Centre for Economic Performance

Discussion Paper

ISSN 2042-2695

No. 1974
January 2024

The changing nature of pollution, income and environmental inequality in the United States

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Economic and Social Research Council

Abstract
This paper uses administrative tax records linked to Census demographic data and high-resolution measures of fine small particulate (PM2.5) exposure to study the evolution of the Black-White pollution exposure gap over the past 40 years. In doing so, we focus on the various ways in which income may have contributed to these changes using a statistical decomposition. We decompose the overall change in the Black-White PM2.5 exposure gap into (1) components that stem from rank-preserving compression in the overall pollution distribution and (2) changes that stem from a reordering of Black and White households within the pollution distribution. We find a significant narrowing of the Black-White PM2.5 exposure gap over this time period that is overwhelmingly driven by rank-preserving changes rather than positional changes. However, the relative positions of Black and White households at the upper end of the pollution distribution have meaningfully shifted in the most recent years.

Keywords: air pollution, income, environmental inequality, decomposition

This paper was produced as part of the Centre's Growth Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

Any opinions and conclusions expressed herein are those of the author(s) and do not reflect the views of the U.S. Census Bureau. The Census Bureau has reviewed this data product to ensure appropriate access, use, and disclosure avoidance protection of the confidential source data used to produce this product (Data Management System (DMS) number: P-7505723, Disclosure Review Board (DRB) approval numbers CBDRB-FY24-CES014-008, CBDRB-FY24-0075 and CBDRB-FY24-0116). We would like to thank Patrick Kline and Danae Hernandez-Cortes for helpful comments.
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Published by
Centre for Economic Performance
London School of Economic and Political Science
Houghton Street
London WC2A 2AE

1 Introduction

Social scientists have long wondered whether observed environmental inequalities stem from significant differences in income and/or wealth. Over the past 40 years, there have been at least three major changes to income and pollution which have the potential to affect measures of environmental inequality. First, improvements in air quality have shifted the distribution of pollution exposure, narrowing pollution exposure gaps by race in the process (Colmer, Hardman, Shimshack, and Voorheis, 2020; Currie, Voorheis, and Walker, 2023). Second, there have been substantial changes in the distribution of income, which have also differed by race (Bayer and Charles, 2018). Third, the "return to income," captured by the relationship between income and pollution exposure, has changed significantly over time, especially for Black households (Colmer, Qin, Voorheis, and Walker, 2023).

This paper decomposes the narrowing racial gap in fine particulate matter ($PM_{2.5}$) exposure between 1984–2015 into (1) changes related to the distribution of pollution and income over time and (2) changes in the relative position of racial groups within these distributions. We combine administrative data from the universe of de-identified, IRS 1040 tax returns (containing information on residential location and income) with high-resolution, remote sensing measurements of $PM_{2.5}$, and additional sociodemographic information from linked survey and decennial Census data.

We first present new facts about racial disparities in pollution exposure over the past three decades. We extend Currie, Voorheis, and Walker (2023) by exploring data prior to 2000 and trends over time for different *quantiles* of the pollution distribution. We draw inspiration from the recent literature on racial earnings inequality (Bayer and Charles, 2018) and focus on two measures of environmental inequality: (i) the pollution exposure gap, defined as the difference in pollution exposure between Black and White households at the same percentile in their respective pollution distributions, and (ii) the pollution rank gap, defined as the difference in the percentile rank a Black household's pollution exposure would hold in the Black pollution distribution compared to the White pollution distribution.

Using quantile regression methods, we show that the median Black-White $PM_{2.5}$ exposure gap has narrowed by over 60 percent since 1984. Exposure gaps at both the top and bottom of the pollution distribution have narrowed similarly. By contrast, there has been almost no change in pollution rank gap; the relative position of the median Black household has remained at the 72nd percentile of the White household pollution distribution since 1984.

