contribute more than one person-period to the analysis, and because inter-neighborhood mobility is a repeatable event, the usual assumption of the stochastic independence of error terms underlying tests of statistical significance is violated (Bye and Riley 1989). We correct for this non-independence of observations using the cluster procedure available in Stata to compute robust standard errors in all of our regression models (StataCorp 2008).[10]

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[10] The multi-level structure of our data would ordinarily call for the use of multilevel modeling strategies to relax the assumption that individual- and tract-level regression residuals are independent and to examine variation in the effects of lower-level (individual- and household-level) characteristics across tracts (Bryk and Raudenbush 1992; DiPrete and Forristal 1994; Teachman and Crowder 2002). However, the low level of clustering of individual PSID respondents within census tracts (many tracts have just one respondent and the average is less than two per tract) undermines the utility of such models.

Results

Table 1 provides descriptive statistics for all the variables included in our regression analyses, disaggregated by race/ethnicity. These statistics show that there are fairly large differences in residential mobility levels across the four race/ethnic groups: over one-third of both black and Asian householders moved to a different tract during the average two-year mobility interval, but just over one-quarter of Latino and white householders experienced this type of inter-neighborhood migration. Group differences in other characteristics also reinforce well-known patterns. For example, the number of years of completed schooling is lowest among Latino householders, with an average just slightly below that among black householders, and highest among Asian householders, followed by non-Latino whites. The family incomes for members of these racial and ethnic groups follow a similar ranking, although the average family income for blacks is slightly lower than for Latinos in the sample. Non-Latino black households are also more likely than other households to be headed by unmarried individuals and women. Only about 40% of non-Latino blacks own their own homes, compared to 48% of Latinos, 59% of Asians, and 71% of whites, and Latino and black households tend to contain more children and have more people per room than those of other racial and ethnic groups.

Most importantly, however, Table 1 reveals sharp group differences in proximity to industrial pollution. Figure 1 graphically illustrates these differences, which provide a baseline description of racial and ethnic disparities in residential proximity to industrial pollution. Specifically, the figure shows the average proximate pollution level in and around tracts occupied by all members of each of the racial/ethnic groups represented in our data at both the beginning and the end of the average observation period (times t and t+2). Here it is important to reiterate that these hazard data are based on distance- and emissions-weighted estimates of TRI facility activity within 1.5 miles of census tracts occupied by individual householders distributed across over 300 metropolitan areas.

Consistent with the results of at least some past aggregate-level studies, the descriptive statistics in Figure 1 point to pronounced racial and ethnic differences in residential proximity to industrial pollution. Specifically, at the end of the average observation period, the average level of proximate industrial pollution in and around tracts occupied by Latino respondents (84,013) was almost twice the level experienced by non-Latino whites (43,556), while the level for non-Latino black respondents (106,947) was almost 2.5 times the level experienced by non-Latino whites. Not surprisingly, these differences are statistically significant. In contrast, Asian householders experienced, on average, less proximate industrial pollution in their tract of origin (25,180) than did non-Latino whites, a difference that is also statistically significant.

Also noteworthy is the fact that the four groups differed in terms of their short term hazard trajectories. For example, white, Asian, and Latino householders experienced, on average, slightly lower levels of proximate industrial pollution at the end of the mobility interval (time t+2) than at the beginning (time t), although only the change for Latinos was statistically significant. In contrast, the average level of industrial pollution experienced by black householders actually increased significantly from the beginning to the end of the average observation period.

These observed group differences in pollution proximity confirm the existence of high levels of environmental racial inequality at the individual level. However, these descriptive statistics provide little information about the source of this inequality. Most importantly, it is unclear whether these group differences in residential context reflect group differences in socioeconomic resources and other characteristics that affect residential attainment.

Moreover, while group differences in hazard proximity and hazard trajectory likely reflect, at least in part, the effect of group-differentiated mobility patterns, the precise nature of these mobility differences is currently unknown. For example, group differences in hazard proximity, and changes in hazard proximity over time, could reflect group differences in the likelihood of leaving hazardous neighborhoods or group differences in the hazard levels in and around the neighborhoods to which movers relocate. In addition, racial and ethnic differences in mobility patterns are likely themselves influenced by group differences in sociodemographic resources and other factors that shape migration behaviors more generally.

In order to test competing theoretical explanations for these group differences in residential proximity to industrial hazards, Table 2 presents a series of models that regress *proximate industrial pollution* at the end of the observation interval (time t+2) on a set of individual- and household-level indicators measured at the beginning of the observation interval. Model 1 examines overall group differences in pollution proximity while controlling for the year of observation. As noted above, this control helps to account for group differences in the distribution of person-period observations across the years of the study and possible temporal trends in levels of neighborhood pollution. The coefficient for year of observation indicates that individual-level proximity to industrial pollution is, on average, lower in later observation periods than in early periods. Net of this effect, substantial and statistically significant racial/ethnic differences in residential proximity to pollution persist. Specifically, average levels of proximate industrial pollution are about 34,000 points higher for Latino householders and almost 63,000 points higher for black householders than for whites (the reference category). Similarly, the effect of Asian race remains significant after controlling for year of observation, with the average pollution level experienced by Asian householders about 14,000 points lower than the average for white householders. Although these results point to important group differences in exposure to neighborhood pollution, it is worth noting that the contrast between Latinos and whites is somewhat sensitive to the thresholds used in the construction of the pollution measure. While pollution measures using both larger (600-foot) grid cells and alternative distances (0.5 and 2.5 miles) at which decay functions reach zero consistently point to greater exposure to pollution for Latinos than for whites, this difference is statistically significant only when using the 400-foot grid cell size and 1.5-mile threshold distance, as in the analysis described here.

