Work-Residence Pollution Exposure Gap in the United States*

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Abstract

When assessing individual pollution exposure, the focus is often on residential locations. However, pollution levels can differ widely between home and work. Individuals who spend considerable time working in different geographic areas may experience exposure levels that differ from those at home. Workplace exposure to air pollution in the U.S., calculated using Longitudinal Employer Household Dynamics Origin-Destination Employment Statistics linked with satellite-derived PM2.5 data, consistently exceeds residential exposure, with the pollution gap between work and home increasing from 0.17 $\mu g/m^3$ in 2002 to 0.25 $\mu g/m^3$ in 2019. This difference in exposure reduces the measured Black-White pollution gap by 20 to 42 percent for workers commuting more than 20 miles. Remote workers experience a 0.21 $\mu g/m^3$ reduction in pollution exposure, as telecommuting allows them to live farther from high-pollution workplaces.

Keywords: air pollution, work-residence pollution gap, racial gap

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1 Introduction

Air quality significantly influences worker productivity and public health. Extensive research has highlighted the detrimental effects of increased exposure to fine particulate matter (PM2.5) on various health and non-health outcomes (Aguilar-Gomez et al., 2022). Elevated PM2.5 levels are linked to declines in cognitive function (Laurent et al., 2021), reduced productivity (He, Liu, and Salvo, 2019; Hill et al., 2023; Chang et al., 2016), worsening mental health (Chen, Oliva, and Zhang, 2024), and even increased crime rates (Burkhardt et al., 2019). Accurate measurement of pollution exposure is crucial for generating precise estimates of these negative impacts and for designing effective policies to reduce exposure.

When evaluating individual exposure to pollution, the focus is typically on residential locations. However, around 62 percent of the U.S. population participates in the labor force (U.S. Bureau of Labor Statistics, 2024) and work in areas different from their home locations. As a result, a large part of the day is spent at work, where workers often encounter pollution levels that differ significantly from those at their home. Ignoring workplace exposure risks overlooking a critical aspect of daily pollution exposure, especially for those commuting across regions with differing air quality. In 2019, approximately 95 percent of the working population in the U.S. commuted to work, covering an average distance of 21 miles with a mean travel time of 25 minutes. Consequently, workplaces significantly influence individuals' exposure to pollution across time and space. Given that people spend at least a third of their day at work, including this exposure offers a more comprehensive measure of overall pollution exposure. This paper investigates the following question: How large is the work-residence exposure gap in pollution? Understanding this gap is crucial, as it highlights the potential limitations of relying solely on residence-based measures, which may not fully capture the impact of daily activities, particularly time spent at work.

Measuring air pollution exposure at work can also help design policies that target workplace pollution reduction. PM2.5 can have harmful effects even at levels significantly below established thresholds. Therefore, integrating PM2.5 guidelines into workplace policies is vital, with the initial step being accurately assessing the pollution levels present in various work environments. A significant portion of the workforce spends considerable time in these environments, yet the Occupational Safety and Health Administration (OSHA), which oversees safe working conditions in the U.S., currently lacks a defined permissible exposure limit for PM2.5

concentration.[1] Establishing explicit guidelines for PM2.5 exposure in commercial buildings can contribute to targeted pollution reduction efforts in mitigating workplace pollution exposure.

Data on origin-destination employment statistics and individual trip information facilitates the measurement of work-residence disparities in pollution exposure. The origin-destination employment statistics, which provide detailed information on the work and residence locations of the U.S. workforce from 2002 to 2019, enable an examination of how these disparities have evolved over nearly two decades. I use aggregate counts of workers at their home and work locations to calculate their pollution exposure in both settings. While this aggregate data allows for broader analysis, it does not provide the level of detail required to identify the specific characteristics of individual workers traveling between home and work locations. For instance, at each work location, I know the aggregate demographics of the workforce but can trace only the origins of the workers without being able to identify their specific demographic characteristics. To overcome this limitation, I use a private synthetic population dataset. Replica's Places for 2019 and 2021 provides individual-level data, allowing me to analyze how the pollution exposure gap varies by commuting patterns and demographic characteristics.

The findings highlight that in-person workers face higher pollution levels at their workplaces than at home, with more than two-thirds of them working in locations with worse air quality. This work-residence gap is particularly pronounced among the White population and long distance commuters.

Measuring the disparity in pollution exposure between work and residence offers a new perspective on environmental justice. Does including workplace exposure change our understanding of these disparities? Existing evidence indicates that the Black population is exposed to 0.5 $\mu g/m^3$ more PM2.5 than their White counterparts, highlighting concerns about environmental inequity (Currie, Voorheis, and Walker, 2023). Understanding the work-residence gap is essential for evaluating its influence on the broader racial disparities in pollution exposure.

The disparity in pollution levels at work and residence implies that remote workers might experience lower pollution levels than those who work in-person. Does the positive work-residence gap mean that remote workers are exposed to lower pollution levels? This exploration can shed light on how remote work impacts individual exposure to pollution.

[1] In California, the air quality index (AQI) for PM2.5 is set to 151 (approximately, 12.1 g/m^3) when wildfire smoke poses a risk, requiring employers to reduce PM2.5 levels below this threshold or relocate work to areas meeting the AQI standard.

I make four contributions to the existing studies. First, I measure work-residence disparity in pollution exposure at the national level using a finer geographic scale. To achieve this, I combine census data on aggregate worker shares, an individual-level dataset on the U.S. workforce and satellite-derived PM2.5 data. I find a fairly constant work-residence exposure gap[2] (henceforth, WREG) of 0.25 $\mu g/m^3$[3]. This study is closely related to the existing works by Yoo, Cooke, and Eum (2023) and Kim and Kwan (2020). Yoo, Cooke, and Eum (2023) examine workplace exposure across eight metropolitan statistical areas and find that while PM2.5 exposure tends to be higher at workplaces, NO_2 and ozone exposure are generally greater at residences. Kim and Kwan (2020) further underscore these differences in pollution exposure through the concept of the "neighborhood effect averaging problem" (NEAP), which arises when individual mobility-based exposures converge towards the population mean. Their work using individual travel diary data in Los Angeles demonstrates that neglecting daily mobility can lead to inaccurate assessments of pollution exposure gaps between different social groups.

Second, I highlight the role of distance to work as a major determinant of the work-residence exposure gap. As the distance between a person's home and workplace increases, the likelihood of differences in pollution levels also rises. The cross-sectional 2019 data reveals a positive correlation between the work-residence exposure gap and the distance commuted for work. For distances exceeding 10 miles, WREG ranges from 0.18 $\mu g/m^3$ to 1.02 $\mu g/m^3$. A work-residence exposure gap of 0.18-1.02 $\mu g/m^3$ is 36-204% of the documented 0.5 $\mu g/m^3$ Black-White pollution gap. Brazil (2022) employed anonymized mobile phone data to examine air pollution exposure in 88 U.S. cities, finding that residents from minority and low-income neighborhoods tend to travel to areas with higher pollution levels compared to their White and non-poor counterparts. I find that the work-residence gap for the White population is about 0.20-1.07 $\mu g/m^3$ but it is either insignificant or substantially lower for the Black population.

Third, accounting for exposure at work reduces the estimate of the racial gap in pollution exposure by at least 20% for long distance commuters. I, therefore, contribute to the existing studies on environmental justice (Banzhaf, Ma, and Tim-

[2] All estimates are stated for a typical 8 hour workday. To get the corresponding measures for a 24 hour day, divide the exposure differences by 3. For example, if exposure at home is 9 $\mu g/m^3$ and that at work is 12 $\mu g/m^3$, leading to a WREG gap of 3 $\mu g/m^3$, the actual 24 hour exposure increases by only 1 $\mu g/m^3$.

[3] Back-of-the-envelope calculations using estimates from existing studies, Borgschulte, Molitor, and Zou (2022) and Cabral and Dillender (2024), suggest that a daily increase in exposure of 0.25 $\mu g/m^3$ at work could reduce annual earnings by 2756 USD per year and increase injury claims by 0.4% of the mean daily rate per 100,000 workers.

mins, 2019). Colmer et al. (2020) illustrate that even though pollution declined between 1981 and 2016 in the U.S., relative disparities persisted. Black, Hispanic, and Asian communities experience higher pollution exposure compared to predominantly White communities (Jbaily et al., 2022). Low-income groups also experience a higher pollution burden than high-income groups. Currie, Voorheis, and Walker (2023) find that the mean gap in Black-White pollution exposure reduced from 1.5 $\mu g/m^3$ in 2000 to 0.5 $\mu g/m^3$ in 2015. The Clean Air Act amendment of 2005, accounted for over 60 percent of the relative improvement in this gap. The Clean Air Act amendment also contributed to narrowing the Urban-Rural PM2.5 exposure disparities (Sager and Singer, 2022). These studies use the population distribution at residence for studying the exposure disparities. By using workplace pollution in addition to residence, I provide an alternative measure of the racial gap in pollution at the national level, leading to my third contribution.

Fourth, using individual-level data on remote workers, I find that the average pollution exposure for a remote worker is 0.21 $\mu g/m^3$ lower than if they worked in person. While previous studies have examined the implications of remote work on productivity (Barrero, Bloom, and Davis, 2023), time savings (Aksoy et al., 2023), and changes in spending patterns in cities (Barrero, Bloom, and Davis, 2021), the dimension of pollution exposure remains underexplored, to which I contribute with this analysis.

2 Data

2.1 Air Pollution Data

I use estimated ground-level PM2.5 concentrations data developed and made available by van Donkelaar et al. (2021) to measure exposure to air pollution.[4] These annual concentrations estimated using satellite retrievals, chemical transport modeling and ground-based measurements are made available at a fine geographic scale of $0.01°$ by $0.01°$ for 1998-2022.

The unit of analysis is either an individual at the census block-group level or the

[4] It has been shown that indoor and outdoor fine particulate matter exhibit high correlation suggesting that it can impact all types of workers irrespective of whether they work indoors or outdoors (Neidell and Pestel, 2023). Indoor PM levels are dependent on several factors including outdoor levels, infiltration, types of ventilation and filtration systems used, indoor sources, and personal activities of occupants. In homes without smoking or other strong particle sources, indoor PM would be expected to be the same as, or lower than, outdoor levels. See U.S. Environmental Protection Agency (EPA), *Indoor Particulate Matter*, https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter (accessed September 29, 2024).

aggregated working population at the block-group level. To assign PM2.5 measures to the geographical unit of analysis i.e. a block-group, I calculate the mean of PM2.5 concentrations for every grid point that falls within the polygon of a block-group. For block-groups without any grid point, I assign the value of PM2.5 at the nearest grid point that falls within 1000m of the concerned block-group. Block-groups with no such grid points are excluded from the analysis.

2.2 Aggregate Origin-Destination Data

The U.S. Census' Longitudinal Employer Household Dynamics Origin-Destination Employment Statistics (LODES) product provides data on the working population[5] at the census the block level for 2002-2021[6]. The data is divided into three categories: origin-destination , residence area characteristics and workplace area characteristics. The characteristics files provide information on income, age and industry of the employed population at the block level. From 2009 onwards, they also contain information on race, ethnicity, sex and education.

For multi-establishment firms, a worker is more likely to be assigned to an establishment when it is large and close to that worker's residential address (based on great-circle distance). Such imputation could result in an error in assigning a worker to their physical work location. By aggregating to a higher geographic level than the block level, the possibility of such an error reduces. Therefore, to reduce error in assignment of place of work based on an employer's location and for computational feasibility, I aggregate the block level data to the block-group level.

2.3 Individual Trip Data

Replica's Places database[7] provides trip-level data for an average typical weekday in a 13-week season (Fall or Spring) for each megaregion[8]. Each trip observation provides details on trip origin and destination (at the block-group level), purpose (work, school, shopping etc.), distance, duration and transit mode. It also provides

[5]Workers covered by state unemployment compensation programs are included. Federal jobs (except military and some security-related civilian jobs) are included as well.

[6]Most states have data for all 20 years. The details for data coverage and state availability can be found in the technical document available online.

[7]I gratefully acknowledge the support of Georgetown University's library for providing access to Replica's dataset used in this study.

[8]Places data are delivered by megaregions, each covering between 10 and 50 million residents. Trips from other megaregions are not included in each megaregions data. However, trips from bordering counties may be included and are classified as 'out-of-region' in the origin and destination modules.

demographic (age, sex, personal income, race, ethnicity, employment status, employment industry, primary language, home and work block-group) details for the trip taker. Replica uses Census datasets (ACS/PUMS, Census Transportation Planning Products, LEHD) to create a "synthetic population". It also uses private data sources to minimize sampling bias and improve data quality. These comprise mobile location (location-based services, vehicle in-dash GPS and point-of-interest) data, built environment (transportation network, land use, real estate) data and ground truth (auto/traffic counts, transit ridership counts, taxi counts) data.

I use the Places database to divide the employed population into those working in-person and those working remotely. For the working in-person category, the trips are filtered to include work trips that begin from the trip taker's home block-group and end in the work block-group. I also restrict the data to those trips that are a maximum of 90 minute commute one-way.

2.4 Block Group Distance Data

This database provides the great circle distances among block-groups for distances up to 50 miles. The distances are calculated based on the Haversine formula[9].

3 Methods

3.1 Work-Residence Pollution Exposure Gap

3.1.1 Aggregate Origin-Destination Data

I use block-group level counts for the working population's work and residence locations along with information on demographic characteristics to calculate the population weighted measures of PM2.5 exposure.

$$P\bar{M}2.5_{Xj} = \frac{\sum_{j=1}^{n} X_j \cdot PM2.5_j}{\sum_{i=1}^{n} X_j}$$

To get the PM2.5 exposure for group X at work (residence), I calculate the weighted mean of PM2.5 where weights are the counts of the group X in each block-group (j) at work (residence). The difference between PM2.5 exposure at work and the PM2.5 exposure at residence gives the work-residence exposure gap at the national level. I use the origin-destination files combined with the data on block-group dis-

[9]Last accessed: Block Group Distance Database on April 20, 2024. Please see the referenced document for more details

tances to calculate the work-residence exposure gap for origin-destination block-group pairs in the following categories: 0, (0-2], (2-5], (5-10], (10-20], (20-30] and (30-40] miles.

3.1.2 Individual Trip Data

To determine the work-residence exposure gap across regions, I estimate the following linear regression model:

$$Y_{ij} = \beta_0 + \sum_{d=1}^{7} \beta_1^d 1[distance_i^d] + \epsilon_{ij} \tag{1}$$

Y_{ij} is the difference in exposure at work and residence for individual 'i' residing in block-group 'j'. The coefficient β_1^d gives the work-residence exposure gap for an individual who falls in the distance bin d. The standard errors are clustered at the county-of-residence level.