We decompose the changes in pollution level gaps at different quantiles into components that are driven by what the existing literature refers to as either "positional" or "distributional" changes (Bayer and Charles, 2018). Positional convergence refers to changes in the relative position or rank of Black and White households within the pollution distribution. This could be driven by relative changes in the preferences or constraints of households over this time period. Distributional convergence reflects changes in the overall shape of the pollution distribution, which affect exposure gaps due to differences in initial positions within the distribution (i.e. holding ranks fixed). Environmental regulations, like the Clean Air Act, which disproportionately affect high pollution areas, could contribute to distributional convergence by compressing the distribution of pollution concentrations from the top.

We find that the narrowing of Black-White $PM_{2.5}$ exposure gaps throughout the pollution distribution was primarily driven by distributional convergence. Various regulations, including the Clean Air Act, have led to significant improvements in air quality in the upper end of the pollution distribution, which disproportionately affects Black households (Currie, Voorheis, and Walker, 2023). Positional convergence has only led to modest changes in pollution exposure gaps at all levels of the pollution distribution.

Finally, we assess the role of income in explaining changes in the pollution exposure gaps. Our analysis shows that, while Black households at the median of the pollution distribution would have experienced modest positional gains, these gains were offset by changes in the way that income translated into pollution exposure — changes that disproportionately disadvantaged Black households. In the most recent decade, however, positional forces are responsible for a significant portion of the improvement in the $PM_{2.5}$ level gap at the top end of the pollution distribution. Understanding the changing nature of income and the changing ways it affects pollution exposure should be a priority for future research.

2 Data

We leverage confidential microdata from the US Census Bureau, linking administrative tax records with demographic information (age, race and ethnicity) from Decennial Census and American Community Survey data. We start from the universe of 1040 tax returns in 1984, 1989, 1994, 1995 and 1998-2016, using information on all primary and secondary tax filers. The tax records give us information on each tax unit's adjusted gross income (AGI) and residential location, which we resolve at the Census block group level using 2010 vintage boundaries.[1] These taxpayers are linked to their responses in the 2000 and 2010 Decennial Census and the 2005-2019 American Community Surveys, using Protected Identification Keys (PIKs). We restrict observations to positive AGI tax units and prime aged (25-54) taxpayers. We define race and ethnicity using mutually exclusive categories of race and Hispanic origin, although we focus here on non-Hispanic Black and non-Hispanic White individuals (which we refer to simply as "White" and "Black" throughout for brevity).

We combine our data on individuals with high-resolution, remote sensing measurements of fine particulate matter ($PM_{2.5}$) from Meng, Li, Martin, van Donkelaar, Hystad, and Brauer (2019), aggregated to the Census Block Group level using 2010 Census Block Group boundary definitions. We focus on $PM_{2.5}$ due to its high morbidity and mortality risk, its disproportionate impact on the monetized benefits of federal regulation, and the recent availability of detailed data spanning nearly four decades.

[1]AGI, our primary measure of income is a pre-tax income measure, which includes labor market earnings, earnings from self-employment and pass-through entities, capital income, and various taxable transfers. AGI is only available for the 1040 filing population; in related work (Colmer, Qin, Voorheis, and Walker, 2023) we explore the changing composition of this population over time, especially as it relates to changes in filing incentives and pollution aggregates.