Model 2 provides a crucial test of the central tenet of the income-inequality/assimilation perspective by adding controls for the education of the household head and the total income of the family. Both of these variables exert significant negative effects on pollution proximity in the neighborhood of residence: proximate industrial pollution is 3,000 points lower for each additional year of education and about 82 points lower for each additional $1,000 in income. Thus, as predicted by the income-inequality/assimilation perspective, householders with greater socioeconomic resources are better able to avoid high-pollution areas.

Including householder education and family income in the regression model also results in the attenuation of the Asian race coefficient, providing further support for the income-inequality/assimilation perspective. In fact, the Asian race coefficient in Model 2 is statistically non-significant and half the size of the coefficient in Model 1. Thus, in these data, it appears that the lower level of proximate industrial pollution experienced by Asian householders, relative to that experienced by white householders, is largely attributable to Asian's slightly greater socioeconomic resources. In sharp contrast, however, disparities in education and income explain relatively little of the higher proximate pollution levels experienced by Latino and African American householders. Controlling for these socioeconomic resources does reduce the Latino coefficient by about 30% (from 34.11 in

Model 1 to 23.83 in Model 2) and the black coefficient by just under 12% (from 62.86 in Model 1 to 55.42 in Model 2). However, both of these coefficients remain sizable and statistically significant in Model 2, lending support to the central argument of the discrimination/stratification perspective. Moreover, the results in Model 3 show that controls for age, gender, and other individual- and household-level characteristics reduce these significant black and Latino disadvantages only slightly.[11] In other words, comparing householders with similar education, income, and other household- and individual-level characteristics, Latino and especially African American householders face levels of proximate industrial pollution that are substantially higher than those faced by white householders.[12]

Model 4 of Table 2 highlights group differences in the effect of socioeconomic resources on residential proximity to pollution, thereby providing a test of additional tenets of the stratification perspective. Here group differences are assessed by interacting family income with the dummy variables for race/ethnicity. The coefficients for these interaction terms provide some evidence that the negative effect of income on residential proximity to pollution is stronger for black and Latino householders than for white householders.[13] Specifically, the coefficients for the interactions between income and both Latino ethnicity and black race are negative and statistically significant. The fact that the negative effect of income is especially strong among members of these minority groups is consistent with the argument presented in Logan and Alba’s (1993) weak version of the stratification perspective, which assumes that white respondents of virtually all socioeconomic strata are able to avoid disadvantageous residential areas, but high levels of economic resources are requisite for minority householders to improve their residential lot..

This dynamic is further illustrated in Figure 2 which presents predicted levels of proximate industrial pollution for householders from different racial and ethnic groups at three distinct income levels. These predicted values are based on the coefficients in Model 4 of Table 2 and assume mean values from the pooled sample of movers for all variables except income which is altered to represent low-income ($11,000, about the 25th percentile), middle-income ($28,000, about the 50th percentile), and high-income ($52,000, about the 75th percentile) householders.

Again, consistent with the weak version of the stratification perspective, the differences in neighborhood pollution between low-, middle-, and high-income black respondents and between Latino householders of different income levels is more pronounced than the stratification across income categories for whites (and Asians). In fact, for white householders of all incomes, the level of neighborhood pollution tends to be uniformly low whereas even high-income black and Latino householders still tend to reside in neighborhoods with higher levels of proximate industrial pollution than do even low-income white householders.

Overall, these results highlight the fact that, at a given point in time, Latino and black householders face substantially higher levels of proximate industrial pollution than do whites, and that these racial/ethnic disparities cannot be explained by group differences in economic resources or other individual characteristics. However, these results provide us with no information about the group-differentiated mobility patterns through which

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[11] The variance inflation factor (VIF) scores involving variables in this and all other models in the analysis are consistently below 4, indicating that multicollinearity does not substantially affect our inferences (Menard 1995).

[12] The net differences in proximate industrial pollution between Asian householders and both black and Latino householders are statistically significant at the .05 level and the difference between Latino and black householders is significant at the .10 level (p = .079, two-tailed test).

[13] Additional tests (not shown) indicate no significant variations in the effects of education.

environmental racial inequality is likely to be shaped and maintained. Table 3 presents a series of logistic regression models designed to assess the possibility that racial and ethnic differences in pollution proximity arise out of group differences in the likelihood of moving away from environmentally hazardous neighborhoods. Here the dependent variable represents the log-odds that the PSID householder moved out of their census tract of origin between successive interviews. Model 1 shows the effectof the level of proximate industrial pollution in the tract of origin on out-mobility for a pooled sample of all respondents, controlling only for the year of observation. The positive logit coefficient indicates that the likelihood of moving out of the tract increases with the level of industrial pollution in the area. However, the coefficient is very small and does not approach statistical significance (p = .354).

While the overall effect of local industrial pollution on the likelihood of leaving the neighborhood appears to be weak, any racial and ethnic differences in this effect could help to produce the large group differences in proximate industrial pollution observed in the previous analyses. To investigate this possibility, the second model adds dummy variables indicating the race/ethnicity of the respondent along with a set of product terms representing the interactions between race/ethnicity and proximate industrial pollution in the tract of origin. The results point to a number of important differences in the mobility patterns of the four racial and ethnic groups. First, the coefficients for the group dummies indicate that when proximate industrial pollution is at zero, the likelihood of changing tracts is significantly higher for black and Latino householders than for whites.