3.2 Applications to Environmental Inequity and Teleworking

3.2.1 Environmental Inequity

To determine the unconditional mean gap[10] in work-residence pollution gap between the Blacks and Whites, I estimate the following linear regression model (with and without county-of-residence fixed effect):

$$Y_{ij} = \beta 1[Black_{ij}] + \gamma_{k(j)} + \epsilon_{ij} \tag{2}$$

Three outcome variables (1) PM2.5 at residence (2) PM2.5 at work and (3) WREG (PM2.5 at work less PM2.5 at residence) are used to get the racial gap at residence, the racial gap at work and the change in the measure of racial gap after accounting for workplace exposure, respectively. Y_{ij} denotes the outcome Y for individual 'i' residing in block-group 'j'. $\gamma_{k(j)}$ is the county-of-residence fixed effect. Standard errors are clustered by county-of-residence. I run the above regression model

[10]Use of conditional mean gap which includes covariates age, sex and log(income), does not change the racial gap results. The estimating equation in that case is:

$$Y_{ij} = \beta 1[Black_{ij}] + \theta X + \gamma_{k(j)} + \epsilon_{ij}$$

, where X is a vector of controls which includes individual's age, log(income) and sex and the block-group level median housing value.

separately for each commuting distance (commuting time) bandwidth with White workers as the reference category.

For the region-level regressions, I estimate the following linear regression[11]:

$$Y_{ij} = \beta_1 1[Black_{ij}] + \sum_{d=1}^{7} \beta_2^d 1[distance_i^d] + \sum_{d=1}^{7} + \beta_3^d 1[distance_i^d]^* Black_{ij} + \gamma_{k(j)} + \epsilon_{ij} \quad (3)$$

I discretize the distance commuted for work into eight categories: 0, (0-2], (2-5], (5-10], (10-20], (20-30], (30-40] and >40 miles. The coefficient β_2^d gives the work-residence exposure gap for a White individual who falls in the distance bin d. The sum of coefficients $\beta_1 + \beta_2^d + \beta_3^d$ gives the work-residence exposure gap for a Black individual in the distance bin d.

To get the partially corrected[12] measure of pollution exposure, I calculate the time-weighted pollution exposure ($TWPM2.5$) for each individual i. I assume a typical individual spends 8 hours at their work location and 16 hours at their residence on any given work day. Thus, the partially corrected measure of pollution exposure for an individual is calculated as follows:

$$TWPM2.5_i = \frac{1}{3} \cdot \text{PM2.5 at Work Block Group} + \frac{2}{3} \cdot \text{PM2.5 at Home Block Group}$$

To get the partially corrected racial gap in pollution exposure, I use $TWPM2.5_i$ as the outcome variable in Equation 2 and 3 above.

Finally, despite the high correlation between indoor and outdoor particulate matter concentrations, there may be substantial differences in exposure across different industries. For example, an individual working in a manufacturing plant without air-conditioning will experience different pollution levels than someone working in an air-conditioned high-rise, even if the outdoor pollution concentrations are the same. Therefore, I conduct a sub-group analysis by industry to compare individuals working in similar sectors. I focus on the skilled scalable services, construction and manufacturing industries[13].

[11]Again, for the conditional mean differences, the vector of X controls is included. The main racial gap results don't change.

[12]Using workplace exposure corrects the bias introduced by using solely the residence-based exposure. However, the correction is not complete as individuals also spend time engaging in activities other than work such as shopping, recreation etc. at different locations. An entirely correct measure will also include and weigh the pollution levels in these various locations by the time spent in those locations.

[13]I use the classification system followed by Althoff et al. (2022) to assign the workers in the respective industry sub-groups based on the two digit NAICS code. Resources, trade, transport,

3.2.2 Teleworking

I use the Replica database to filter individuals who report working remotely on the modeled day. Using data on these remote workers, I estimate Equation 2 without county-of-residence fixed effects to get the racial gap in pollution exposure for these remote workers at home, work and the difference between the two. The average work-residence exposure gap is also calculated for these workers.

4 Results

4.1 Work-Residence Exposure Gap

Figure 1 illustrates the decline in pollution levels across both residence and work block-groups from 2002-2019. It further illustrates, that the level of PM2.5 at work locations is higher than that at residence resulting in a positive work-residence pollution exposure gap. WREG marginally increases from 0.17 $\mu g/m^3$ in 2002 to 0.25 $\mu g/m^3$ in 2019[14].

Looking at the distribution of population binned according to work-residence disparity in pollution, I find that over half of the working population experience a positive work-residence pollution gap of upto 1 $\mu g/m^3$ (Figure 2). However, about 30 percent of the population also experiences lower levels of pollution at work of similar magnitude i.e. upto 1 $\mu g/m^3$. To further explore the heterogeneity in where workers reside and where they go to work, I look at the flow of workers from one pollution decile to another (Figure 3). I find that people in the lowest polluted home decile primarily work in the lowest polluted work decile but a substantial proportion go to work in higher polluted deciles. Similarly, people residing in areas with the highest level of pollution primarily work in areas with highest level of pollution. Most people either work in a similarly polluted area or a more polluted area. There is no difference in the demographic characteristics, except income, of the population that go to work in areas that are less polluted than their homes and vice versa (Table 1).

Figure 4 illustrates that the work-residence exposure gap in 2019 for different distances to place of work. WREG increases from 0 $\mu g/m^3$ to 0.40 $\mu g/m^3$ as the dis-

education, medical, arts and hospitality industries have been excluded.

[14] A simple counterfactual exercise using estimated reduction in pollution from existing studies in non-attainment counties because of the Clean Air Act amendment (Sager and Singer, 2022) suggests that absence the amendment, the work-residence gap would not change. This follows mechanically, since, the amendment targetted pollution reduction at the county level, reducing pollution at all places within the county, that is, work and residence.

tance between the residence block-group and the work block-group increases. The pollution levels at residence decreases with an increase in distance between the place of residence and work. The pollution levels at work increases with an increase in distance from the place of residence. The lower pollution level at home along with the higher pollution level at work for long distance commuters explains the widening work-residence exposure gap with an increase in commute distance (Table 2).

Using the individual trip data, I find that the positive difference between exposure at work and residence is driven by work trips that end in a metropolitan statistical area (MSA) irrespective of origin. For work trips originating in a MSA and ending in a non-MSA, the exposure at work is lower than that at residence for long commuters (Figure A5). The positive correlation between WREG and distance commuted also holds true across different regions in the U.S. (Figure A7). The largest gap, approximately 1.00 µg/m3, is observed in California-Nevada for work trips longer than 40 miles.

4.2 Applications to Environmental Inequity and Teleworking

4.2.1 Environmental Inequity

U.S.

The results for Equation (2) are reported in Table 3 and shown in Figure 6. In each regression, the omitted category are White workers in the same distance bin. The BW pollution gap is generally higher at home than work. Most of the difference arises from between county differences in pollution levels. The BW work-residence exposure gap is insignificant for distances up to 20 miles. Workplace exposure differences reduces the measured racial gap in pollution exposure at residence by 20% to 42% (0.12 - 0.24 $\mu g/m^3$) for distances exceeding 20 miles. Including county-of-residence fixed effects reduces the BW gap at home, indicating similar levels of pollution within counties. Inclusion of county-of-residence fixed effects reduces the BW gap at work making it close to 0. Therefore, both White and Black workers from within the same county go to work in areas with similar levels of pollution.

Regions

National level results mask the differences across regions which could show different patterns. Given regional heterogeneity, I now examine results from the region-level regressions. The work-residence exposure gap for White individuals increases with the distance commuted across all regions (Figure 5). In other words, there is greater divergence between the PM2.5 exposure at work and at residence, the greater is the distance between the place of residence and work. For the Black individuals, the work-residence exposure gap[15] is lesser than that for the White individuals. CA-NV, Great Lakes, North Atlantic, Northeast and the Northwest regions do not show a significant difference in exposure at work and residence for the Black individuals. Therefore, while the White working population is exposed to higher levels of pollution at work than at residence, that is not necessarily the case for majority of the Black working population.

The summarized results for Equation (3) are reported in Table 4. Accounting for workplace exposure reduces the racial gap in pollution observed at residence. One of the largest reductions in the racial gap is observed for workers commuting more than 40 miles to get to work. About 52-90% of the racial gap in pollution is mitigated for these workers in CA-NV, Southwest, South Central, Great Lakes, North Central and Northeast regions (Figure A4). In absolute terms, the reduction is of the amount 0.21 to 0.51 $\mu g/m^3$ of PM2.5[16]. In the North Atlantic and South Atlantic regions, the racial gap at work is estimated to be negative but close to zero, hence, in these regions, the racial gap is entirely mitigated. Workers in 30-40 miles category also display significant reduction (31-100%) in racial gap in pollution. The largest reduction is observed in CA-NV, with a decline from 1.12 $\mu g/m^3$ racial gap at home to 0.39 $\mu g/m^3$ at work (Figure 7). Workers in the 20-30 mile categories, exhibit a decline of about 31-79% in the racial gap in pollution (Figure A4). For workers commuting lesser than 20 miles to get to work, CA-NV is the only region that displays a significant reduction in PM2.5 exposure gap after accounting for work location.

Most of the differences in pollution exposure between the Whites and Blacks are a result of between county differences. Including county-of-residence fixed effects and comparing workers originating from the same counties, reduces the racial gap at both home and work. Within-county racial gaps in exposure decrease by varying degrees across different commuting distances, often reversing at longer commute distances, where Black workers experience lower pollution levels at work com-

[15] To get the work-residence exposure gap for Black population in miles group 'd', the sum of the intercept and coefficients β_1, β_2^d and β_3^d from 3 without fixed effects is calculated and tested for joint significance

[16] To get the racial gap at home, work or the change in racial gap due to work-residence exposure gap for any mile group 'd', the sum of the coefficients β_1 and β_3^d from Equation 3 is calculated and tested for joint significance. Dividing the gap estimates for WREG by those for home, gives the percentage change in racial gap. For example, see A1, for commuters in > 40 mile category, the racial gap at home is 0.96 $\mu g/m^3$ (0.892 + 0.076) and the racial gap at work is 0.45 $\mu g/m^3$ (0.892 + -0.437). The BW WREG is -0.512 $\mu g/m^3$ (0.0004 + -0.512). Therefore, the reduction in racial gap at home is $\frac{0.512}{0.96}$ times 100 which is approximately 53 percent.

pared to White workers from the same county. This pattern is consistent across multiple regions, indicating that workplace exposure can mitigate or even reverse the racial gap in pollution exposure. For example, in the Great Lakes region, the racial gap at work for long distance commuters is negative (-0.10 to -0.34 $\mu g/m^3$ (Figure 8)). The racial gap at home is 0.07 to 0.09 $\mu g/m^3$ for these same workers. Therefore, workplace exposure would not only reduce the racial gap at home but in fact, reverse it for these long distance commuters.

The partially corrected pollution exposure gap (TWPM2.5) is about 82 percent of the residence-based measure of racial gap in CA-NV. The average residence-based racial gap is about 1.05 $\mu g/m^3$ while the modified racial gap which corrects for work location exposure is about 0.86 $\mu g/m^3$ (Table A2). The gaps are illustrated in left panel of Figure 9. As described previously, the corrected racial gap is lower when looking at within-county racial gaps. The average corrected gap of 0.34 $\mu g/m^3$ is 64 percent of the average residence-based measure of 0.57 $\mu g/m^3$. These are represented in the right panel of Figure 9. The corrected racial gap is on an average 88, 81, and 80 percent of the residence-based racial gap in the Great Lakes, North Central and the Northwest regions for long distance commuters (Table A2).

The racial gap in pollution is higher at residence than work across all three industries. For long commuting distances, the reduction in residence based measure of racial gap in pollution is greater than 50 percent. The racial gap reverses for long commute distances in all three industries. Given a long distance commuter's residence county, the Black workers work in cleaner places than White workers. The results for the three industries, services, construction and manufacturing are reported in Tables A3,A4 and A5.

The results of this analysis are internally consistent and suggest that White workers face a larger work-residence exposure disparity, which increases with the distance between residence and work location. This, in turn, partly mitigates the racial gap in pollution exposure observed at residence. Comparing workers originating from the same counties, drastically reduces the racial gap at home and in select regions makes the racial gap at work negative. The latter provides suggestive evidence that Black workers go to work in cleaner areas when compared with White workers who reside in the same county. In this paper, I take as given the initial distribution of households and work locations across space to study whether there is a change in the racial gap in pollution when I explicitly account for work location exposures. The choice of residence and work locations are simultaneous decisions made by households. The choice becomes more complicated in dual worker households where the choice of residence is likely to be conditional on both spouse's work locations. Given the location of work, do certain households actively sort into cleaner neighborhoods? Furthermore, what is the role of income, real estate prices and public transportation in determining the choice set households are faced with? The population distribution observed in the data is a result of the above choices made by all the households in the economy which I take as given.

4.2.2 Teleworking

For the U.S. (Panel A in Table 6), the results show that the change in the racial gap, if remote workers were to move to working in-person, would be minimal, while the average exposure for everyone would increase by 0.21 $\mu g/m^3$. This analysis assumes that remote workers would not relocate if they switched to in-person work, which simplifies the model but does not fully capture potential changes in residential location choices that could occur as work arrangements change. Nevertheless, the findings suggest that teleworking makes an average individual better off in terms of the pollution they are exposed to. The summary statistics are provided in Table 5 which shows that an increasing percentage of remote workers moved away from their work location in 2021 compared to 2019.

In the CA-NV region (Panel B in Table 6), the reduction in the racial gap for remote workers in 2021, if they had worked in-person, would be 0.30 $\mu g/m^3$, indicating an improvement of about 31.4 percent. Similarly, in the Great Lakes region (Panel C in Table 6), the racial gap would have been 15.65 percent smaller had remote workers been in-person in 2021. In other regions, the racial gaps would not change significantly, but the effect of working in-person would have a negative effect on welfare due to higher pollution exposure at physical work locations.

To enhance the robustness of the analysis, future research could incorporate dynamic location choices by allowing for the possibility that workers might relocate closer to their workplaces if required to return in-person, which could affect both exposure levels and racial disparities. Additionally, examining other factors such as the influence of transportation modes, duration of exposure, and temporal changes in pollution levels during commutes could provide deeper insights into how remote and in-person work arrangements differently affect pollution exposure.

5 Conclusion

This paper presents new insights into the disparities in pollution exposure across the United States, highlighting how differences between residential and workplace environments shape overall exposure levels and affect the racial gap in exposure measures. I use both aggregate-level publicly available census data and a private individual-level database to determine the mean differences in pollution between residence and work. The detailed data also allows me to explore regional heterogeneity across the United States. The individual-level data enables me to study the changes in the racial gap in pollution exposure brought about by workplace-induced mobility. Details on commute distance and commute time at a fine geographic scale coupled with satellite-based measures of pollution enable me to infer the positive correlation between commute distance and pollution exposure disparity.

The results in this paper underscore the critical role that the distance between one's residence and workplace plays in determining individual pollution exposure. To my knowledge, no previous study has examined the work-residence exposure gap across the entire U.S. Additionally, it is the first to estimate the relationship between this exposure gap and the distance commuted to reach the work location. Furthermore, it uniquely provides an estimate of the reduction in the racial pollution gap attributable to workplace exposure. The results highlight that the racial gap in pollution is smaller for people who commute a longer distance to get to work. The results also showcase the regional heterogeneity in this relationship across the U.S., with the racial gap reversing in select areas and distance groups.

The results imply that relying solely on residence-based exposure leads to an underestimation of the pollution exposure an individual worker is exposed to. These findings suggest that place-based measures of pollution reduction that explicitly target pollution reduction to locations with a large workforce may play a relevant role in improving the work-residence pollution exposure gap. The physical work locations play a critical role in reducing the measure of racial inequality. These results also have implications for teleworking. To the extent that physical work locations help in converging the pollution exposure between the two racial groups, a move to teleworking would worsen the disparity. However, since average exposure levels at work is higher than that at residence, teleworking would help reduce the average pollution exposure, albeit at the cost of increased racial inequity.

