Recent Findings and Methodologies in Economics Research in Environmental Justice

Lucas Cain*, Danae Hernandez-Cortes†, Christopher Timmins‡, and Paige Weber§

Introduction

This article is inspired by the recent growth in environmental and urban economics research that studies environmental justice. Such research documents and quantifies disparate exposure to an array of environmental burdens, explores the mechanisms generating these disparities, and studies government interventions that address and interact with these patterns and mechanisms. Our goal is to synthesize the past decade of economics-oriented research in environmental justice by reviewing papers from the fields of economics, environmental and ecological economics, sociology, public health, and general-interest science. We reviewed more than 100 papers published in the last decade and synthesize the body of work in two ways. In the next section, we discuss the types of questions that this work generally seeks to answer. In "Study Design and Methodological Considerations," we present the key methodological decision points and debates in the recent work. In "Discussion," we highlight ongoing discussions and directions for future environmental justice research. Our review focuses on research done by economists or scholars in closely related fields, with a particular focus on empirical applications in the United States, and this article is intended to be instructive for economics-oriented researchers who are seeking to contribute to a growing body of research questions in environmental justice.

This is not the first review of environmental justice literature and is very much related to previous reviews, notably by Banzhaf, Ma, and Timmins (2019a, 2019b). This article's contribution is to cover more recent work published since these reviews, focusing on topics that were not previously emphasized, including advances in methodological approaches and data availability. Previous work includes Agyeman et al. (2016), which reviews the history of the environmental justice movement, paying particular attention to trends and histories of activism

*Federal Reserve Bank of Chicago; †Arizona State University; ‡University of Wisconsin–Madison; §University of California, Berkeley (corresponding author; email: paigeweber@berkeley.edu)

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and policy-making in this area. Mohai, Pellow, and Roberts (2009) review the key trends and methodological debates in environmental justice research at that time. Some of the key debates in Mohai, Pellow, and Roberts (2009) have continued to be at play in the last decade. One of these debates is whether to focus on "race versus class" when studying environmental justice. Another is the "chicken or the egg" problem of where polluters choose to locate versus where people choose to live. Other debates have shifted to newer approaches. Earlier, there was a debate about whether the allocation of environmental burdens across communities should be based on "unit-hazard coincidence" (assigning population to hazards based on geographic coincidence defined by administrative boundaries) or distance to pollution sources. More recent discussions have transitioned to alternative models of how pollution is transported and dispersed.

The political landscape has also evolved in the last decade, with increasing inclusion of environmental justice criteria in environmental policy at federal, state, and local levels. For example, EPA now includes environmental justice criteria in their regulatory impact assessments. In addition, federal agencies must consider environmental justice analyses in their proposed programs and policies via the National Environmental Policy Act. Further, the federal government now aims to advance environmental justice by delivering at least 40 percent of benefits from federal investments in clean energy and climate in socioeconomically disadvantaged communities with the Justice40 Initiative (Young, Mallory, and McCarthy 2021). Given these trends, it is a good time to take stock of the recent literature and findings in environmental justice from the economics community.

Types of Research Questions Addressed

Document and Quantify

Many papers in this literature focus on documenting and quantifying differences in exposure or damages from environmental hazards across different communities. Table 1 includes a list of all papers reviewed in this category, accounting for around 40 percent of all reviewed papers. Documenting the exposure gap remains an important contribution to policy-making. Because there are usually limited resources available for addressing environmental problems, the relative size of the pollution gap across different hazards and settings can help policy makers target regulatory efforts when working toward equity-related goals. Benefit–cost analyses used in regulatory proceedings also benefit from studies that provide monetary estimates of environmental damages, as many of these papers do. Documenting a gap requires defining both the environmental outcome of interest and the subpopulations for which the gap is measured. Studies that characterize disparities in concentrations and exposure (e.g., Colmer and Voorheis 2020; Currie, Voorheis, and Walker 2020) calculate the differences in pollution concentrations (weighted or unweighted) across demographic groups. Others characterize disparities in damages by calculating the differences in hospitalizations, mortality, and morbidity by race or income groups (e.g., Gillingham and Huang 2021). However, limitations in data often determine the research question and the choice of the outcome of interest in a study. "Discussion" discusses how expansions in measurement and data have expanded the available data.