More importantly, there are significant differences in the effects of local industrial pollution on this mobility. In this interactive model, the coefficient for proximate industrial pollution in the tract of origin (b=.0003) indicates that for white respondents, the odds of leaving the tract increase modestly but significantly as levels of local industrial pollution increase. In contrast, the statistically significant negative coefficient for the interaction between black race and proximate industrial pollution (b=−.0003) indicates that the effect of local industrial pollution on out-migration is weaker for black householders than for white householders. In fact, the combination of the baseline effect of proximate industrial pollution and the interaction between black race and proximate industrial pollution indicates that local hazard levels have no effect on the probability of out-mobility for black respondents [.0003+(−.0003)=0]. Overall, the fact that black householders are less likely than white householders to leave environmentally hazardous neighborhoods likely contributes modestly to their relatively high and persistent level of exposure to environmental hazards. There is also some evidence that Hispanic householders are less likely than whites to move away from high levels of pollution, although the negative coefficient for the interaction between Hispanic ethnicity and proximate industrial pollution is small and statistically non-significant (b=−.0002, p=.18). Similarly, the relatively large positive interaction term for Asian race and local pollution (b = .0041) in Model 3 indicates that the lower level of pollution experienced by Asians may be due, in part, to a greater likelihood of leaving highly polluted neighborhoods. However, given the small size of the Asian subsample, this difference is not statistically significant (p=.13).[14]

The remainder of the models in Table 3 attempt to explain the source of these group differences in the effects of proximate industrial pollution on out-mobility. Model 3 tests the argument, drawn from the income-inequality/assimilation perspective, that these modest

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[14] The difference between black and Asian respondents in the effect of proximate industrial pollution is also statistically significant, but the difference between black and Latino householders is not. While supplemental models (not shown) provide some evidence that the effect of local industrial hazard levels on out-mobility has increased over time, this trend does not explain any of the observed racial/ethnic differences in the effects of local hazards.

differences in the probability of moving away from hazardous areas are due to group differences in socioeconomic resources. This argument is tested by adding controls for family income and the education of the householder. The results indicate that education significantly increases and income significantly decreases the likelihood of inter-tract mobility. However, controlling for these resource characteristics does little to attenuate either the effect of local industrial pollution on out-mobility or racial differences in this effect. Specifically, the results are consistent with the Model 2 finding that the likelihood of inter-tract mobility among whites increases with neighborhood hazard levels, and that this effect is not significantly different for Latino or Asian householders. Most importantly, Model 3 provides evidence that the weaker effect of proximate industrial pollution on black householder out-migration is not due to a deficit in socioeconomic resources among blacks.

In order to test whether the effect of local industrial pollution on out-mobility, and group differences therein, are attributable to, or suppressed by, the effects of other mobility predictors, Model 4 adds measures of other basic respondent sociodemographic characteristics. Most of the effects of these characteristics are consistent with theory and prior research. Net of other effects, educational attainment and family income are both significantly and positively associated with the likelihood of moving out of the origin tract.[15] The likelihood of moving decreases significantly with age but this decline tapers off at older ages. Married respondents are less likely than the unmarried to change tracts, and the number of children in the household is inversely associated with inter-tract migration. In addition, the likelihood of moving to a different tract increases significantly with household crowding and is significantly lower for those who own their own home and those who have been in their home for at least three years.[16]

Most importantly, the positive effect of proximate industrial pollution on the log-odds of out-mobility among white householders becomes statistically non-significant after controlling for these significant micro-level predictors of mobility, as does the interaction coefficient indicating the difference in this effect between black and white householders. Supplemental models (not shown) indicate that controlling for the age of the respondents is primarily responsible for these changes to the coefficients. Specifically, adding controls for age and its polynomial without controlling for the other sociodemographic characteristics drops the coefficients for proximate industrial pollution and the interaction involving black race to non-significance. This reflects the fact that while age is not significantly correlated with hazard levels in the neighborhood of origin among most groups, the correlation is actually negative ($r = -.05$) and statistically significant among white householders, indicating that younger white householders tend to originate in neighborhoods with somewhat higher hazard levels than those in which older white householders originate. Combined with the generally negative influence of age on residential mobility observed in our research and most other studies, this higher concentration of younger, more mobile whites in more polluted areas and older, less mobile whites in less polluted areas produces the relatively higher risk of out-mobility from polluted neighborhoods among white householders observed in the preceding models. Thus, controlling for this age effect brings the effect of pollution among whites closer to zero, more in line with the non-effect among black householders.

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[15] The change in sign of the income coefficient from Model 3 to Model 4 reflects the influence of homeownership. Ownership is strongly and positively associated with income and negatively associated with the log-odds of moving. This net negative association is reflected in the coefficient for income in Model 3 where ownership is not controlled. Controlling for this effect in Model 4 reveals the net positive association between income and out-mobility.

[16] In additional tests we also controlled for two potential neighborhood-level mobility determinants: the level of neighborhood disadvantage and tract racial composition. These variables proved to be statistically non-significant in our analyses and their inclusion did not change the apparent effects of proximate industrial pollution or the observed group differences therein.

Overall, the results presented in Table 3 provide modest support for the argument that dramatic racial and ethnic differences in proximity to industrial hazards are due to differential propensities to escape polluted neighborhoods, with the likelihood of leaving hazardous areas slightly higher among white householders than among black householders. Somewhat contrary to the income-inequality thesis, this differential cannot be explained by racial differences in income or education. Instead, the greater tendency for whites to leave highly polluted areas appears to be primarily due to the concentration of younger whites in neighborhoods that are more polluted than those in which older whites live. Thus, there is little evidence to suggest that minority householders are less responsive than whites to high levels of pollution. In fact, comparing white and minority individuals with similar characteristics reveals similar mobility responses to the level of pollution in and around the neighborhood of residence.