References

Aguilar-Gomez, Santiago, Hannah Dwyer, Joshua Graff Zivin, and Matthew Neidell. 2022. "This is air: The "nonhealth" effects of air pollution." *Annual Review of Resource Economics* 14:403–425.

Aksoy, Cevat Giray, Jose Maria Barrero, Nicholas Bloom, Steven J. Davis, Mathias Dolls, and Pablo Zarate. 2023. "Time Savings When Working from Home." Working Paper 30866, National Bureau of Economic Research, Cambridge, MA. URL http://www.nber.org/papers/w30866.

Althoff, Lukas, Fabian Eckert, Sharat Ganapati, and Conor Walsh. 2022. "The Geography of Remote Work." *Regional Science and Urban Economics* 93:103770. URL https://www.sciencedirect.com/science/article/pii/S0166046222000011.

Banzhaf, Spencer, Lala Ma, and Christopher Timmins. 2019. "Environmental Justice: The Economics of Race, Place, and Pollution." *Journal of Economic Perspectives* 33 (1):185–208.

Barrero, Jose Maria, Nicholas Bloom, and Steven J. Davis. 2021. "Why Working from Home Will Stick." Working Paper 28731, National Bureau of Economic Research, Cambridge, MA. URL http://www.nber.org/papers/w28731.

———. 2023. "The Evolution of Working from Home." URL https://siepr.stanford.edu/publications/2023/evolution-working-home.

Borgschulte, Mark, David Molitor, and Eric Zou. 2022. "Air Pollution and the Labor Market: Evidence from Wildfire Smoke." (29952). URL http://www.nber.org/papers/w29952.

Brazil, Noli. 2022. "Environmental inequality in the neighborhood networks of urban mobility in US cities." *Proceedings of the National Academy of Sciences* 119 (17). URL https://www.pnas.org/doi/abs/10.1073/pnas.2117776119. Edited by Susan Hanson, Clark University, Worcester, MA; received September 27, 2021; accepted March 9, 2022.

Burkhardt, Jesse, Jude Bayham, Ander Wilson, Ellison Carter, Jesse D. Berman, Katelyn O'Dell, Bonne Ford, Emily V. Fischer, and Jeffrey R. Pierce. 2019. "The effect of pollution on crime: Evidence from data on particulate matter and ozone." *Journal of Environmental Economics and Management* 98:102267.

Cabral, Marika and Marcus Dillender. 2024. "Air Pollution, Wildfire Smoke, and

Worker Health." (32232). URL https://www.nber.org/papers/w32232. Revision Date: August 2024.

Chang, Tom, Joshua Graff Zivin, Tal Gross, and Matthew Neidell. 2016. "Particulate Pollution and the Productivity of Pear Packers." *American Economic Journal: Economic Policy* 8 (3):141–169.

Chen, Shuai, Paulina Oliva, and Peng Zhang. 2024. "Air Pollution and Mental Health: Evidence from China." *AEA Papers and Proceedings* 114:423–428.

Colmer, Jonathan, Ian Hardman, Jay Shimshack, and John Voorheis. 2020. "Disparities in PM2.5 air pollution in the United States." *Science* 369 (6503):575–578.

Currie, Janet, John Voorheis, and Reed Walker. 2023. "What Caused Racial Disparities in Particulate Exposure to Fall? New Evidence from the Clean Air Act and Satellite-Based Measures of Air Quality." *American Economic Review* 113 (1):71–97. URL https://www.aeaweb.org/articles?id=10.1257/aer.20191957.

Green, James. 2021. "lehdr: An R package to work with the LEHD Origin-Destination Employment Statistics (LODES) data." URL https://github.com/jamgreen/lehdr.

He, Jiaxiu, Haoming Liu, and Alberto Salvo. 2019. "Severe Air Pollution and Labor Productivity: Evidence from Industrial Towns in China." *American Economic Journal: Applied Economics* 11 (1):173–201.

Hill, Alexandra E., Jesse Burkhardt, Jude Bayham, Katelyn O'Dell, Bonne Ford, Emily V. Fischer, and Jeffrey R. Pierce. 2023. "Air pollution, weather, and agricultural worker productivity." *American Journal of Agricultural Economics* URL https://doi.org/10.1111/ajae.12439. Open Access.

Jbaily, Abdulrahman, Xiaodan Zhou, Jie Liu, Ting-Hwan Lee, Leila Kamareddine, Stéphane Verguet, and Francesca Dominici. 2022. "Air pollution exposure disparities across US population and income groups." *Nature* 601:228–233.

Kim, Jinha and Mei-Po Kwan. 2020. "How Neighborhood Effect Averaging Might Affect Assessment of Individual Exposures to Air Pollution: A Study of Ozone Exposures in Los Angeles." *Annals of the American Association of Geographers* 111 (1):121–140.

Laurent, Jose Guillermo Cedeño, Piers MacNaughton, Emily Jones, Anna S Young, Maya Bliss, Skye Flanigan, Jose Vallarino, Ling Jyh Chen, Xiaodong Cao, and Joseph G Allen. 2021. "Associations between acute exposures to PM2.5 and carbon dioxide indoors and cognitive function in office workers: a multicountry longitudinal prospective observational study." *Environmental Research Letters* 16 (9):094047. URL https://dx.doi.org/10.1088/1748-9326/ac1bd8.

National Bureau of Economic Research. 2010. "Block Group Distance Database." URL https://www.nber.org/research/data/block-group-distance-database. Accessed: 2024-06-28.

Neidell, Matthew and Nico Pestel. 2023. "Air pollution and worker productivity." *IZA World of Labor* :363.

Replica. 2024. "Replica Places Dataset." https://studio.replicahq.com/.

Sager, Lutz and Gregor Singer. 2022. "Clean Identification? The Effects of the Clean Air Act on Air Pollution, Exposure Disparities and House Prices." Tech. Rep. 376, London School of Economics, Grantham Research Institute on Climate Change and the Environment. Forthcoming, American Economic Journal: Economic Policy.

U.S. Bureau of Labor Statistics. 2024. "The Employment Situation - August 2024." URL https://www.bls.gov/news.release/pdf/empsit.pdf. Accessed: 2024-09-29.

U.S. Census Bureau. 2002–2019. "LEHD Origin-Destination Employment Statistics (LODES)." URL https://lehd.ces.census.gov/data/.

U.S. Environmental Protection Agency (EPA). n.d. "Indoor Particulate Matter." https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter. [Accessed: 2024-09-29].

van Donkelaar, Aaron, Melanie S. Hammer, Liam Bindle, Michael Brauer, Jeffery R. Brook, Michael J. Garay, N. Christina Hsu, Olga V. Kalashnikova, Ralph A. Kahn, Colin Lee, Robert C. Levy, Alexei Lyapustin, Andrew M. Sayer, and Randall V. Martin. 2021. "Monthly Global Estimates of Fine Particulate Matter and Their Uncertainty." *Environmental Science Technology* .

Yoo, Eun-Hye, Abigail Cooke, and Youngseob Eum. 2023. "Examining the geographical distribution of air pollution disparities across different racial and ethnic groups: Incorporating workplace addresses." *Health & Place* 84:103112. URL https://www.sciencedirect.com/science/article/pii/S1353829223001491.

6 Tables

Table 1: Summary Statistics of Working Population by PM2.5 Exposure at Work and Residence

PM2.5 at Work < PM2.5 at Residence	Yes	No
Within-Group Proportions	0.32	0.68
Proportion in each segment		
White	0.84	0.86
Female	0.49	0.48
College	0.69	0.68
Service Sector	0.13	0.15
Other attributes		
Income (USD)	61037.27	64361.65
Age	43.81	44.56

Notes: The table summarizes the working population based on whether the PM2.5 exposure at their workplace is lower than that at their residence. The first row shows the within-group proportions: 32% of workers experience lower PM2.5 at work compared to home (Yes), while 68% experience higher PM2.5 at work (No). Demographic characteristics are broken down across these two groups, including race, gender, education, and sector of employment. The ”Other attributes” section compares income and age across these groups.

Table 2: Summary Statistics - Contiguous United States

Total	Commute Distance (Miles)	Commute Time (Minutes)	PM2.5 Home	PM2.5 Work
9043637	(0-2]	8.40	7.16	7.18
12306800	(2-5]	15.69	7.23	7.31
14853810	(5-10]	23.25	7.27	7.44
17440720	(10-20]	32.99	7.22	7.49
7732778	(20-30]	44.83	7.10	7.50
3307667	(30-40]	55.50	6.98	7.48
2335357	>40	68.69	6.86	7.45

Notes: The table summarizes in-person worker statistics for the year 2019, using the individual trip database. Columns indicate the count of individuals in each distance bin, their average commute time in minutes, and average PM2.5 exposure at their home and work locations. This summary provides an overview of travel patterns and pollution exposure for workers across the contiguous United States.

Table 3: U.S. 2019

	Dependent variable:					
	PM2.5 Home	PM2.5 Work	WREG	PM2.5 Home	PM2.5 Work	WREG
0-2 Miles						
Black	0.566***	0.566***	0.001	0.062***	0.060***	−0.001
	(0.047)	(0.046)	(0.002)	(0.022)	(0.021)	(0.002)
Constant	7.079***	7.096***	0.017***			
	(0.077)	(0.076)	(0.001)			
Mean	7.16	7.18	0.02	7.16	7.18	0.02
Observations	9,029,095	9,030,724	9,020,729	9,029,095	9,030,724	9,020,729
2-5 Miles						
Black	0.508***	0.519***	0.011	0.066***	0.060***	−0.007
	(0.045)	(0.045)	(0.007)	(0.019)	(0.014)	(0.007)
Constant	7.148***	7.231***	0.083***			
	(0.068)	(0.069)	(0.005)			
Mean	7.23	7.31	0.08	7.23	7.31	0.08
Observations	12,295,225	12,291,449	12,280,148	12,295,225	12,291,449	12,280,148
5-10 Miles						
Black	0.543***	0.549***	0.006	0.083***	0.051***	−0.033**
	(0.057)	(0.055)	(0.014)	(0.024)	(0.014)	(0.013)
Constant	7.178***	7.346***	0.168***			
	(0.070)	(0.072)	(0.008)			
Mean	7.27	7.44	0.17	7.27	7.44	0.17
Observations	14,841,445	14,835,243	14,823,145	14,841,445	14,835,243	14,823,145
10-20 Miles						
Black	0.579***	0.544***	−0.035	0.111***	0.031***	−0.081***
	(0.063)	(0.063)	(0.023)	(0.025)	(0.007)	(0.021)
Constant	7.131***	7.406***	0.275***			
	(0.067)	(0.072)	(0.011)			
Mean	7.22	7.49	0.27	7.22	7.49	0.27
Observations	17,428,030	17,424,018	17,411,414	17,428,030	17,424,018	17,411,414
20-30 Miles						
Black	0.594***	0.472***	−0.122***	0.132***	−0.011	−0.143***
	(0.067)	(0.069)	(0.031)	(0.025)	(0.007)	(0.027)
Constant	7.026***	7.438***	0.412***			
	(0.066)	(0.071)	(0.017)			
Mean	7.1	7.5	0.4	7.1	7.5	0.4
Observations	7,727,870	7,726,992	7,722,113	7,727,870	7,726,992	7,722,113
30-40 Miles						
Black	0.606***	0.413***	−0.193***	0.137***	−0.024**	−0.161***
	(0.067)	(0.064)	(0.033)	(0.025)	(0.010)	(0.030)
Constant	6.910***	7.428***	0.517***			
	(0.062)	(0.068)	(0.021)			
Mean	6.98	7.48	0.49	6.98	7.48	0.49
Observations	3,305,888	3,305,600	3,303,821	3,305,888	3,305,600	3,303,821
>40 Miles						
Black	0.574***	0.331***	−0.242***	0.125***	−0.021**	−0.146***
	(0.058)	(0.052)	(0.030)	(0.021)	(0.009)	(0.024)
Constant	6.796***	7.412***	0.616***			
	(0.054)	(0.069)	(0.030)			
Mean	6.86	7.45	0.59	6.86	7.45	0.59
Observations	2,334,323	2,333,764	2,332,730	2,334,323	2,333,764	2,332,730
County-of-Residence FE	No	No	No	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01. Each observation corresponds to one in-person worker with a maximum commute time of 90 minutes one-way. The reference category are White workers in the respective mile category. Columns (1)-(3) are without county-of-residence fixed effects. Columns (4)-(6) include county-of-residence fixed effects. Standard errors are clustered at the level of county-of-residence.

Table 4: Percentage of Residence Black-White PM2.5 Mitigated by Work Location

	CA-NV	Great Lakes	Mid-Atlantic	North Atlantic	North Central	Northeast	Northwest	South Atlantic	South Central	Southwest
A. Commute Distance (miles)										
0-2	-2.04***	-0.11	2.61	7.95**	0.4	2.18	1.36	-4.91	-2.29	-0.4
2-5	-9.84***	4.1	14.33	21.51	1.49	22.81	5.87	-2.06	-3.09	-1.83
5-10	-22.1*	3.03	-1.86	19.8	0.05	24.4	12.74	-2.76	-6.75	0.84
10-20	-40.88**	-10.07	-33.41	-5.23	-8.35	-12.77	-5.71	8.67	-19.84**	3.42
20-30	-54.96**	-30.53***	-89.38**	-78.75***	-29.43**	-26.93	-49.03	-5.64	-55.47***	-13.94
30-40	-64.69***	-39.51***	-198.58***	-104.91***	-50.62***	-58.29***	-60.15	-23.92	-78.84***	-30.59**
>40	-52.93***	-59.49***	-317.48	-127.16***	-89.14***	-64.57***	-78.47	-134.24***	-79.87***	-51.76***
B. Commute Distance (miles) with fixed effect										
0-2	-8.95	68.1	-55.36	-45.67	-21.13	38.54	-45.66***	-44.16	1.87	-78.83
2-5	-23.99***	183.3***	-435.76	36.27	2.32	-587.78	-31.43	-26.44	-13.35	-58.23
5-10	-42.21*	127.08*	438.08	67.64	-8.34	915.26	-13.11	-28.3	-31.42**	-24.49
10-20	-67.03**	-37.72	-150.31	-45.52	-56.24	-105.86	-39.01*	4.26	-78.9***	3.39
20-30	-95.75***	-208.72***	-287.2	-171.29***	-176.42**	-122.38**	-89.46	-159.04	-199.78***	-91.22
30-40	-123.66***	-286.71***	-462.63***	-214.76***	-264.18***	-284.56***	-132.5	-323.55*	-249.53***	-172.15***
>40	-138.68***	-523.69***	-176.89	-288.3***	-437.19***	-363.63***	-222.12	-517.63***	-230.55***	-322.26***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. This table contains results from estimation of Equation 3. It shows the percentage difference in Black-White PM2.5 exposure mitigated by work location, disaggregated by commute distance and region. Negative values indicate a reduction in the Black-White disparity, while positive values suggest a worsening of the disparity. In Panel B, county-of-residence fixed effects are included.