Table 1 Environmental justice papers by contribution type

Contribution	Papers	Count
Document and quantify	Morello-Frosch, Pastor, and Sadd 2001; Downey and Hawkins 2008; Wolverton 2009; Hipp and Lakon 2010; Abel and White 2011; Fann et al. 2011; Gamper-Rabindran and Timmins 2011; Shadbegian and Gray 2012; Currie et al. 2013; Bouvier 2014; Clark, Millet, and Marshall 2014, 2017; Pais, Crowder, and Downey 2014; Prochaska et al. 2014; Ard 2015; Bento, Freedman, and Lang 2015; Boyce, Zwickl, and Ash 2016; Collins, Munoz, and JaJa 2016; De Silva 2016; Kravitz-Wirtz et al. 2016; Currie, Greenstone, and Meckel 2017; Isen, Rossin-Slater, and Walker 2017; Voorheis 2017c; Aizer et al. 2018; Mikati et al. 2018; Paolella et al. 2018; Aizer and Currie 2019; Deryugina et al. 2019; Holland et al. 2019; Colmer et al. 2020; Currie, Voorheis, and Walker 2020; Nardone et al. 2020; Gillingham and Huang 2021; Hsu et al. 2021; Tessum et al. 2021; Wang et al. 2021; Ho 2022; Sager and Singer 2022; Hernandez-Cortes and Meng 2023; Hernandez-Cortes, Meng, and Weber 2023	40
Mechanisms	Downey and Hawkins 2008; Wolverton 2009; Gamper-Rabindran and Timmins 2011; Fowlie, Holland, and Mansur 2012; Grainger 2012; Shadbegian and Gray 2012; Pais, Crowder, and Downey 2014; Abel and White 2015; Currie et al. 2015; Cushing et al. 2015, 2018; Collins, Munoz, and JaJa 2016; De Silva 2016; Andaloussi and Isaksen 2017; Haninger, Ma, and Timmins 2017; Voorheis 2017a, 2017b; Keenan, Hill, and Gumber 2018; Aizer and Currie 2019; Banzhaf, Ma, and Timmins 2019b; Anderson, Plantinga, and Wibbenmeyer 2023; Bakkensen and Ma 2020; Christensen, Sarmiento-Barbieri, and Timmins 2020; Fowlie, Walker, and Wooley 2020; Hoffman, Shandas, and Pendleton 2020; Nardone et al. 2020; Dauwalter and Harris 2023; Davis and Hausman 2021; Hausman and Stolper 2021; Heblich, Trew, and Zylberberg 2021; Konisky, Reenock, and Conley 2021; Morehouse and Rubin 2021; Shapiro and Walker 2021; Wang 2021; Wang et al. 2021; Christensen and Timmins 2022; Melstrom and Mohammadi 2022; Timmins and Vissing 2022; Hernandez-Cortes, Meng, and Weber 2023	39
Welfare impacts	Anthoff and Tol 2010; Maguire and Sheriff 2011; Grainger 2012; Bouvier 2014; Currie et al. 2015; Depro, Timmins, and O'Neil 2015; Bayer et al. 2016; Cropper, Krupnick, and Raich 2016; Voorheis 2016; Haninger, Ma, and Timmins 2017; Currie and Walker 2019; Goulder et al. 2019; Hsiang, Oliva, and Walker 2019; Bakkensen and Ma 2020; Colmer and Voorheis 2020; Sheriff and Maguire 2020; Campa and Muehlenbachs 2023; Hausman and Stolper 2021; Heblich, Trew, and Zylberberg 2021; Mansur and Sheriff 2021; Wang 2021; Melstrom and Mohammadi 2022; Timmins and Vissing 2022	23
Government intervention	Levy, Wilson, and Zwack 2007; Gamper-Rabindran and Timmins 2011; Fowlie, Holland, and Mansur 2012; Bento, Freedman, and Lang 2015; Andaloussi and Isaksen 2017; Bin, Bishop, and Kousky 2017; Haninger, Ma, and Timmins 2017; Adams and Charnley 2018; Cushing et al. 2018; Grainger and Ruangmas 2018; Currie and Walker 2019; Fowlie, Walker, and Wooley 2020; Campa and Muehlenbachs 2023; Konisky, Reenock, and Conley 2021; Hernandez-Cortes and Meng 2023	15
Climate justice	Bin, Bishop, and Kousky 2017; Hardy and Hauer 2018; Keenan, Hill, and Gumber 2018; Goulder et al. 2019; Holland et al. 2019; Pizer and Sexton 2019; Anderson, Plantinga, and Wibbenmeyer 2023; Hoffman, Shandas, and Pendleton 2020; Auffhammer 2021; Dauwalter and Harris 2023; Davis and Hausman 2021; Hsu et al. 2021; Borenstein and Bushnell 2022; Borenstein, Fowlie, and Sallee 2022; Doremus, Jacqz, and Johnston 2022; Deshmukh et al. 2023a, 2023b	17