Of course, the gross racial differences in mobility away from neighborhood pollution have important implications for overall patterns of environmental inequality, especially in the context of profound differences in the types of neighborhoods in which members of different groups originate. The fact that Latino and black householders are much more likely than white householders to originate in highly polluted areas (see Table 1), and also slightly less likely than white householders to escape high levels of pollution in and around their neighborhoods of origin, helps to maintain profound racial and ethnic differences in the levels of proximate industrial pollution experienced by these groups.

However, group differences in mobility away from polluted areas represent just one of the ways that mobility dynamics might shape existing patterns of environmental inequality. Table 4 assesses the extent to which the influence of out-mobility on environmental inequality is complemented or contradicted by racial/ethnic differences in mobility destinations. Specifically, Table 4 presents the results of a series of Heckman-corrected linear regression models designed to examine the effects of race, ethnicity, and the other explanatory variables on industrial pollution levels in and around the tracts to which mobile PSID householders relocate, adjusting for the non-random selection of respondents into the mover category.[17] Here it is important to note that many of the mobility predictors included in the preceding analysis (e.g., age, gender, marital status, etc.) are included only in the selection model since they are assumed to affect the likelihood of moving, but not necessarily the choice of destinations.[18]

The first model in Table 4 presents the gross differences in proximate industrial pollution in destination tracts among the four racial/ethnic groups (non-Latino whites define the reference category). The results indicate that conditional upon moving, Latino householders enter neighborhoods characterized by a level of proximate industrial pollution that is over 32,000 points greater than that experienced by white movers. This hazard proximity disadvantage is even more pronounced for black householders who, on average, enter neighborhoods in which the level of local industrial pollution is almost 75,000 points higher than in neighborhoods entered by white movers.[19] In sharp contrast, Asian householders tend to move to tracts with slightly lower levels of proximate industrial pollution than do whites, complementing their somewhat stronger reaction to local hazard levels in making the

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[17] Models that do not use the Heckman correction for the non-random selection of mobile householders produce results that are substantively similar to those reported here.

[18] This assumption was confirmed with models in which sociodemographic characteristics were also introduced as predictors in the second stage of the Heckman models. None of these sociodemographic characteristics proved to be a significant predictor of proximate industrial pollution in the destination tracts net of their significant influences on the likelihood of selection into mobility status. Moreover, the inclusion of these variables did not alter the relative effects of race/ethnicity or the observed group differences in income.

[19] The difference in destination hazard levels between Asians and Latinos and between Asians and blacks are statistically significant but the difference between Latino and black householders is not.

decision to move (see Table 3). All of these group contrasts in destination hazard levels are statistically significant and provide support for the argument that the overall level of environmental inequality revealed in Table 2 is shaped substantially by differences in the types of neighborhoods to which members of different racial/ethnic groups move.[20]

Key to the racial income-inequality and related assimilation theses is the assumption that these racial/ethnic differences in destination outcomes are due primarily to group differences in socioeconomic resources. Accordingly, the residual effects of race/ethnicity on destination hazard levels should be largely attenuated when the resource characteristics of respondents are controlled. In contrast, the residential discrimination/stratification thesis suggests that even after controlling for socioeconomic resources, significant group differences in destinations will persist as minority-group members are blocked from accessing the best quality neighborhoods.

Model 2 of Table 4 provides a test of these competing theoretical arguments by incorporating two primary measures of socioeconomic resources, the education of the householder and total taxable income of the family. Not surprisingly, the coefficients for both of these characteristics are negative, although only the net effect of income is statistically significant. Thus, higher-income movers are apparently better able than lower-income movers to gain access to less hazardous neighborhoods: after controlling for respondents' race/ethnicity and education, and conditional on mobility, a $1,000 increment in income is associated with a reduction of just over 204 points in the dependent variable ($-.2044*1000=-204.4$).

Providing further support for the income-inequality/assimilation perspective, controlling for the significant effect of family income helps to attenuate some of the gross racial/ethnic differences in destination outcomes. Specifically, from Model 1 to Model 2, the positive coefficient for Hispanic ethnicity is reduced by 24% (from 32.2852 to 24.4690) and the negative coefficient for Asian race is reduced by over 40% (from −19.5604 to −11.6381), and both of these coefficients become statistically non-significant. Thus, a sizable portion of the higher level of destination pollution experienced by Hispanic movers, relative to that experienced by white movers, is explained by their relatively lower incomes, and the relatively lower level of destination pollution experienced by Asian householders in comparison to whites largely reflects their relatively higher socioeconomic standing.

However, in a finding that supports the basic assumptions of the residential-discrimination/stratification thesis, controls for socioeconomic resources do little to attenuate the black disadvantage in the level of pollution experienced in destination tracts. While this disadvantage is reduced by about 11% from Model 1 (74.8391) to Model 2 (66.3391), the coefficient for black race remains statistically significant net of the effects of education and income.[21] Thus, even among those with similar socioeconomic resources, mobile black householders enter neighborhoods that are substantially more polluted than those accessed by white movers.

Model 3 adds a series of interaction terms to test for racial/ethnic differences in the benefits of income for avoiding highly polluted destinations.[22] One of the interesting repercussions of adding these interaction terms is that the positive coefficient for Latino ethnicity increases

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[20] The statistically significant, negative lambda coefficients in all models in Table 4 indicate that those respondents who move during the mobility interval (i.e., are selected into this second stage of the analysis) tend to experience significantly lower levels of proximate industrial pollution at the end of the mobility interval than do those respondents who do not move.

[21] The difference in destination pollution between Asian and black movers also remains statistically significant with controls for education and income but the difference between Asians and Latinos becomes statistically non-significant.