Table 5: Summary Statistics for Remote Workers

Remote Workers: 2019			
Race	Remote (%)	Same Block-Group	Different Block-Group
Black	2.89	68.75	31.25
White	5.76	79.74	20.26
Total	5.34	78.87	21.13
Remote Workers: 2021			
Race	Remote (%)	Same Block-Group	Different Block-Group
Black	23.18	13.16	86.84
White	26.11	22.78	77.22
Total	25.69	21.52	78.48

Notes: The table summarizes remote worker statistics for the years 2019 and 2021, using the individual trip database. Columns indicate the percentage of individuals who worked remotely (Remote %) and whether they lived in the same or a different block-group compared to their work location.

Table 6: Racial Gap for Remote Workers

	Dependent variable:					
	2019			2021		
	PM2.5 Home	PM2.5 Work	WREG	PM2.5 Home	PM2.5 Work	WREG
U.S.						
Black	0.734***	0.740***	0.006***	0.376***	0.341***	−0.042**
	(0.070)	(0.070)	(0.002)	(0.092)	(0.082)	(0.018)
Constant	7.068***	7.079***	0.011***	8.113***	8.330***	0.214***
	(0.089)	(0.089)	(0.001)	(0.103)	(0.107)	(0.009)
Mean	7.13	7.14	0.01	8.16	8.37	0.21
Observations	4,733,877	4,733,462	4,728,247	22,422,032	22,335,955	22,169,641
CA-NV						
Black	1.091***	1.079***	−0.011**	0.961**	0.659	−0.302***
	(0.274)	(0.273)	(0.005)	(0.481)	(0.407)	(0.092)
Constant	7.850***	7.863***	0.012***	10.008***	10.359***	0.348***
	(0.423)	(0.423)	(0.003)	(0.457)	(0.470)	(0.045)
Mean	7.92	7.93	0.01	10.11	10.43	0.32
Observations	540,914	541,231	539,836	2,167,029	2,165,464	2,156,184
Great Lakes						
Black	0.687***	0.692***	0.005	0.690***	0.579***	−0.108***
	(0.081)	(0.080)	(0.004)	(0.104)	(0.091)	(0.021)
Constant	7.930***	7.939***	0.008***	8.923***	9.094***	0.168***
	(0.133)	(0.133)	(0.001)	(0.107)	(0.095)	(0.015)
Mean	7.98	7.99	0.01	8.99	9.15	0.16
Observations	713,073	712,782	712,418	4,054,731	4,030,299	4,014,040
County-of-Residence FE	No	No	No	No	No	No

Note: *p<0.1; **p<0.05; ***p<0.01. Each observation is a working individual who did remote work in the respective years under consideration. Columns (1)-(3) are estimates for the year 2019. Columns (4)-(6) are estimates for the year 2021. Standard errors are clustered at the level of county-of-residence.

7 Figures

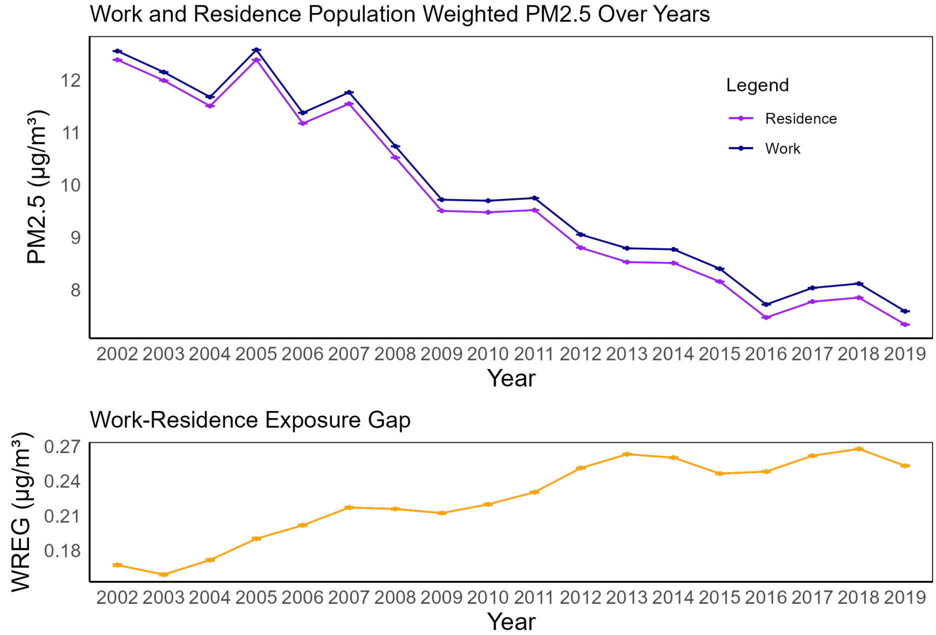


Figure 1: Work-Residence Exposure Gap from 2002 to 2019

Note: The top panel shows the work and residence population-weighted PM2.5 levels in the U.S. from 2002 to 2019, using census aggregate employment data. The bottom panel illustrates the trend over time of the difference between pollution exposure at work and residence.

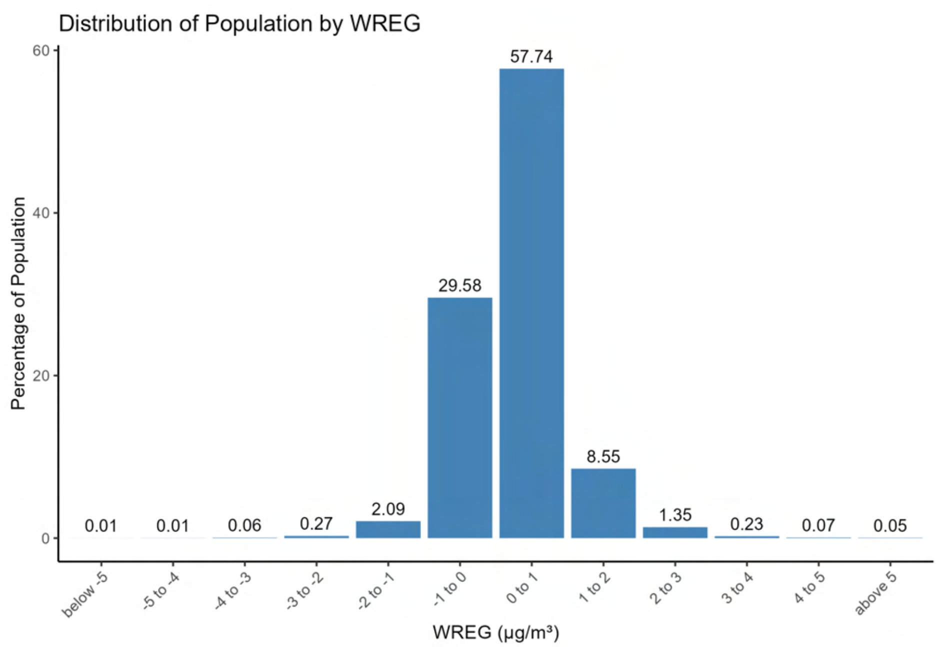


Figure 2: PM2.5 Distribution at Home and Work

Note: This figure shows the distribution of the working population binned by the difference between work and home exposure. It is based on individual-level data.

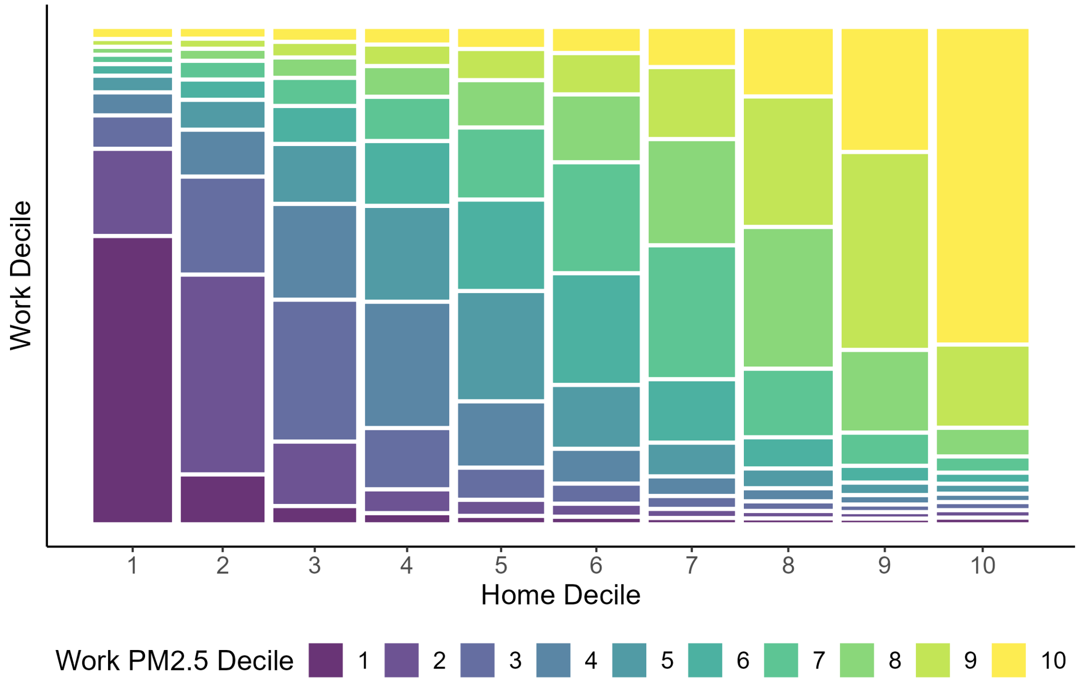


Figure 3: Movement of People Between Home and Work Pollution Deciles

Note: This figure depicts the proportion of workers residing in a particular pollution decile and commuting to work in various pollution deciles. The block groups were classified into ten pollution deciles, which were used to determine the pollution decile for both the residence and work locations of each worker.

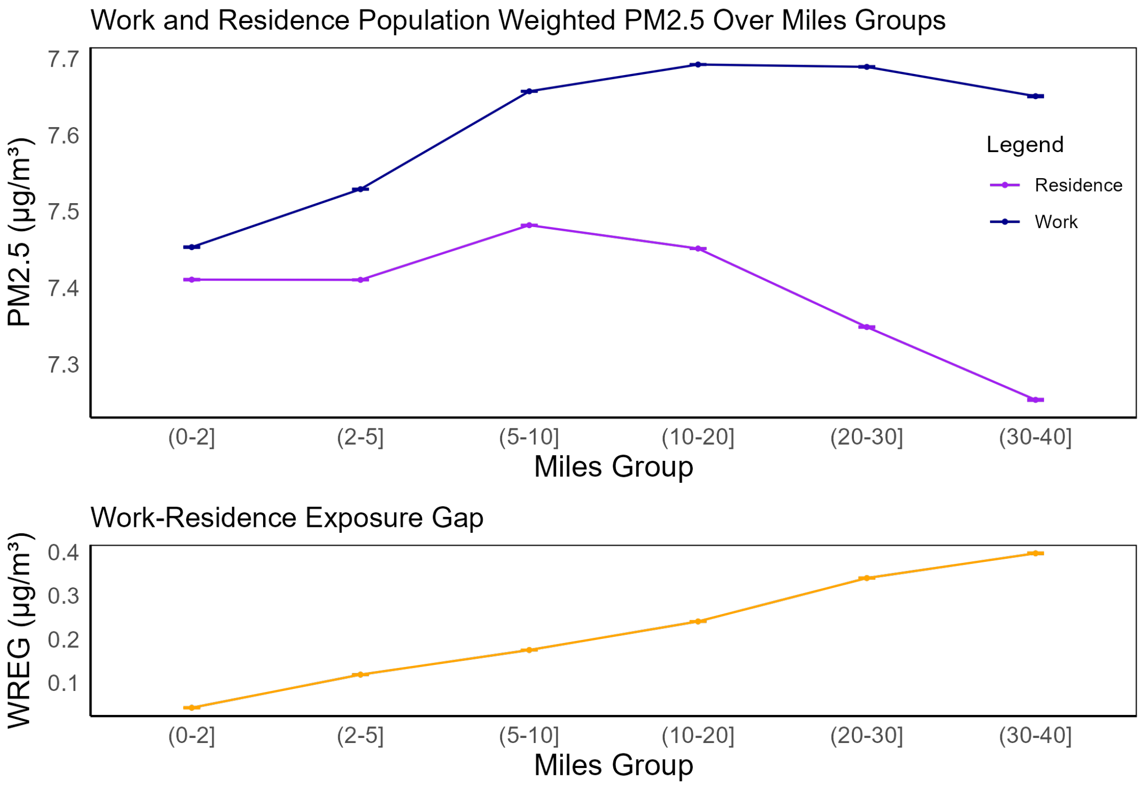


Figure 4: Work-Residence Exposure Gap By Distance

Note: The top panel illustrates the PM2.5 levels for workers across various commute distance bins. The blue line represents the PM2.5 levels at residence, while the purple line indicates the levels at work. The bottom panel displays the difference between work and residence PM2.5 levels, highlighting the relationship between the work-residence pollution exposure gap and commute distance. Census data were utilized to generate this plot.