3 Trends in Level and Rank Pollution Exposure Gaps

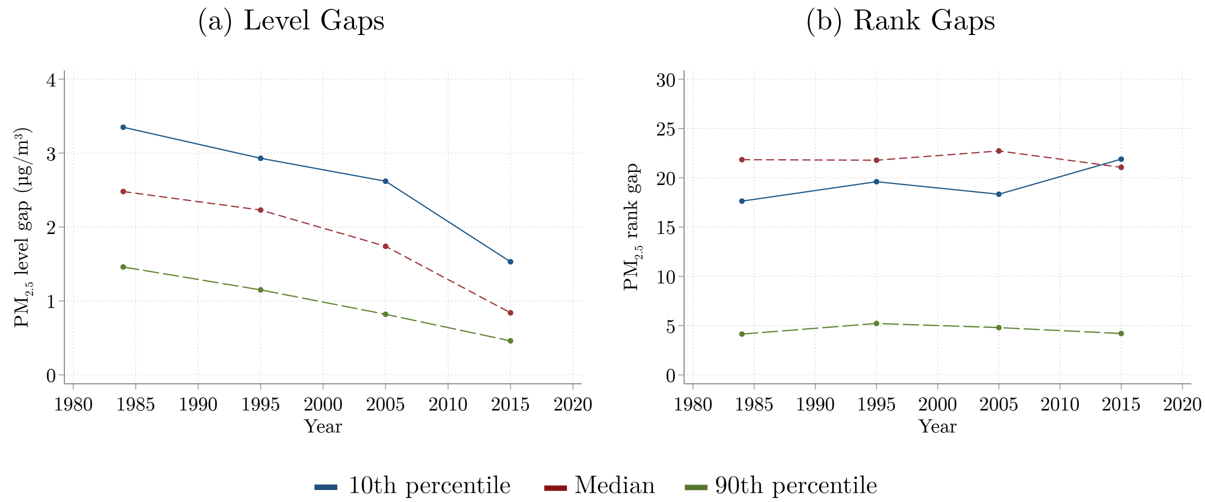
We focus on two measures of exposure differences for Black and White households, which we adapt from Bayer and Charles (2018), who study the evolution of racial earnings gaps: (1) the pollution exposure gap and (2) the pollution rank gap. We define the the pollution exposure gap at a percentile q as the difference in pollution levels for Black and White households at the qth percentile of their respective pollution distributions. The pollution rank gap is the difference between a Black household's percentile rank in the Black pollution distribution at percentile q and the percentile rank their pollution exposure would translate to in the White pollution distribution.

We use quantile regression methods to estimate these level gaps and rank gaps at different quantiles $q \in \{10, 50, 90\}$. We estimate the level gap for a quantile q by regressing $PM_{2.5}$ concentrations for a household in a given year on an indicator variable equal to 1 when the tax filer is Black. The coefficient on this indicator variable reveals the average difference in exposure for a Black household relative to a White household for a given quantile q. We estimate the rank gap at a given quantile q by regressing a household's percentile rank in the White pollution distribution on an indicator for whether the tax filer in the household is Black. The coefficient on this indicator variable captures the average difference in pollution rank for a Black household relative to a White household at a given quantile.

Figure 1a presents estimates of the average level gap in $PM_{2.5}$ between Black and White households at different quantiles of the the race-specific pollution distributions. In 1984, the median Black household was exposed to $2.48\mu g/m^3$ more $PM_{2.5}$, on average, than the corresponding median White household. In the 30 years after, this gap narrowed to $0.84\mu g/m^3$, a 66% decrease. We observe similar gains at both the 10th and 90th percentiles of the pollution distribution.

Figure 1b plots corresponding estimates of the pollution rank gap. In contrast to the level gains seen above, the rank gap, or relative position, of the median Black household remained almost constant between 1984 and 2015 — equivalent to the 72nd percentile of

Figure 1: Level and Rank Gap by Pollution Quantile



NOTES: Figures display the pollution exposure gap and pollution rank gap for 1984, 1995, 2005, and 2015 as estimated from quantile regressions. Each point represents a separate regression estimate.