[22] Supplemental analyses (not shown) indicate no significant race/ethnic variation in the effects of education on destination pollution.

and becomes statistically significant at the .10 level (p= .051) with the addition of the interaction terms, suggesting a relatively pronounced contrast in destination pollution between white and Latino movers at the bottom of the income distribution. Similarly, the negative coefficient for Asian race becomes larger and statistically significant in Model 3. Thus, among mobile householders with no income, Asian householders tend to enter neighborhoods with significantly lower levels of pollution than those entered by white householders. However, this difference dissipates at higher levels of income, as indicated by the (non-significant) positive interaction between Asian race and income.

More marked are the significant negative interactions between income and both Latino ethnicity and black race. These interactions suggest that, in contrast to the small and non-significant effect of income among white householders (b = −.0611), income is significantly more important in determining the residential destinations of black and Latino householders. Once again, these significant differences in the effects of income are consistent with the existence of discriminatory barriers in the housing market as summarized in the weak version of the discrimination/stratification perspective. Regardless of their level of income, whites are able to avoid moving into highly hazardous neighborhoods, while black and Latino householders must attain high levels of income in order to improve their destination outcomes. Even so, predicted values based on the coefficients in Model 3 confirm that even the lowest-income white movers tend to enter neighborhoods with pollution proximity levels far below those entered by the highest-income black and Latino movers. These patterns highlight the significant disadvantages faced by black and Latino householders in the effort to avoid neighborhood pollution and suggest that disparities in mobility destinations play an important role in shaping overall differences in proximity to local industrial pollution.

Conclusion and Discussion

The urgency of understanding the magnitude and causes of racial and ethnic disparities in exposure and proximity to environmental hazards has grown along with researchers' recognition that proximity and exposure can significantly and negatively affect physical and psychological well-being, educational success, perceptions of social order, and local economic activity. Yet past environmental inequality research has relied on aggregate-level data linking neighborhood racial characteristics to area hazard levels, often focusing on neighborhoods within one or a small number of metropolitan areas. As a result, prior research has provided an inconsistent picture of the magnitude of environmental inequality and left untested key theoretical arguments about the micro-level forces that shape it. By linking individual-level data from the nationally-representative sample of PSID householders to unique, neighborhood-level measures of proximate industrial pollution, the current study provides a clearer picture of the magnitude of environmental inequality in U.S. metropolitan areas, important insights into the residential mobility processes that shape disparities in proximity to pollution, and the first direct test of key theoretical arguments offered to explain this inequality.

Our findings confirm the existence of significant racial and ethnic differences in household proximity to neighborhood industrial pollution and highlight underlying mobility dynamics that are at least partially consistent with multiple theoretical perspectives. The income-inequality and related spatial assimilation theses receive some support from the finding that family income and householder education significantly decrease householder proximity to industrial pollution and that higher levels of income are associated with lower levels of pollution in the destinations of mobile householders. Moreover, these effects, which highlight the potentially important role of socioeconomic resources in shaping environmental inequality, explain a large portion of the disparity in proximate neighborhood pollution between Asian and white householders. While white and Asian householders display a similar likelihood of leaving highly polluted neighborhoods, Asians tend to relocate to areas with somewhat lower levels of proximate industrial pollution when they do move and this difference contributes to modestly (but significantly) lower levels of proximate neighborhood pollution for Asian householders. In support of the basic tenets of the income-inequality/assimilation thesis, these differences are largely attenuated when significant effects of socioeconomic resources are controlled, with Asians' relatively higher levels of education and family income allowing them to gain access to less polluted areas.

Despite this support for the income-inequality/assimilation perspective, our results also indicate that group differences in socioeconomic resources are insufficient to fully explain observed patterns of environmental inequality by race and ethnicity. In particular, the residential experiences of Latino and especially black householders are highly consistent with the existence of restrictive housing market conditions such as those stressed in the discrimination/stratification perspective. Non-Latino black householders experience significantly higher levels of proximate industrial pollution than do non-Latino whites, and this difference in proximity remains large and statistically significant even when differences in socioeconomic resources are controlled. Although the statistical significance of the difference between Latino and white householders appears to be somewhat sensitive to the method used to measure local hazard levels, Latinos also appear to face an elevated level of neighborhood pollution. Thus, even among householders with similar levels of education and income, black and Latino householders tend to reside in areas with more industrial pollution than do white householders, with the disadvantage experienced by blacks being especially pronounced.

For Latino householders, these differences in proximity appear to be affected primarily by the fact that Latino movers are more likely than white movers to enter neighborhoods with high levels of proximate industrial pollution. However, the especially high levels of local pollution experienced by black householders appear to be maintained by both a relatively lower likelihood of escaping the highly polluted neighborhoods in which they originate and a tendency to relocate to destinations with higher levels of proximate industrial pollution than those experienced by mobile white householders. The fact that these differences in mobility destinations and overall hazard proximity levels persist even with controls for income, education, and a wide range of other sociodemographic characteristics is consistent with the argument that discriminatory real estate practices restrict residential options for members of at least some minority groups and that these restrictions are especially virulent in limiting opportunities for black householders. Furthermore, whereas white householders of all economic strata are able to avoid highly polluted neighborhoods, high levels of income appear to be especially important in determining residential outcomes for both black and Latino householders. Yet, even the highest-income black and Latino householders tend to end up in neighborhoods with higher levels of pollution than those experienced by even low-income whites, a finding consistent with at least one variant of the discrimination/stratification perspective.