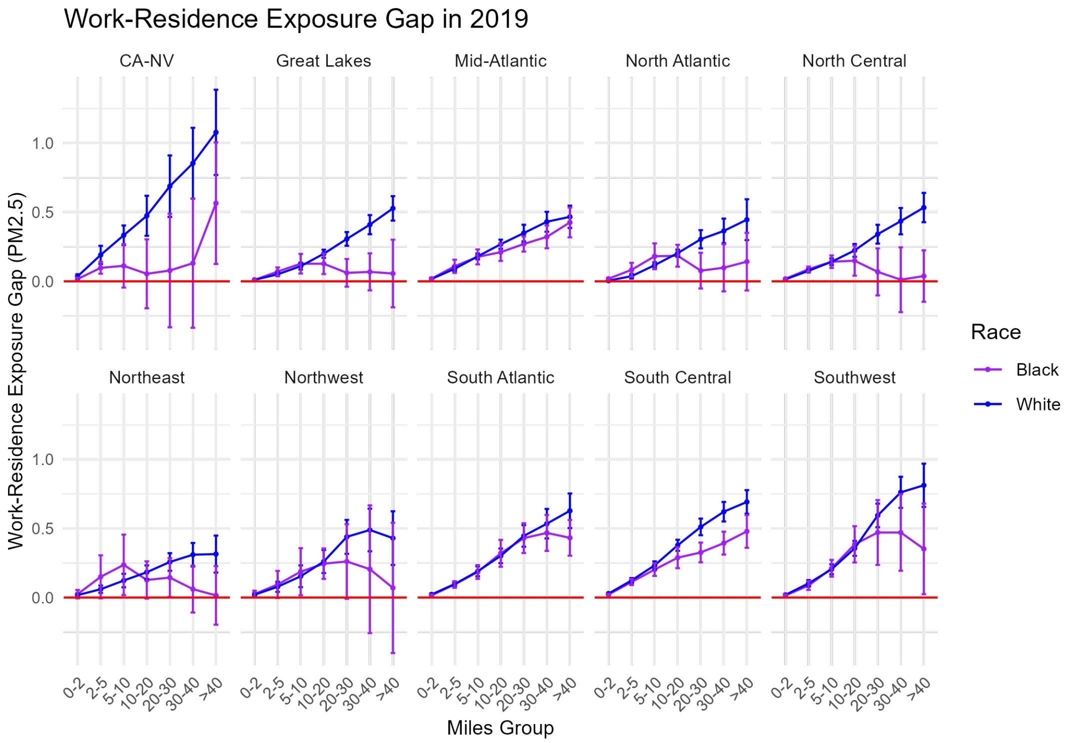
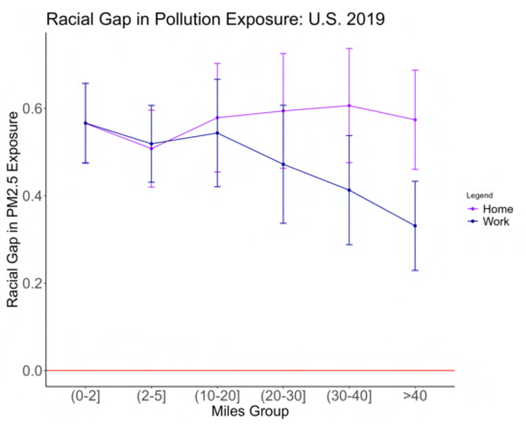
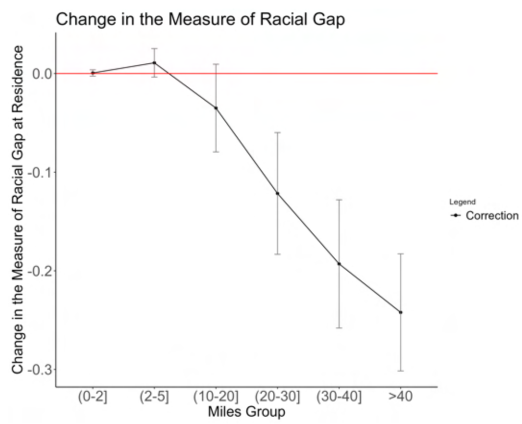


Figure 5: WREG: Distance

Note: This figure presents the estimates from Equation 3 for each of the ten regions on the outcome of PM2.5 at work minus PM2.5 at home. It illustrates that the positive correlation between the work-residence exposure gap and commute distance is consistent for White workers across all regions. However, this correlation is not universally applicable to Black workers.



(a)

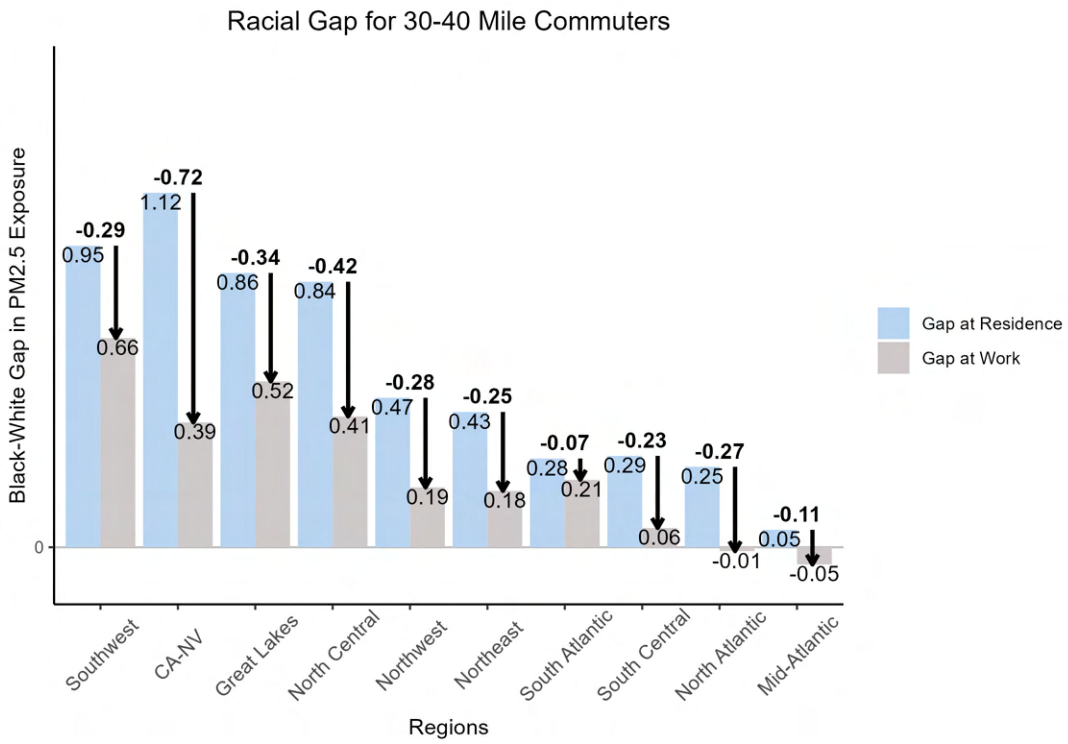


(b)

Figure 6: Racial Gap in U.S.

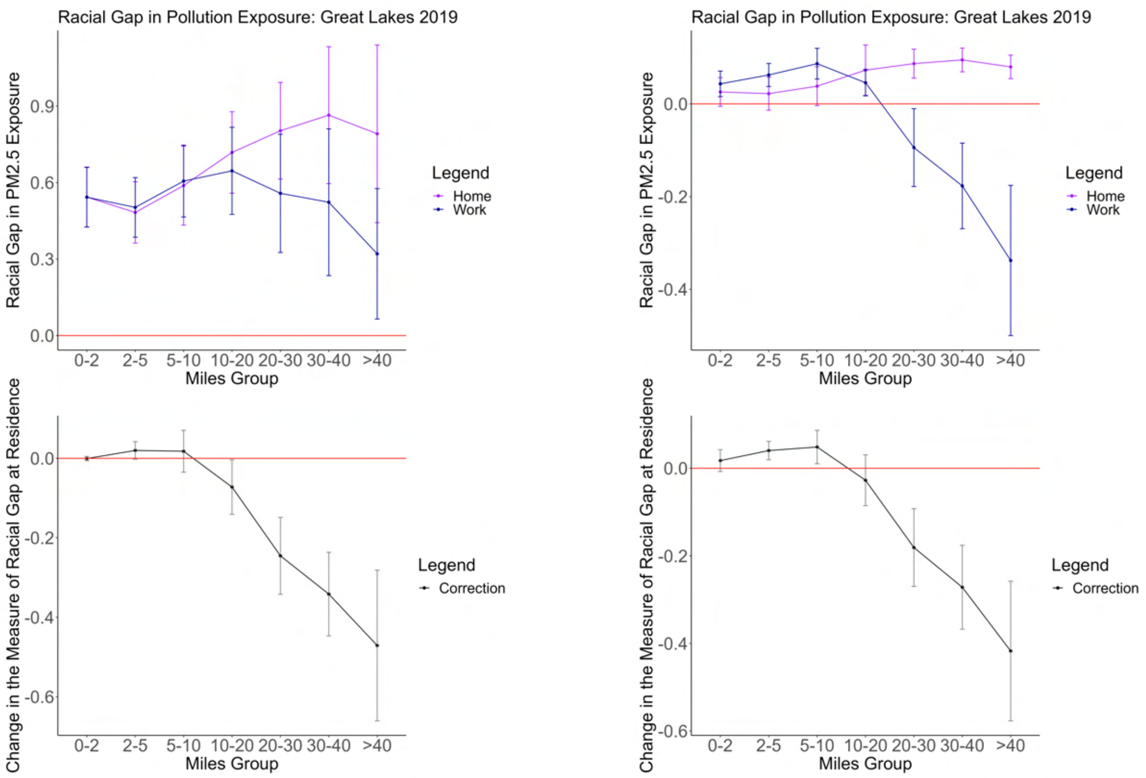
Note: This figure presents the estimates from Equation 2 for the following outcomes: (1) PM2.5 levels at home (2) PM2.5 levels at work, and (3) the difference between PM2.5 levels at work and home. Panel (a) displays the racial gap in PM2.5 exposure at home (purple line) and at work (blue line). Panel (b) illustrates the change in the racial gap when workplace pollution is taken into account.

Figure 7: Racial Gap for (30-40] Mile Commuters



Note:

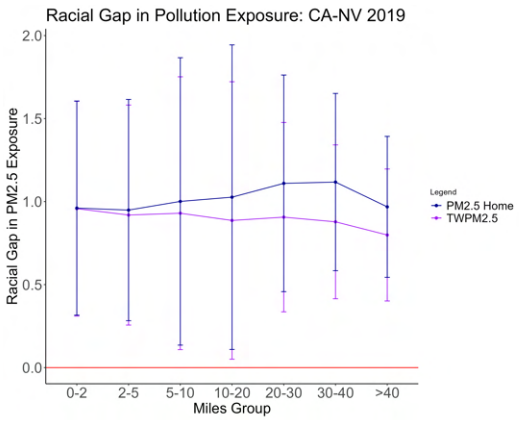
This figure presents the estimates from Equation 3 for the following outcomes: (1) PM2.5 levels at residence and (2) PM2.5 levels at work for workers commuting between 30 and 40 miles. The blue bars represent the racial gap at residence, while the gray bars illustrate the racial gap at work.



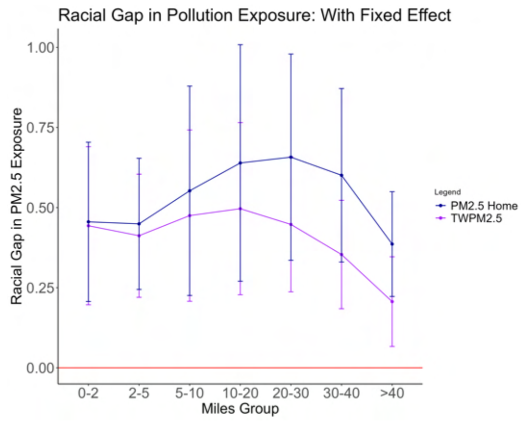
(a) Without FE (b) With FE

Figure 8: Racial Gap in Great Lakes Region

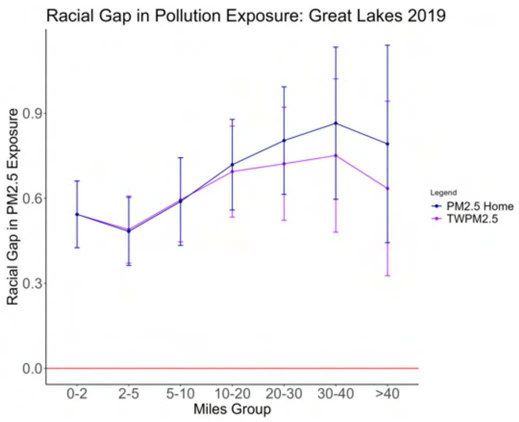
Note: This figure presents the estimates from Equation 3 for the following outcomes in the Great Lakes region: (1) PM2.5 levels at home, (2) PM2.5 levels at work, and (3) the difference between PM2.5 levels at work and home. Panel (a) presents the estimates without county-of-residence fixed effects, while Panel (b) incorporates these fixed effects.



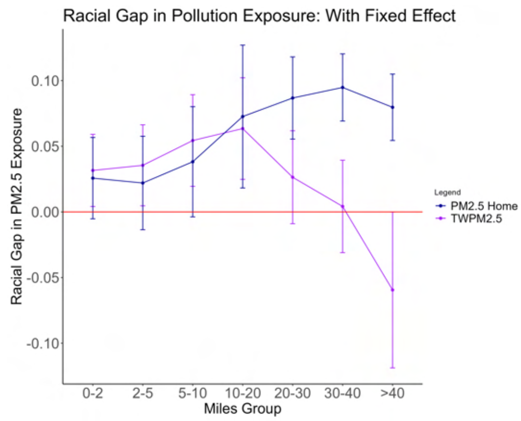
(a) Without FE (CA-NV)



(b) With FE (CA-NV)



(c) Without FE (Great Lakes)



(d) With FE (Great Lakes)

Figure 9: Racial Gap in CA-NV and Great Lakes Regions

Note: This figure presents the estimates from Equation 3 for (1) PM2.5 exposure at home and (2) TWPM2.5 in California-Nevada and the Great Lakes region. The left panel displays results without county-of-residence fixed effects, while the right panel incorporates these effects. The blue line represents the racial gap in PM2.5 exposure at home, and the purple line illustrates the partially corrected measure of the racial gap after accounting for pollution exposure at work.

A Appendix

A.1 Additional Tables

Table A1: CA-NV 2019

	Dependent variable:					
	PM2.5 Home	PM2.5 Work	WREG	PM2.5 Home	PM2.5 Work	WREG
	(1)	(2)	(3)	(4)	(5)	(6)
Black	0.892**	0.892**	−0.0004	0.549***	0.544***	−0.004
	(0.377)	(0.377)	(0.001)	(0.173)	(0.171)	(0.028)
Miles (0-2]	−0.148**	−0.114	0.035***	0.027	0.092	0.065***
	(0.069)	(0.073)	(0.008)	(0.053)	(0.064)	(0.015)
Miles (2-5]	−0.160	0.030	0.191***	−0.019	0.204**	0.224***
	(0.117)	(0.125)	(0.034)	(0.067)	(0.080)	(0.036)
Miles (5-10]	−0.098	0.236	0.333***	−0.004	0.358***	0.362***
	(0.161)	(0.168)	(0.036)	(0.077)	(0.093)	(0.035)
Miles (10-20]	−0.221	0.256	0.474***	−0.056	0.441***	0.497***
	(0.167)	(0.190)	(0.073)	(0.061)	(0.119)	(0.069)
Miles (20-30]	−0.271**	0.421**	0.688***	−0.230***	0.468***	0.698***
	(0.134)	(0.165)	(0.113)	(0.083)	(0.143)	(0.110)
Miles (30-40]	−0.346*	0.510**	0.854***	−0.351***	0.513***	0.865***
	(0.209)	(0.236)	(0.131)	(0.105)	(0.170)	(0.128)
Miles > 40	−0.476	0.604*	1.077***	−0.492***	0.592***	1.083***
	(0.316)	(0.343)	(0.157)	(0.125)	(0.155)	(0.143)
Black:Miles (0-2]	0.069	0.051	−0.019***	−0.093	−0.130*	−0.037***
	(0.100)	(0.100)	(0.004)	(0.067)	(0.068)	(0.011)
Black:Miles (2-5]	0.057	−0.037	−0.093***	−0.100	−0.204*	−0.104***
	(0.122)	(0.132)	(0.028)	(0.091)	(0.105)	(0.031)
Black:Miles (5-10]	0.109	−0.112	−0.221**	0.004	−0.225*	−0.229**
	(0.146)	(0.157)	(0.092)	(0.059)	(0.121)	(0.095)
Black:Miles (10-20]	0.134	−0.289	−0.419***	0.090	−0.333**	−0.424***
	(0.162)	(0.179)	(0.156)	(0.073)	(0.162)	(0.157)
Black:Miles (20-30]	0.218	−0.397	−0.610***	0.109	−0.518**	−0.625***
	(0.137)	(0.255)	(0.203)	(0.087)	(0.199)	(0.192)
Black:Miles (30-40]	0.225	−0.498	−0.723***	0.052	−0.686***	−0.739***
	(0.220)	(0.322)	(0.216)	(0.091)	(0.221)	(0.204)
Black:Miles > 40	0.076	−0.437	−0.512***	−0.163	−0.697***	−0.531***
	(0.347)	(0.387)	(0.153)	(0.188)	(0.256)	(0.144)
Constant	8.151***	8.151***	0.0005			
	(0.449)	(0.450)	(0.001)			
Mean	8.07	8.43	0.36	8.07	8.43	0.36
County-of-Residence FE	No	No	No	Yes	Yes	Yes
Cluster SE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,019,114	5,017,868	4,995,624	5,019,114	5,017,868	4,995,624
R^2	0.030	0.021	0.044	0.638	0.633	0.074
Adjusted R^2	0.030	0.021	0.044	0.638	0.633	0.074

Note: *p<0.1; **p<0.05; ***p<0.01

Each observation corresponds to one in-person worker. The reference category are White workers who commute 0 miles to get to work. Columns (1)-(3) are without county-of-residence fixed effects. Columns (4)-(6) include county-of-residence fixed effects. Standard errors are clustered at the county-of-residence.