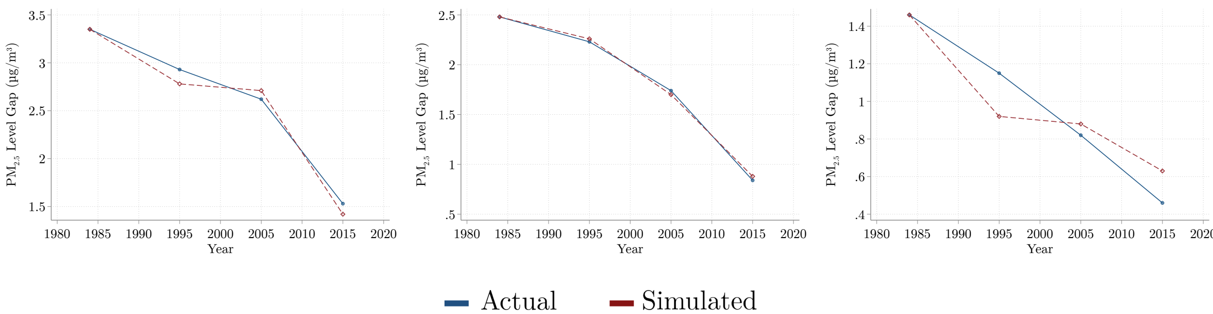
the White household pollution distribution. Black households at the 10th percentile of the pollution distribution experienced a worsening relative position during this time period — the estimated rank gap increased from 18 percentile points in 1984 to 22 percentile points in 2015. Similar to the median, rank gaps at the 90th percentile of the pollution distribution have remained nearly constant over time.

4 Decomposing Changes in Racial Pollution Exposure

We formally decompose the change in Black-White $PM_{2.5}$ level gaps into components that stem from distributional convergence and positional convergence using a counterfactual simulation proposed by Bayer and Charles (2018). The counterfactual thought exercise considers how the $PM_{2.5}$ level gap would differ over time if Black and White households maintained their initial relative positions in the pollution distribution, but experienced the change in pollution levels associated with each position over time. This counterfactual holds rank or relative positions fixed. By simulating what pollution levels would have been, holding position or rank constant, the difference between the simulated gap and observed gap at a given point in time reflects the effect of any positional convergence on pollution exposure gaps.[2]

Figure 2: Actual versus Simulated Pollution Exposure Gaps

(a) 10th Percentile (b) 50th Percentile (c) 90th Percentile



Notes: Figures display actual and simulated pollution exposure gaps at the median, 10th, and 90th percentiles over time from 1984–2015.

Figure 2 plots our estimates of the actual and simulated pollution level gaps by decadal intervals for the median, 90th, and 10th percentiles of the pollution distribution. The downward sloping solid blue lines in each figure reflect the fact that pollution level gaps are shrinking over time at all quantiles of the pollution distribution. The dashed red line in each figure simulates the counterfactual where each household's initial position in the pollution distribution remains constant but pollution levels change over time, i.e., where there is no scope for positional convergence. The vertical distance between the red line and the blue line reflects the contribution of positional convergence or divergence on the Black-White $PM_{2.5}$ level gap. Figure 2a shows that the actual pollution level gap at the 10th percentile narrowed from 3.4 to just under $3\mu g/m^3$ between 1984–1995. However, the difference between the dashed red and solid blue lines suggests that positional divergence over this time period eroded some of the distributional gains that would have otherwise occurred. Conversely, Figure 2c shows that, at the upper end of the pollution distribution in more recent years, positional convergence contributed to a further narrowing of the pollution level gap relative to a counterfactual in which relative rank was held fixed (i.e. the dashed red line) in recent years.

[2] In auxiliary decompositions below, we explicitly evaluate the role that income has played in contributing to positional convergence or divergence.

Table 1: Decomposing Pollution Exposure Gaps into Positional versus Distributional Factors

	(1)	(2)	(3)
	Overall change, 1984-2015		
	10th percentile	50th percentile	90th percentile
Total change in PM2.5-Level Gap	-1.82	-1.64	-1.00
Distributional convergence	-1.99	-1.61	-1.00
Positional convergence	0.17	-0.03	0.00
Returns to income	0.02	0.04	0.06
Convergence in income	0.06	0.05	0.00
Within-income convergence	0.09	-0.12	-0.06

NOTES: Table displays various decompositions of the overall change between 1984–2015 in pollution exposure gaps at the median, 10th, and 90th quantiles of the pollution exposure distribution.