Thus, the research presented here not only provides a first assessment of the magnitude of environmental inequality at the individual level but illuminates the theoretically central roles of economic conditions and racial barriers in shaping underlying micro-level mobility dynamics. Yet this research represents only a first step in developing a full understanding of the individual-level processes that maintain and reinforce environmental inequality, leaving open a number of important issues for future research. For example, this study utilizes a single measure of proximate industrial pollution based on the distance to TRI facilities and the amount of air pollution emitted by these facilities. While this measure represents an improvement over other hazard proximity measures currently found in the literature, future research would do well to employ alternative environmental hazard estimates, including hazard proximity estimates that incorporate actual data on facility size or facility visibility, toxicity-weighted pollutant concentration estimates that more closely approximate the relative physical health risks of residing in different neighborhoods, and estimates that utilize data on other types of environmental hazard.

Furthermore, additional analyses should be dedicated to understanding the extent to which racial disparities in mobility between more- and less-hazardous neighborhoods are conditioned by the effects of broader metropolitan structures. For example, the propensity for Asian individuals to move to neighborhoods with relatively low levels of pollution, and the propensity for black and Latino movers to enter neighborhoods with relatively high levels of pollution, might be partly dependent on the housing options available in metropolitan areas in which these groups are most highly represented. In this sense, additional insight could be gained by examining the concentration of housing vacancies across more- and less-polluted neighborhoods and the relative availability of new housing away from industrial centers in the metropolitan areas occupied by these groups.

Finally, future research on individual-level environmental racial inequality should incorporate data on the processes related to the location and operation of polluting facilities. This would allow researchers to compare the relative importance of facility siting versus racially differentiated mobility patterns in shaping environmental inequality. Such analyses would substantially bolster our understanding of the structural forces shaping the broad, pronounced and persistent racial and ethnic differences in proximity and exposure to environmental hazards revealed in this study.

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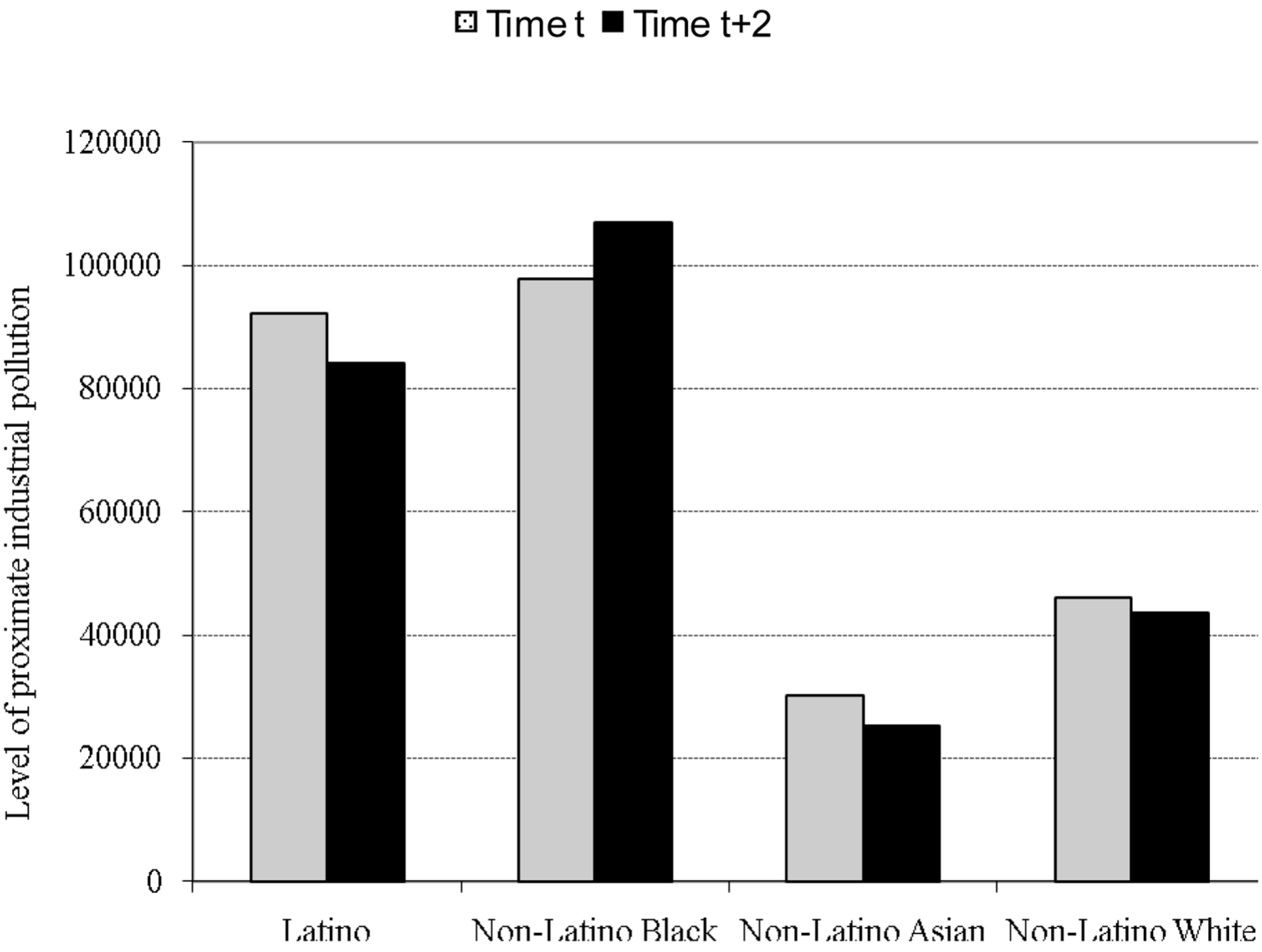

Figure 1.