Table A2: Time-Weighted PM2.5 in 2019

	Dependent variable: TWPM2.5							
	CA-NV		Great Lakes		North Central		Northwest	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Black	0.892**	0.547***	0.786***	0.067***	0.843***	0.131***	0.408***	0.150*
	(0.377)	(0.172)	(0.062)	(0.025)	(0.256)	(0.035)	(0.122)	(0.079)
Miles (0-2]	−0.139**	0.048	0.119	0.036	0.089**	0.035***	−0.043	−0.007
	(0.070)	(0.057)	(0.103)	(0.025)	(0.036)	(0.007)	(0.066)	(0.058)
Miles (2-5]	−0.098	0.056	0.172	0.028	0.337***	0.040***	0.100	−0.016
	(0.119)	(0.070)	(0.121)	(0.025)	(0.059)	(0.010)	(0.103)	(0.069)
Miles (5-10]	0.012	0.117	0.203	0.008	0.489***	0.020	0.184	−0.065
	(0.164)	(0.081)	(0.131)	(0.024)	(0.074)	(0.013)	(0.123)	(0.073)
Miles (10-20]	−0.064	0.109	0.178	−0.022	0.493***	−0.016	0.107	−0.140
	(0.172)	(0.078)	(0.147)	(0.028)	(0.081)	(0.016)	(0.136)	(0.085)
Miles (20-30]	−0.042	0.002	0.101	−0.021	0.320***	−0.032	−0.146	−0.220**
	(0.135)	(0.094)	(0.150)	(0.031)	(0.079)	(0.021)	(0.137)	(0.101)
Miles (30-40]	−0.061	−0.063	0.001	0.007	0.158*	−0.009	−0.286*	−0.210*
	(0.210)	(0.116)	(0.164)	(0.034)	(0.081)	(0.022)	(0.155)	(0.117)
Miles > 40	−0.117	−0.131	−0.128	0.062*	−0.015	0.050**	−0.404***	−0.141
	(0.317)	(0.117)	(0.186)	(0.037)	(0.081)	(0.022)	(0.144)	(0.096)
Black:Miles (0-2]	0.066	−0.104	−0.243***	−0.035*	0.023	−0.028	−0.055	−0.050
	(0.100)	(0.067)	(0.053)	(0.019)	(0.126)	(0.022)	(0.135)	(0.092)
Black:Miles (2-5]	0.027	−0.135	−0.297***	−0.032*	−0.072	−0.023	−0.121	−0.054
	(0.124)	(0.094)	(0.051)	(0.019)	(0.129)	(0.021)	(0.125)	(0.095)
Black:Miles (5-10]	0.038	−0.072	−0.192***	−0.013	−0.038	−0.006	−0.137	−0.015
	(0.145)	(0.072)	(0.056)	(0.020)	(0.155)	(0.027)	(0.115)	(0.097)
Black:Miles (10-20]	−0.006	−0.051	−0.092	−0.004	0.024	0.005	−0.141	0.008
	(0.152)	(0.082)	(0.066)	(0.021)	(0.190)	(0.034)	(0.123)	(0.096)
Black:Miles (20-30]	0.014	−0.100	−0.065	−0.041	−0.009	−0.064***	−0.103	0.038
	(0.158)	(0.099)	(0.100)	(0.032)	(0.198)	(0.023)	(0.155)	(0.093)
Black:Miles (30-40]	−0.014	−0.194*	−0.035	−0.063**	−0.147	−0.112***	−0.030	−0.008
	(0.237)	(0.111)	(0.142)	(0.031)	(0.199)	(0.030)	(0.138)	(0.099)
Black:Miles > 40	−0.093	−0.341*	−0.152	−0.126***	−0.452*	−0.183***	−0.069	−0.101
	(0.353)	(0.202)	(0.161)	(0.033)	(0.242)	(0.046)	(0.150)	(0.079)
Constant	8.151***		7.801***		6.375***		5.763***	
	(0.449)		(0.211)		(0.097)		(0.162)	
Mean	8.19	8.19	8.01	8.01	6.77	6.77	5.82	5.82
County-of-Residence FE	No	Yes	No	Yes	No	Yes	No	Yes
Cluster SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,995,624		12,440,373		5,838,176		3,316,396	
R^2	0.025	0.696	0.044	0.908	0.063	0.939	0.024	0.825
Adjusted R^2	0.025	0.696	0.044	0.908	0.063	0.939	0.024	0.825

Note: *p<0.1; **p<0.05; ***p<0.01

This table presents estimates from Equation 3 for time-weighted PM2.5 exposure. The reference category is White workers commuting 0 miles. Columns (1), (3), (5), and (7) do not include county-of-residence fixed effects, while Columns (2), (4), (6), and (8) do. Standard errors are clustered by county of residence.

Table A3: U.S. 2019: Skilled Scalable Service

	Dependent variable:					
	PM2.5 Home	PM2.5 Work	WREG	PM2.5 Home	PM2.5 Work	WREG
	(1)	(2)	(3)	(4)	(5)	(6)
Black	0.287**	0.286**	−0.002***	−0.029	−0.053	−0.025*
	(0.145)	(0.145)	(0.001)	(0.059)	(0.055)	(0.015)
Miles (0-2]	−0.119*	−0.099	0.019***	0.037**	0.055*	0.017
	(0.066)	(0.068)	(0.006)	(0.019)	(0.031)	(0.018)
Miles (2-5]	−0.127	−0.019	0.108***	−0.033	0.066*	0.099***
	(0.086)	(0.092)	(0.015)	(0.020)	(0.036)	(0.029)
Miles (5-10]	−0.172	0.039	0.210***	−0.102***	0.085**	0.187***
	(0.105)	(0.109)	(0.013)	(0.022)	(0.040)	(0.028)
Miles (10-20]	−0.271**	0.059	0.328***	−0.189***	0.099**	0.287***
	(0.119)	(0.119)	(0.018)	(0.023)	(0.044)	(0.032)
Miles (20-30]	−0.404***	0.107	0.508***	−0.275***	0.172***	0.446***
	(0.121)	(0.124)	(0.028)	(0.027)	(0.049)	(0.042)
Miles (30-40]	−0.540***	0.080	0.618***	−0.295***	0.245***	0.541***
	(0.133)	(0.137)	(0.033)	(0.030)	(0.053)	(0.046)
Miles > 40	−0.686***	0.028	0.712***	−0.246***	0.398***	0.644***
	(0.151)	(0.155)	(0.039)	(0.030)	(0.057)	(0.050)
Black:Miles (0-2]	0.086	0.085	−0.0001	0.061	0.061*	0.001
	(0.093)	(0.094)	(0.005)	(0.037)	(0.037)	(0.010)
Black:Miles (2-5]	0.059	0.063	0.005	0.066	0.078*	0.013
	(0.111)	(0.116)	(0.012)	(0.045)	(0.047)	(0.016)
Black:Miles (5-10]	0.094	0.093	0.0004	0.076*	0.092*	0.017
	(0.113)	(0.124)	(0.018)	(0.039)	(0.050)	(0.022)
Black:Miles (10-20]	0.145	0.110	−0.034	0.102**	0.081	−0.021
	(0.128)	(0.142)	(0.027)	(0.042)	(0.054)	(0.026)
Black:Miles (20-30]	0.193	0.074	−0.116***	0.124***	0.011	−0.112***
	(0.135)	(0.154)	(0.044)	(0.047)	(0.058)	(0.040)
Black:Miles (30-40]	0.246*	0.069	−0.175***	0.111**	−0.064	−0.174***
	(0.148)	(0.162)	(0.051)	(0.049)	(0.060)	(0.047)
Black:Miles > 40	0.249*	−0.011	−0.258***	0.108*	−0.151**	−0.258***
	(0.149)	(0.148)	(0.049)	(0.060)	(0.069)	(0.045)
Constant	7.773***	7.773***	0.001**			
	(0.180)	(0.180)	(0.001)			
Mean	7.57	7.83	0.26	7.57	7.83	0.26
County-of-Residence FE	No	No	No	Yes	Yes	Yes
Cluster SE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,180,169	12,172,225	12,150,197	12,180,169	12,172,225	12,150,197
R^2	0.017	0.008	0.059	0.714	0.700	0.136
Adjusted R^2	0.017	0.008	0.059	0.714	0.700	0.135

Note: *p<0.1; **p<0.05; ***p<0.01

Each observation corresponds to one in-person worker. The reference category are White workers who commute 0 miles to get to work. Columns (1)-(3) are without county-of-residence fixed effects. Columns (4)-(6) include county-of-residence fixed effects. Standard errors are clustered at the county-of-residence.

Table A4: U.S. 2019: Construction

	Dependent variable:					
	PM2.5 Home	PM2.5 Work	WREG	PM2.5 Home	PM2.5 Work	WREG
	(1)	(2)	(3)	(4)	(5)	(6)
Black	0.411***	0.411***	−0.001	0.117***	0.114***	−0.003
	(0.066)	(0.066)	(0.001)	(0.039)	(0.038)	(0.017)
Miles (0-2]	0.083***	0.095***	0.012***	0.062***	0.079***	0.017***
	(0.029)	(0.029)	(0.001)	(0.012)	(0.014)	(0.004)
Miles (2-5]	0.031	0.100**	0.069***	0.004	0.075***	0.072***
	(0.043)	(0.042)	(0.004)	(0.012)	(0.016)	(0.008)
Miles (5-10]	0.057	0.198***	0.141***	−0.035***	0.103***	0.139***
	(0.046)	(0.045)	(0.007)	(0.013)	(0.019)	(0.010)
Miles (10-20]	0.040	0.274***	0.235***	−0.080***	0.141***	0.221***
	(0.045)	(0.045)	(0.011)	(0.013)	(0.021)	(0.013)
Miles (20-30]	−0.040	0.322***	0.362***	−0.127***	0.202***	0.329***
	(0.046)	(0.048)	(0.017)	(0.013)	(0.024)	(0.018)
Miles (30-40]	−0.120**	0.364***	0.484***	−0.147***	0.290***	0.437***
	(0.050)	(0.053)	(0.020)	(0.015)	(0.025)	(0.020)
Miles > 40	−0.161***	0.444***	0.605***	−0.107***	0.445***	0.552***
	(0.055)	(0.064)	(0.029)	(0.019)	(0.030)	(0.029)
Black:Miles (0-2]	0.028	0.030	0.002	−0.038	−0.042	−0.004
	(0.052)	(0.052)	(0.003)	(0.034)	(0.032)	(0.013)
Black:Miles (2-5]	−0.005	0.023	0.027***	−0.025	−0.004	0.021
	(0.055)	(0.054)	(0.008)	(0.036)	(0.032)	(0.016)
Black:Miles (5-10]	0.012	0.032	0.020	−0.009	0.005	0.014
	(0.062)	(0.061)	(0.015)	(0.035)	(0.033)	(0.021)
Black:Miles (10-20]	0.018	−0.011	−0.030	−0.002	−0.041	−0.040
	(0.063)	(0.063)	(0.021)	(0.035)	(0.035)	(0.026)
Black:Miles (20-30]	−0.024	−0.163**	−0.138***	−0.003	−0.152***	−0.148***
	(0.069)	(0.070)	(0.031)	(0.037)	(0.040)	(0.032)
Black:Miles (30-40]	−0.007	−0.263***	−0.257***	0.019	−0.234***	−0.254***
	(0.077)	(0.071)	(0.035)	(0.037)	(0.045)	(0.037)
Black:Miles > 40	−0.022	−0.343***	−0.320***	−0.010	−0.342***	−0.332***
	(0.080)	(0.066)	(0.046)	(0.038)	(0.056)	(0.048)
Constant	7.418***	7.417***	−0.0005			
	(0.077)	(0.077)	(0.0004)			
Mean	7.47	7.67	0.2	7.47	7.67	0.2
County-of-Residence FE	No	No	No	Yes	Yes	Yes
Cluster SE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,614,571	7,612,471	7,608,830	7,614,571	7,612,471	7,608,830
R^2	0.008	0.008	0.049	0.680	0.655	0.110
Adjusted R^2	0.008	0.008	0.049	0.679	0.655	0.110

Note: *p<0.1; **p<0.05; ***p<0.01

Each observation corresponds to one in-person worker. The reference category are White workers who commute 0 miles to get to work. Columns (1)-(3) are without county-of-residence fixed effects. Columns (4)-(6) include county-of-residence fixed effects. Standard errors are clustered at the county-of-residence.