Table 1 summarizes the magnitude and sign of these two forces over the 30 year horizon of our study. The first row, titled "Total Change", shows that the Black-White gap in $PM_{2.5}$ exposure has narrowed over time for each observed quantile of the pollution distribution. Rows 2 and 3 present the relative contributions of distributional and positional convergence. For example, we see that at the 10th percentile of the pollution distribution, the pollution level gap fell by $1.82\mu g/m^3$. Distributional forces were overwhelmingly responsible for these improvements. In fact, changes in positional ranks over this time period eroded $0.17\mu g/m^3$ of the narrowing that would have occurred under distributional convergence alone. The dominant role of distributional forces is apparent at the median and at the 90th percentile when looking at the 30 year changes. Appendix Table 3 documents heterogeneity in the role that positional forces have played within our study period by looking at decade by decade changes.

5 Income and Pollution Exposure Gaps by Race

Both scholars and policy makers have historically emphasized the importance of differences in income for racial differences in environmental outcomes. In this section, we explore the extent to which changes in income during this period may have contributed to the lack of positional gains in pollution exposure. There have been at least two major changes related to income that could have affected the racial differences in the distribution of pollution exposure over the past 30 years. First, there have been large changes in the distribution of income that differ by racial group (Bayer and Charles, 2018). Second, how income is related to location choice and ultimately environmental exposures has changed over this time period, and these changes also differ by race (Colmer, Qin, Voorheis, and Walker, 2023).

We use auxiliary simulations to decompose the overall positional gains or losses shown in Figure 2 and Table 1 into three aspects of income-related changes: (i) changes in the "returns to income," (ii) convergence in income, and (iii) within-income rank gains. In a first simulation, we calculate conditional decompositions, i.e., we hold constant a household's initial position within the pollution distribution, conditional on income decile, and we apply the new pollution distribution for that income level from the next period. The conditional decomposition is constructed by replicating the procedure used for the unconditional case. By holding fixed households' initial positions within each discrete income decile, the difference in pollution gaps between this conditional decomposition and the baseline decomposition reflects positional gains/losses attributed to changes in "returns to income."

In a second simulation, we further decompose the relative importance of gains due to convergence in income and within-income positional changes. We do this by adjusting the share of households in each race-income cell over time, rather than holding the share of households in each race-income cell constant at the level observed in the initial time period. We attribute the change in the pollution gap between this simulation and the one described in the paragraph above as stemming from income convergence. The residual, unexplained positional convergence/divergence is attributed to within-income positional changes.

The bottom half of Table 1 summarizes the results from these two simulations. Rows 4-6 decompose positional convergence into three separate channels: (i) changes in the "returns to income," (ii) convergence in income, and (iii) within-income convergence. Column (1) shows that, at the 10th percentile of the pollution distribution, positional divergence led to an expansion of the Black-White pollution level gap of 0.17μg/m^3. Why did this occur? Row 6 of Table 1 shows that over half of this convergence is due to within-income decile changes in the relative rank of Black and White households, leading to a 0.09μg/m^3 widening of the $PM_{2.5}$ level gap.

Table 2 shows these same decompositions, separately by decade, for the 90th percentile of the pollution distribution. Column (3) shows that positional forces account for a much larger share of the change in the pollution level gap at the 90th percentile between the year 2005-2015 than in earlier time periods. Quantitatively, 47 percent of the 2005-2015 change in the pollution level gap at the 90th percentile can be attributed to positional convergence, while the remaining 53 percent is attributable to distributional convergence. Additional results for the 10th and 50th percentile can be found in Appendix Table 3.