Observed Proximate Industrial Pollution by Race/Ethnicity

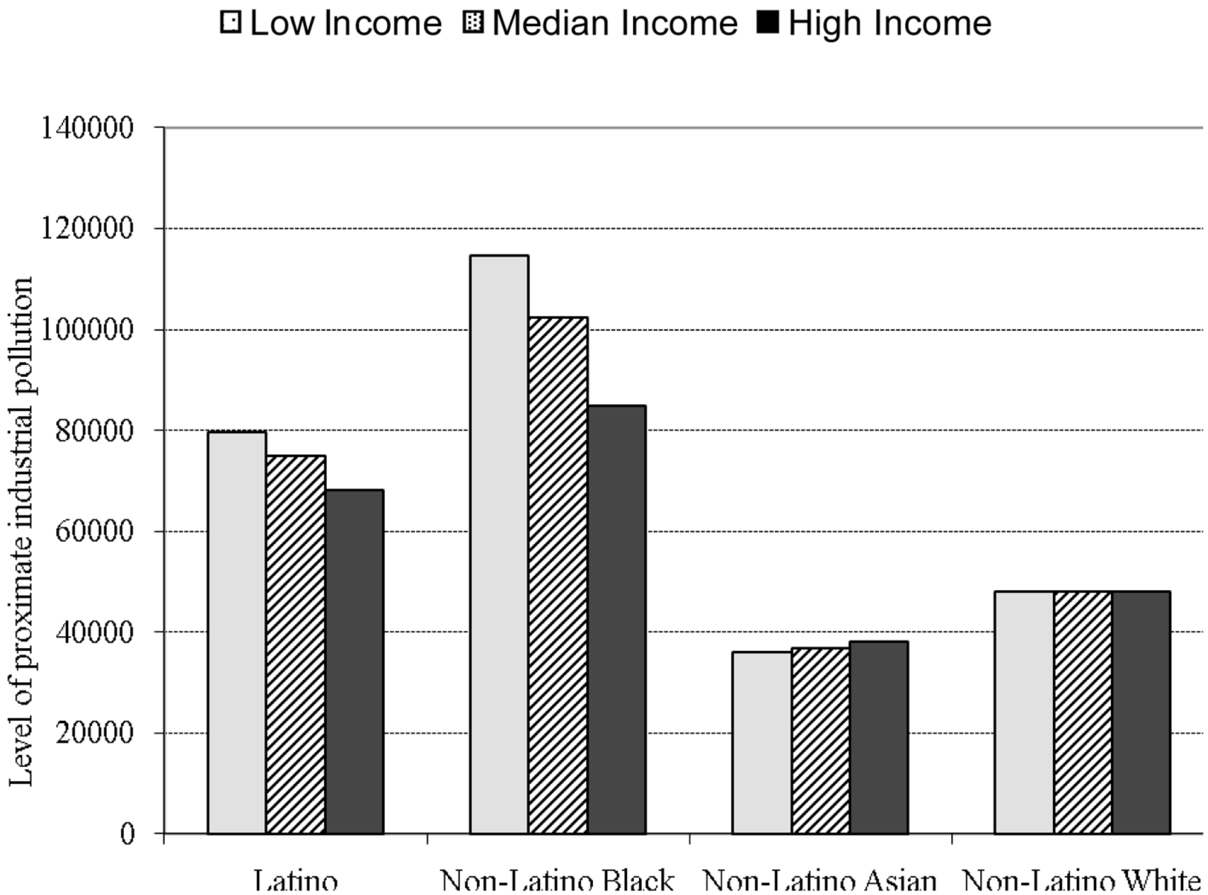

Figure 2.
Predicted Level of Proximate Industrial Pollution in Tract of Residence by Race/Ethnicity and Household Income

Table 1

Descriptive Statistics for Variables in Models of Residential Mobility between Census Tracts by Race/Ethnicity: PSID Householders, 1990–2003.

	Latino		**Non-Latino Black**		**Non-Latino Asian**		**Non-Latino White**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Dependent Variables								
Proximate Industrial Pollution in tract at time t+2 (1000s)	84.013	425.576	106.947	1100.760	25.180	52.426	43.556	198.058
Changed Tracts, time t to t+2 (1=yes)	.274	.446	.336	.472	.345	.476	.259	.438
Independent Variables								
Proximate Industrial Pollution in tract at time t (1000s)	92.081	499.615	97.698	786.039	30.190	103.263	46.120	224.120
Education	10.755	4.013	11.973	2.584	15.467	3.327	13.602	2.877
Family Income (in $1000’s)	33.018	38.275	27.127	30.048	75.190	80.545	56.761	73.058
Age	41.977	15.487	40.705	14.459	42.849	14.659	44.776	16.443
Female (1=yes)	.288	.453	.503	.500	.243	.430	.238	.426
Married (1=yes)	.617	.486	.380	.485	.641	.481	.651	.477
Number of Children	1.272	1.381	1.271	1.353	.846	1.150	.767	1.073
Homeowner (1=yes)	.477	.499	.396	.489	.588	.493	.711	.453
Persons per Room	.792	.501	.639	.381	.546	.376	.468	.249
In Same House 3+ Years (1=yes)	.375	.485	.455	.498	.557	.498	.558	.497
Year of observation	1992.685	3.732	1994.980	3.843	1997.017	3.800	1995.191	3.767
N of person-periods	5,561		14,817			345	25,747	
N of persons	2,636		3,951			130	6,046	

Table 2

Coefficients for Linear Regression of Proximate Industrial Pollution in Census Tract of Residence: PSID Householders, 1990–2003.