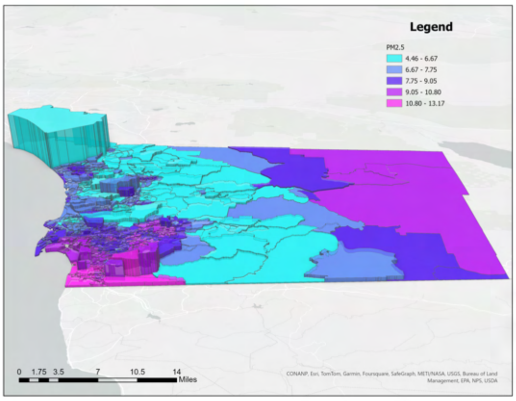
Table A5: U.S. 2019: Manufacturing

	Dependent variable:					
	PM2.5 Home	PM2.5 Work	WREG	PM2.5 Home	PM2.5 Work	WREG
	(1)	(2)	(3)	(4)	(5)	(6)
Black	0.357***	0.358***	0.001	0.041	0.031	−0.010
	(0.083)	(0.083)	(0.001)	(0.045)	(0.046)	(0.018)
Miles (0-2]	−0.011	0.009	0.020***	0.076***	0.123***	0.048***
	(0.047)	(0.047)	(0.002)	(0.016)	(0.025)	(0.013)
Miles (2-5]	0.014	0.119**	0.104***	0.027	0.150***	0.123***
	(0.056)	(0.054)	(0.007)	(0.017)	(0.030)	(0.018)
Miles (5-10]	0.011	0.204***	0.192***	−0.040**	0.161***	0.201***
	(0.059)	(0.057)	(0.012)	(0.018)	(0.032)	(0.022)
Miles (10-20]	−0.046	0.236***	0.282***	−0.107***	0.173***	0.280***
	(0.061)	(0.058)	(0.015)	(0.017)	(0.034)	(0.025)
Miles (20-30]	−0.142**	0.254***	0.395***	−0.153***	0.219***	0.372***
	(0.064)	(0.063)	(0.019)	(0.017)	(0.038)	(0.030)
Miles (30-40]	−0.224***	0.275***	0.498***	−0.157***	0.301***	0.458***
	(0.067)	(0.070)	(0.024)	(0.017)	(0.040)	(0.033)
Miles > 40	−0.264***	0.349***	0.612***	−0.119***	0.442***	0.561***
	(0.074)	(0.079)	(0.034)	(0.020)	(0.041)	(0.039)
Black:Miles (0-2]	−0.016	−0.017	−0.001	0.041	0.025	−0.016
	(0.071)	(0.071)	(0.003)	(0.039)	(0.040)	(0.013)
Black:Miles (2-5]	−0.067	−0.062	0.005	0.045	0.046	0.001
	(0.076)	(0.078)	(0.007)	(0.041)	(0.043)	(0.015)
Black:Miles (5-10]	−0.011	−0.021	−0.009	0.059	0.045	−0.014
	(0.073)	(0.077)	(0.013)	(0.039)	(0.045)	(0.017)
Black:Miles (10-20]	−0.008	−0.059	−0.051***	0.067*	0.008	−0.059***
	(0.077)	(0.080)	(0.018)	(0.040)	(0.046)	(0.020)
Black:Miles (20-30]	−0.044	−0.187**	−0.143***	0.080*	−0.076	−0.155***
	(0.079)	(0.082)	(0.025)	(0.042)	(0.050)	(0.028)
Black:Miles (30-40]	−0.093	−0.272***	−0.179***	0.083*	−0.111**	−0.194***
	(0.081)	(0.084)	(0.028)	(0.043)	(0.054)	(0.031)
Black:Miles > 40	−0.126	−0.361***	−0.234***	0.058	−0.178***	−0.235***
	(0.084)	(0.085)	(0.034)	(0.043)	(0.055)	(0.035)
Constant	7.603***	7.603***	0.0004			
	(0.096)	(0.096)	(0.001)			
Mean	7.59	7.84	0.25	7.59	7.84	0.25
County-of-Residence FE	No	No	No	Yes	Yes	Yes
Cluster SE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,099,137	12,101,653	12,095,974	12,099,137	12,101,653	12,095,974
R^2	0.011	0.007	0.045	0.695	0.677	0.159
Adjusted R^2	0.011	0.007	0.045	0.695	0.677	0.159

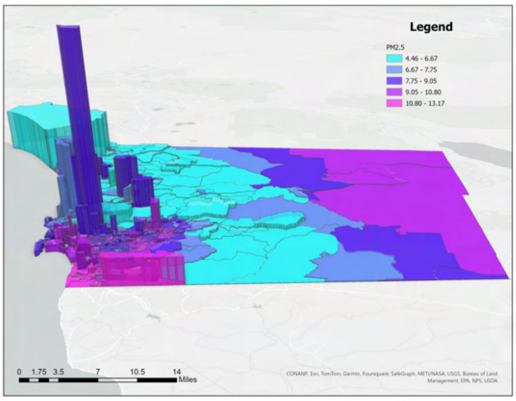
Note: *p<0.1; **p<0.05; ***p<0.01

Each observation corresponds to one in-person worker. The reference category are White workers who commute 0 miles to get to work. Columns (1)-(3) are without county-of-residence fixed effects. Columns (4)-(6) include county-of-residence fixed effects. Standard errors are clustered at the county-of-residence.

A.2 Additional Figures



(a) Residents in San Diego County



(b) Workers in San Diego County

Figure A1: Distribution of Residents and Workers in San Diego County.

Note: These maps depict the distribution of PM2.5 concentrations across San Diego County, California, at the block-group level. In subfigure (a), the height of each block group represents the number of residents, while in subfigure (b), it corresponds to the number of workers. The visualization highlights how the distribution of residents and workers can vary within the same county in relation to air pollution exposure.

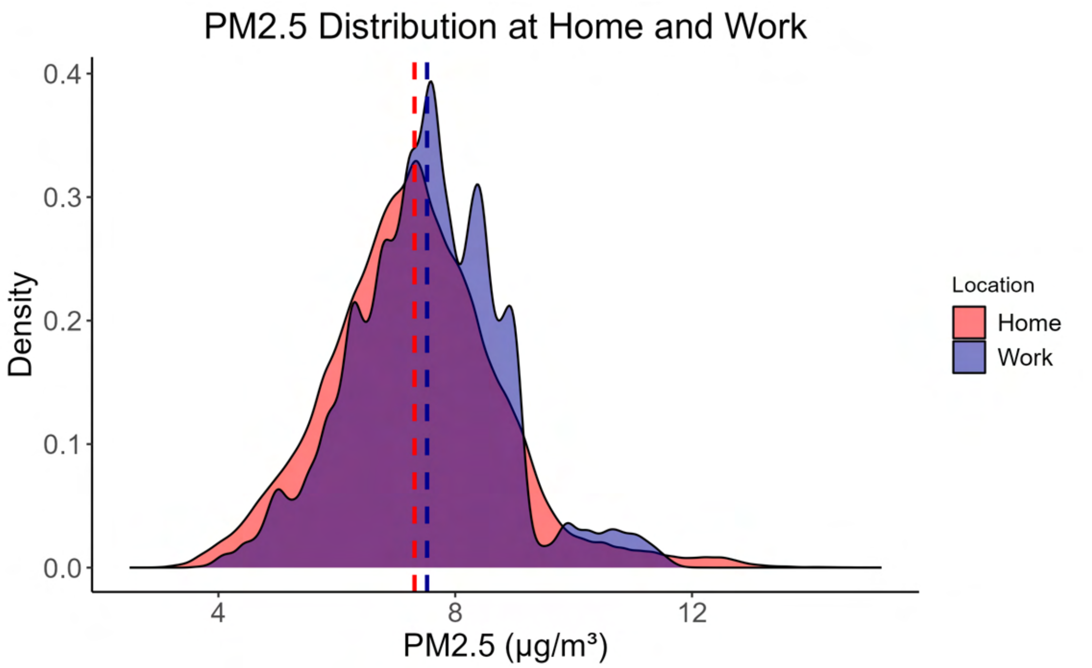
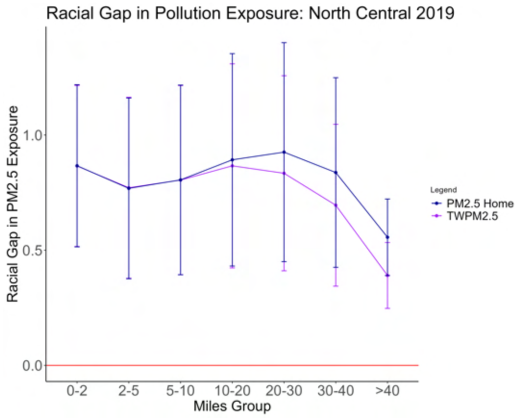
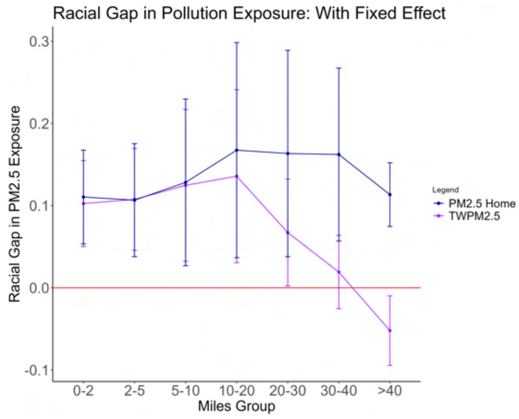


Figure A2: PM2.5 Distribution at Home and Work

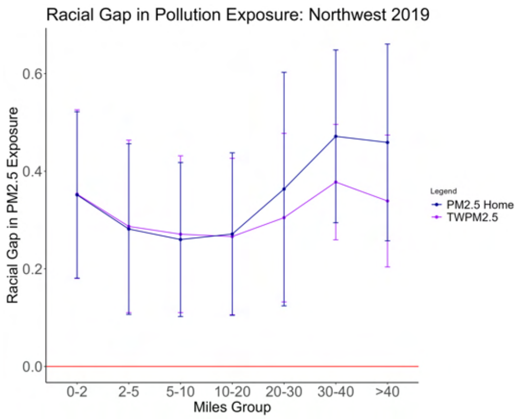
Note: This figure shows the distribution of PM2.5 at home and work locations grouped by home block group. PM2.5 is more concentrated at work than home which shows a wider spread. This means that there is greater heterogeneity in PM2.5 across home locations than work locations.



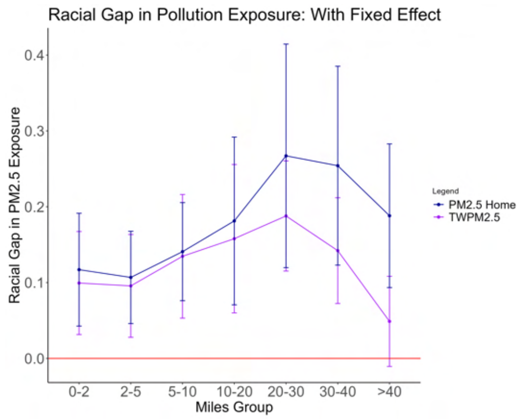
(a) Without FE (North Central)



(b) With FE (North Central)



(c) Without FE (Northwest)



(d) With FE (Northwest)

Figure A3: Racial Gap in North Central and Northwest Regions

Note: This figure presents the estimates from Equation 3 for (1) PM2.5 exposure at home and (2) TWPM2.5 in the North Central and Northwest regions. The left panel displays results without county-of-residence fixed effects, while the right panel incorporates these effects. The blue line represents the racial gap in PM2.5 exposure at home, and the purple line illustrates the partially corrected measure of the racial gap after accounting for pollution exposure at work.

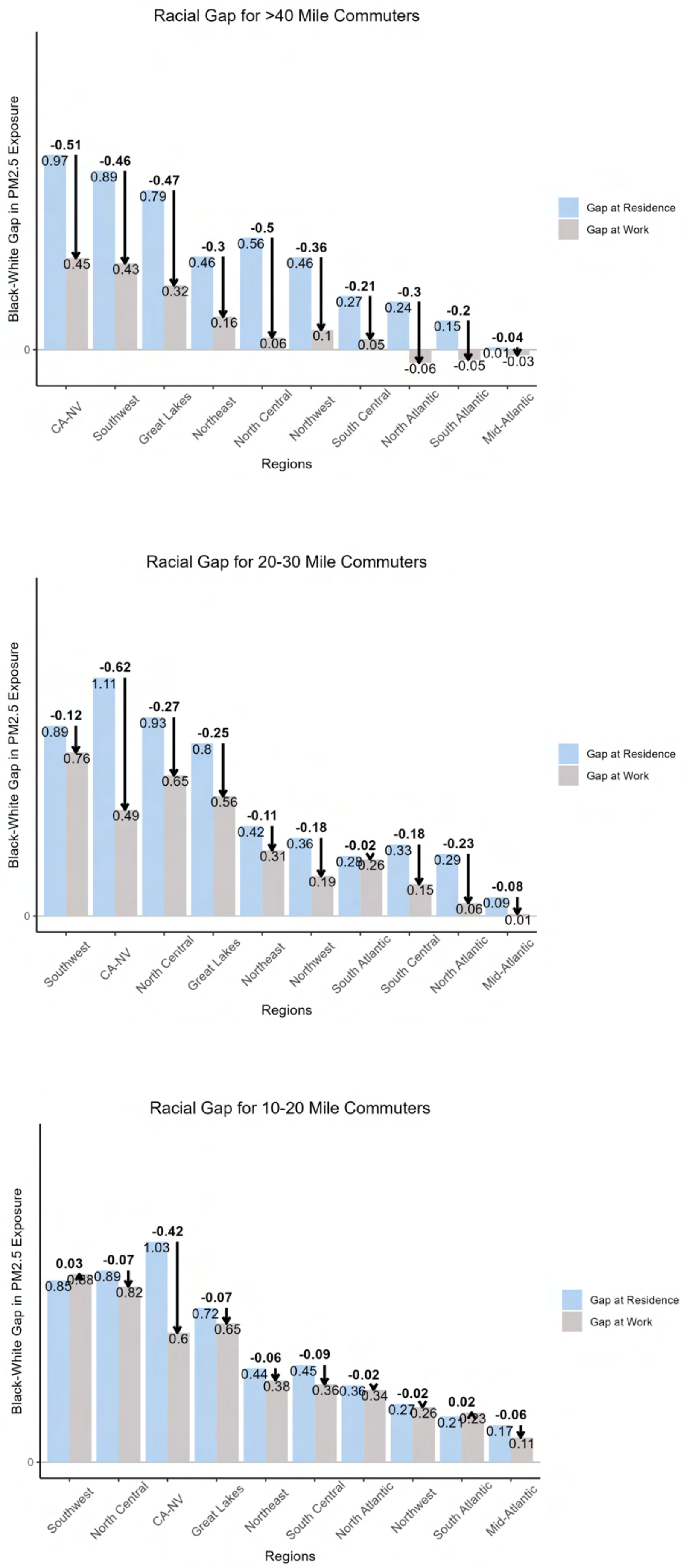


Figure A4: Racial Gap for Commuters Across Different Distance Ranges

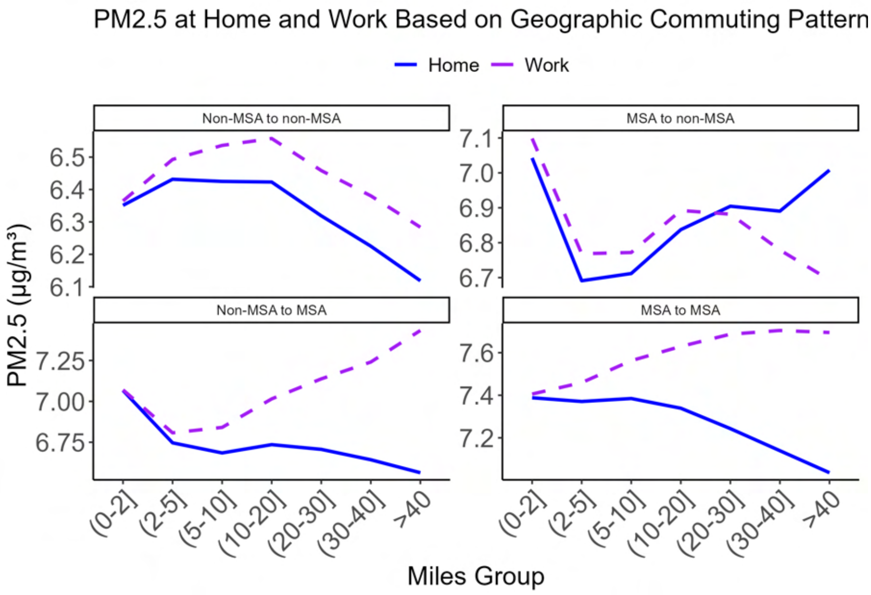


Figure A5: Exposure at Work and Residence By Geographic Commute Pattern

Note: This figure shows the difference in pollution exposure at work and home based on individual trip data and the geographic commute pattern. The positive difference in exposure is driven by work trips ending in a metropolitan statistical area (MSA), irrespective of origin.