Table 2: Decomposing Pollution Exposure Gap at 90th Percentile, by Decade

	(1)	(2)	(3)	(4)
	1984-1995	1995-2005	2005-2015	Overall 1984-2015
Total change	-0.31	-0.33	-0.36	-1.00
Distributional convergence	-0.54	-0.27	-0.19	-1.00
Positional convergence	0.23	-0.06	-0.17	0.00
Returns to income	0.10	-0.02	-0.02	0.06
Convergence in income	0.01	0.01	-0.02	0.00
Within-income convergence	0.12	-0.05	-0.13	-0.06

NOTES: Table displays decompositions of the overall change in pollution exposure gaps at 90th percentile across the three decades in our sample time period.

6 Conclusion

We have shown that there have been significant improvements in the $PM_{2.5}$ level gap between Black and White households over the past 30 years. These improvements in the $PM_{2.5}$ level gap have occurred at all points of the pollution distribution. By contrast, the relative position, or rank gap, of Black and White households within the pollution distribution has remained constant or expanded in this same time frame. Statistical decompositions show that the vast majority of the convergence in the $PM_{2.5}$ level gap over this time period came from distributional forces. Due to the initial positions of Black and White households within the pollution distribution, these distributional forces led to convergence in $PM_{2.5}$ exposure levels. More recently, positional forces, or changes in the relative ranks of Black and White households within the pollution distribution, have been responsible for a significant improvement in the $PM_{2.5}$ level gap at the top end of the pollution distribution. Why these positional forces have started to emerge and whether or not they persist should be a priority for future research.

References

Bayer, P., and K. K. Charles (2018): "Divergent paths: A new perspective on earnings differences between black and white men since 1940," *The Quarterly Journal of Economics*, 133(3), 1459–1501.

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

Colmer, J., S. Qin, J. Voorheis, and R. Walker (2023): "Income, Wealth, and Environmental Inequality in the United States," *Working Paper*.

Currie, J., J. Voorheis, and R. 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.

Meng, J., C. Li, R. V. Martin, A. van Donkelaar, P. Hystad, and M. Brauer (2019): "Estimated long-term (1981–2016) concentrations of ambient fine particulate matter across North America from chemical transport modeling, satellite remote sensing, and ground-based measurements," *Environmental science & technology*, 53(9), 5071–5079.

A Appendix Tables

Table 3: Decomposing Pollution Exposure Gaps into Positional versus Distributional Factors, by Year

	1984-1995	1995-2005	2005-2015	Overall 1984-2015
	10th Percentile, PM2.5			
Total change	-0.42	-0.31	-1.09	-1.82
Distributional convergence	-0.57	-0.22	-1.20	-1.99
Positional convergence	0.15	-0.09	0.11	0.17
Returns to income	-0.06	0.07	0.01	0.02
Convergence in income	0.04	0.02	0.00	0.06
Within-income convergence	0.17	-0.18	0.10	0.09
	50th Percentile, PM2.5			
Total change	-0.25	-0.49	-0.90	-1.64
Distributional convergence	-0.22	-0.53	-0.86	-1.61
Positional convergence	-0.03	0.04	-0.04	-0.03
Returns to income	0.02	-0.01	0.03	0.04
Convergence in income	0.01	0.04	0.00	0.05
Within-income convergence	-0.06	0.01	-0.07	-0.12
	90th Percentile, PM2.5			
Total change	-0.31	-0.33	-0.36	-1.00
Distributional convergence	-0.54	-0.27	-0.19	-1.00
Positional convergence	0.23	-0.06	-0.17	0.00
Returns to income	0.10	-0.02	-0.02	0.06
Convergence in income	0.01	0.01	-0.02	0.00
Within-income convergence	0.12	-0.05	-0.13	-0.06

NOTES: Table displays the full set of decompositions of the overall change in pollution exposure gaps at the median, 10th, and 90th quantiles across the three decades in our sample time period.

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