	Model 1		Model 2		Model 3		Model 4	
Independent Variables	**b**	**se**	**b**	**se**	**b**	**se**	**b**	**se**
Race/ethnicity								
Latino	34.1117 ***	8.3181	23.8303 **	8.8712	21.2989 *	8.8720	34.9612 **	11.6239
Non-Latino Black	62.8562 ***	11.7298	55.4183 ***	10.9210	49.9052 ***	11.6609	74.8465 ***	19.0920
Non-Latino Asian	−13.7517 *	5.5479	−6.8215	6.2606	−7.2600	7.0481	−12.5669 †	7.3878
Non-Latino White	*reference*		*reference*		*reference*		*reference*	
Education			−3.1247 **	1.1391	−3.6871 **	1.2532	−3.1749 **	1.1749
Family Income (in $1000’s)			−.0807 **	.0298	−.0429	.0293	.0006	.0279
Age					−.6629 *	.2640	−.7332 **	.2727
Female (1=yes)					19.4013	14.2161	17.4679	13.7753
Married (1=yes)					−3.5453	12.9793	1.3838	14.0842
Number of Children					−3.7653	3.5902	−4.1611	3.6566
Homeowner (1=yes)					7.1227	9.4360	9.9540	9.7538
Persons per Room					4.1611	14.9745	2.0092	15.1260
In Same House 3+ Years (1=yes)					−3.6796	7.5025	−3.7005	7.5364
Interactions								
Income × Latino							−.2828 *	.1432
Income × Non-Latino Black							−.7282 **	.2756
Income × Non-Latino Asian							.0514	.0434
Year of observation (1990=0)	−2.5322 *	1.200	−2.3210 *	1.0848	−2.2034 *	.9769	−2.1169 *	.9612
Constant	56.7007 ***	6.3183	102.6884 ***	19.2178	132.8816 ***	30.3641	122.7080 ***	29.0957
Model R-squared	.022		.025		.029		.032	

N of observations = 46,470; N of persons = 12,763.

† <.10.

* p<.05.

** p<.01.

*** $p<.001$.

Table 3

Logistic Coefficients for Regression Analyses of Residential Mobility Out of Census Tract of Origin: PSID Householders, 1990–2003

	Model 1		Model 2		Model 3		Model 4	
Independent Variables	**b**	**se**	**b**	**se**	**b**	**se**	**b**	**se**
Proximate Industrial Pollution in tract, time t	.0001	.0001	.0003*	.0001	.0003*	.0001	.0001	.0001
Race/ethnicity								
Latino			.144**	.0468	.1974***	.0490	−.1957***	.0506
Non-Latino Black			.3877***	.0340	.3628***	.0354	−.0421	.0352
Non-Latino Asian			.2536	.1726	.2371	.1741	−.0182	.1435
Non-Latino White			*reference*		*reference*		*reference*	
Interactions								
Pollution × Latino			−.0002	.0001	−.0001	.0001	−.0000	.0001
Pollution × NL Black			−.0003*	.0001	−.0003*	.0001	−.0001	.0001
Pollution × NL Asian			.0041	.0027	.0041	.0027	.0034	.0021
Education					.0515***	.0053	.0388***	.0055
Family Income (in $1000's)					−.0041***	.0004	.0010***	.0002
Age							−.1215***	.0051
Age-squared							.0009***	.0001
Female (1=yes)							.0330	.0406
Married (1=yes)							−.2581***	.0386
Number of Children							−.0875***	.0143
Homeowner (1=yes)							−1.0151***	.0323
Persons per Room							.3276***	.0460
In Same House 3+ Years (1=yes)							−.3294***	.0308
Year of observation (1990=0)	.0244***	.0030	.0254***	.0031	.0244***	.0031	.0487***	.0034
Constant	−1.0382***	.0231	−1.1966***	.0293	−1.6750***	.0718	2.2859***	.1321
Log likelihood	−27773.900		−27624.217		−27449.483		−23494.184	

N of observations = 46,470; N of mobility events = 13,297; N of persons = 12,763.

†<.10;

*$p<.05$;

**$p<.01$;

***$p<.001$.

Table 4

Coefficients for Regression of Proximate Industrial Pollution in Census Tract of Destination: Mobile PSID Householders, 1990–2003.

	Model 1		Model 2		Model 3	
Independent Variables	**b**	**se**	**b**	**se**	**b**	**se**
Latino	32.2852 *	14.7079	24.4690	16.3764	47.8518 †	24.5006
Non-Latino Black	74.8391 **	24.9314	66.3391 **	23.0889	93.5397 **	34.6657
Non-Latino Asian	−19.5604 *	8.4280	−11.6381	10.3606	−20.5386 *	9.5897
Non-Latino White	*reference*		*reference*		*reference*	
Education			−2.4448	1.7318	−1.7577	1.6511
Family Income (in $1000’s)			−.2044 ***	.0528	−.0611	.0427
<u>Interactions</u>						
Income × Latino					−.5827 *	.2959
Income × NL Black					−.9248 *	.4641
Income × NL Asian					.0774	.0610
Year of observation (1990=0)	−1.9545	3.3246	−1.7685	3.2818	−1.5917	3.2238
Constant	88.3111 ***	27.2076	129.2168 **	48.3672	110.9511 *	44.0266
Lambda	−30.4127 **	10.5578	−28.9559 **	10.5092	−28.1464 **	10.2368
Log Likelihood	−132407.60		−132406.10		−132404.00	

Note. - Models estimated with maximum-likelihood Heckman selection using regressors shown in Table 3 in selection equation. N of uncencored observations = 13,297; N of censored observations = 33,173; N of observations total = 46,470; N of persons = 12,763.

[†] <.10.

[*] p<.05.

[**] p<.01.

[***] p<.001.