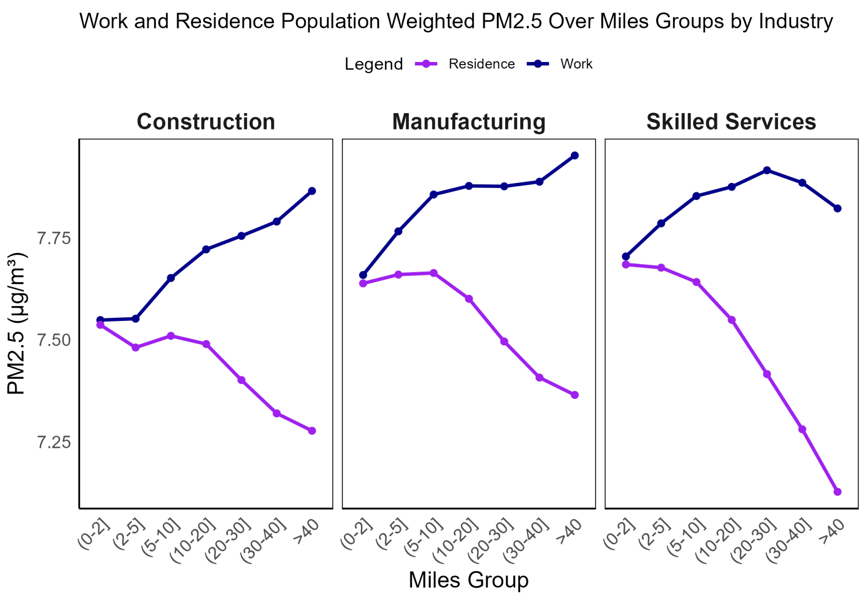


Figure A6: Exposure at Work and Residence by Industry

Note: This figure illustrates the levels of PM2.5 exposure at home and work across the construction, manufacturing, and services industries. The exposure to pollution at work is similar across manufacturing and service industries, while the exposure at home is lower for workers who commute long distances in the service industry.

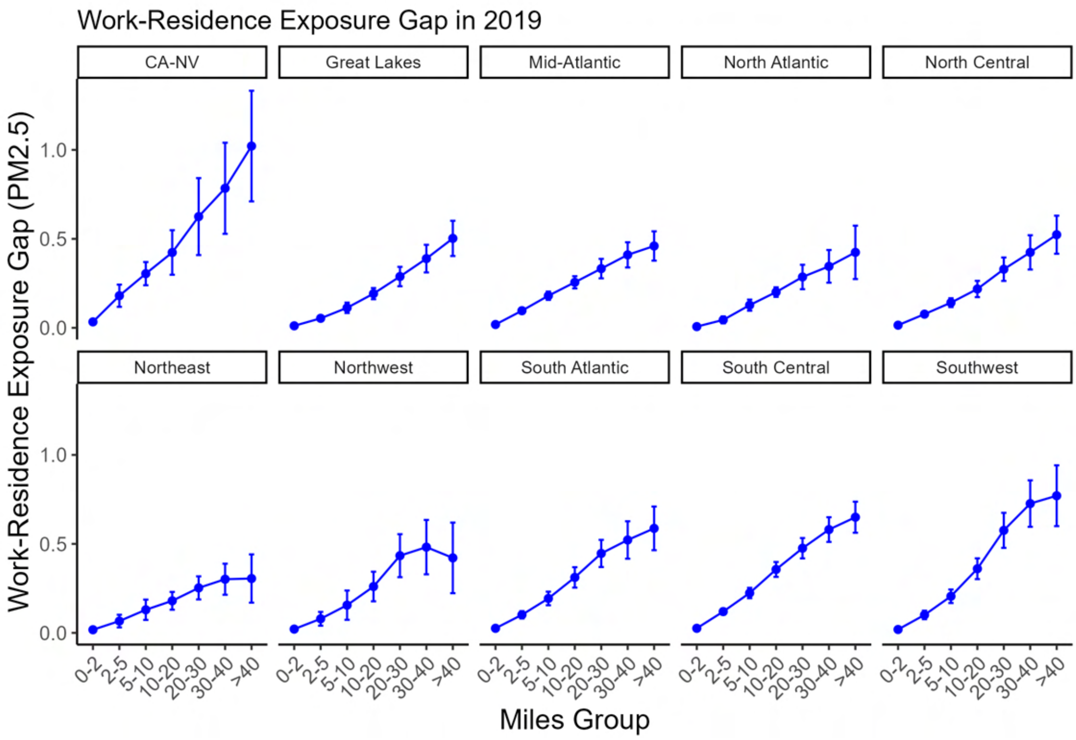


Figure A7: Work-Residence Exposure Gap Across Regions by Distance

Note: This figure plots the estimates from Equation 4 for each of the 10 regions. It demonstrates that the positive correlation between the Work-Residence Exposure Gap (WREG) and distance commuted holds true across different regions in the U.S. The largest gap, approximately 1.00 $\mu g/m^3$, is observed in the California-Nevada region for work trips longer than 40 miles.

A.3 Environmental Inequity: Time to Work

Commute time:

$$Y_{ij} = \beta_1 1[Black_{ij}] + \sum_{d=1}^{6} \beta_2^m 1[minutes_i^m] + \sum_{m=1}^{6} + \beta_3^m 1[minutes_i^m]^* Black_{ij} + \gamma_{k(j)} + \epsilon_{ij} \tag{4}$$

I discretize the commute time into seven categories: 0, (0-15], (15-30], (30-45], (45-60], (60-75] and (75-90] minutes.

A.3.1 U.S.

The results for Equation (2) with subsets based on commute time are reported in Table A6. In each regression, the omitted category are White workers in the same commute time bin. The BW pollution gap is higher at home than work with most of it being driven by urban areas. The BW gap is marginally higher at work than residence for workers residing in rural areas. Most of the difference arises from between county differences in pollution levels. Including county-of-residence fixed effects reduces the BW gap at home, indicating similar levels of pollution within counties. Inclusion of county-of-residence fixed effects makes the BW gap at work less than 0.062 $\mu g/m^3$. Average BW gap at work, without county-of-residence fixed effects, is approximately, 0.5 $\mu g/m^3$. Workplace exposure differences eliminates approximately, 16.5-24.7 percent (0.10 - 0.18 $\mu g/m^3$) of the racial gap at residence for workers who commute more than 45 minutes to reach place of work.

A.3.2 Regions

I now examine commute time region-level regressions to account for regional heterogeneity. The summarized results for Equation (4) with and county-of-residence fixed effects are reported in Table A7.

The work-residence exposure gap for White individuals increases with the time commuted across all regions (A8). For the Black individuals, the work-residence exposure gap is lesser than that for the White individuals.

Accounting for work location exposure reduces the home-based measure of racial gap in pollution by 16-55 percent for workers with a commute time that exceeds 30 minutes in CA-NV, Great Lakes, North Central and South Central regions. Inclusion of county-of-residence fixed effect, results in the racial gap at work of 0 or lesser for most of the workers implying a greater than 100 percent mitigation of the home-based measure of racial gap in pollution. Workers with a commute time between 75-90 minutes in the Great Lakes, North Central and Southwest regions have a racial gap at work between -0.10 to -0.15 $\mu g/m^3$. This means that the Black workers from the same county go to work at cleaner places than their White counterparts.

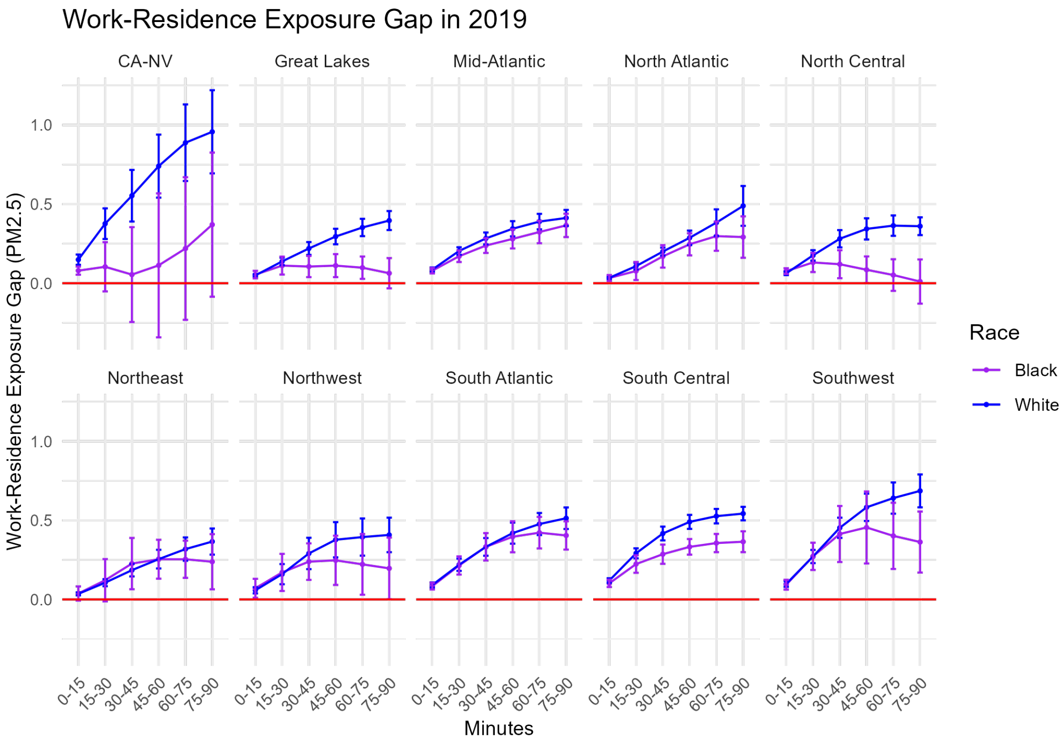


Figure A8: WREG: Time

Table A6: U.S. 2019

	Dependent variable:					
	PM2.5 Home	PM2.5 Work	WREG	PM2.5 Home	PM2.5 Work	WREG
0-15 Minutes						
Black	0.548***	0.549***	0.0001	0.078***	0.061***	−0.017***
	(0.048)	(0.048)	(0.004)	(0.020)	(0.017)	(0.004)
Constant	7.132***	7.207***	0.075***			
	(0.070)	(0.071)	(0.004)			
Mean	7.21	7.29	0.07	7.21	7.29	0.07
Observations	20,146,390	20,146,560	20,132,863	20,146,390	20,146,560	20,132,863
15-30 Minutes						
Black	0.530***	0.504***	−0.026*	0.092***	0.038***	−0.054***
	(0.056)	(0.055)	(0.014)	(0.023)	(0.010)	(0.014)
Constant	7.189***	7.388***	0.198***			
	(0.069)	(0.072)	(0.009)			
Mean	7.27	7.47	0.19	7.27	7.47	0.19
Observations	21,800,025	21,800,327	21,780,569	21,800,025	21,800,327	21,780,569
30-45 Minutes						
Black	0.561***	0.498***	−0.064***	0.106***	0.025***	−0.081***
	(0.059)	(0.059)	(0.022)	(0.025)	(0.006)	(0.022)
Constant	7.107***	7.415***	0.308***			
	(0.068)	(0.071)	(0.013)			
Mean	7.19	7.49	0.3	7.19	7.49	0.3
Observations	13,189,542	13,184,374	13,173,218	13,189,542	13,184,374	13,173,218
45-60 Minutes						
Black	0.616***	0.514***	−0.102***	0.124***	0.024***	−0.100***
	(0.063)	(0.061)	(0.025)	(0.025)	(0.006)	(0.026)
Constant	6.969***	7.363***	0.394***			
	(0.064)	(0.067)	(0.015)			
Mean	7.06	7.44	0.38	7.06	7.44	0.38
Observations	6,672,089	6,667,881	6,662,560	6,672,089	6,667,881	6,662,560
60-75 Minutes						
Black	0.671***	0.533***	−0.138***	0.137***	0.029***	−0.108***
	(0.067)	(0.064)	(0.025)	(0.025)	(0.006)	(0.027)
Constant	6.821***	7.275***	0.454***			
	(0.058)	(0.062)	(0.018)			
Mean	6.91	7.34	0.44	6.91	7.34	0.44
Observations	3,338,317	3,335,380	3,332,870	3,338,317	3,335,380	3,332,870
75-90 Minutes						
Black	0.729***	0.550***	−0.180***	0.144***	0.036***	−0.108***
	(0.071)	(0.063)	(0.024)	(0.025)	(0.010)	(0.030)
Constant	6.683***	7.184***	0.500***			
	(0.050)	(0.057)	(0.021)			
Mean	6.77	7.25	0.48	6.77	7.25	0.48
Observations	1,741,158	1,738,921	1,737,684	1,741,158	1,738,921	1,737,684
County-of-Residence FE	No	No	No	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01. Each observation corresponds to one in-person worker with a maximum commute time of 90 minutes one-way. The reference category are White workers in the respective time to work category. Columns (1)-(3) are without county-of-residence fixed effects. Columns (4)-(6) include county-of-residence fixed effects. Standard errors are clustered at the level of county-of-residence.

Table A7: Percentage of Residence Black-White PM2.5 Mitigated by Work Location

	CA-NV	Great Lakes	Mid-Atlantic	North Atlantic	North Central	Northeast	Northwest	South Atlantic	South Central	Southwest
A. Commute Time (minutes)										
0-15	-7.39***	1.02	-6.54	-0.66	1.75	0.6	4.55	-5.53	-5.03	-0.6
15-30	-28.65**	-4.49	-20.6	-11.31	-5.79	3.71	4.4	-2.68	-16.09***	0.13
30-45	-45.57***	-16.29***	-29.65	-7.73	-17.28***	9	-16.71	0.27	-31.76***	-4.43
45-60	-51.85***	-21.95***	-49.64	-8.62	-23.19***	-0.13	-29.9	-8.21	-42.25***	-13.03
60-75	-54.87***	-25.81***	-57.09	-16.87	-26.16***	-11.9	-31.05	-20.79	-49.14***	-21.53**
75-90	-48.15**	-29.93***	-51.11	-36.69***	-28.22***	-22.53	-33.57**	-46.79**	-51.83***	-26.09***
B. Commute Time (minutes) with county-of-residence fixed effect										
0-15	-19.29***	121.07**	-316.23	-25.82	-7.63	-43.47	-43.62***	-36.05	-21.16*	-75.62*
15-30	-51.18**	19.02	-87.51	-60.21	-40.96	-4.22	-28.89**	-34.05	-61.31***	-42.29
30-45	-78.35***	-89.86	-286.05	-49.27	-93.31***	102.13	-51.68*	-51.19	-111.69***	-58.49
45-60	-96.49***	-136.91***	-265.57	-48.16	-128.69***	-50.85	-78.83*	-161.65	-147.03***	-104.73*
60-75	-107.2***	-172.07***	-145.43	-83.95*	-151.57***	-125.18*	-85.27*	-270.89**	-156.57***	-141.36***
75-90	-113.79***	-207.98***	-64.01	-158.11***	-175.15***	-158.07**	-94.94***	-266.85***	-156.81***	-159.19***