Table 1 (*Continued*)

Contribution	Papers	Count
Frontier methods or data	Levy et al. 2009; Su et al. 2009; Anthoff and Tol 2010; Fann et al. 2011; Sadd et al. 2011; Leelőssy et al. 2014; Ard 2015; Depro, Timmins, and O'Neil 2015; Bayer et al. 2016; Boyce, Zwickl, and Ash 2016; Cropper, Krupnick, and Raich 2016; Voorheis 2016, 2017a, 2017b; Adams and Charnley 2018; Grainger and Ruangmas 2018; Paolella et al. 2018; Deryugina et al. 2019; Hsiang, Oliva, and Walker 2019; Baker et al. 2020; Christensen, Sarmiento-Barbieri, and Timmins 2020; Colmer and Voorheis 2020; Colmer et al. 2020; Currie, Voorheis, and Walker 2020; Sheriff and Maguire 2020; Mansur and Sheriff 2021; Tessum et al. 2021; Christensen and Timmins 2022	28
Meta-analysis or review	Maguire and Sheriff 2011; Cushing et al. 2015; Agyeman et al. 2016; Banzhaf, Ma, and Timmins 2019a, 2019b; Pizer and Sexton 2019; Baker et al. 2020	7

Note: Categories are not mutually exclusive, and reviewed papers are allowed up to two categorizations. Many papers can be seen as contributing to more than two categories, and selected categories represent our judgment of the two key contribution types. Papers in the "document and quantify" category document or study a disparity in a benefit or harm related to environmental concerns, irrespective of findings; this category does not include disparities in prices or expenditures. Papers in the "government intervention" category take a broad stance on what constitutes a government intervention and include government policies and programs. The "welfare impacts" category includes papers that study or estimate people's willingness to pay for environmental benefits, as well as impacts to individual or social welfare that are related to environmental justice.

Computing a gap also requires choosing comparison groups. Existing studies have used different definitions depending on the question or institutional details of the setting. For example, Currie, Voorheis, and Walker (2020) and Gillingham and Huang (2021) compare gaps in exposure to pollution and health effects between African American/Black and white populations. Other studies also consider other minority groups such as Hispanic/Latino or Asian American (Fowlie, Holland, and Mansur 2012; Hausman and Stolper 2021; Mansur and Sheriff 2021; Shapiro and Walker 2021). Additional work compares exposure differences between low- and high-income groups or compares groups above and below the federal poverty line (Fowlie, Holland, and Mansur 2012; Hausman and Stolper 2021; Mansur and Sheriff 2021; Shapiro and Walker 2021). The choice of comparison groups determines the types of conclusions these papers can make. For example, these studies have two main findings: (i) that African American/Black, Hispanic/Latino, and Asian American communities experience higher pollution exposure compared with predominantly white communities and (ii) that low-income groups experience a higher pollution burden than high-income groups.

Studies have also made use of specific policy or institutional details related to their setting to calculate pollution disparities or analyze how the consequences of policies are distributed across different populations. For instance, Hoffman, Shandas, and Pendleton (2020) and Nardone et al. (2020) compare differences in environmental risk by historical status as a redlined area. Other studies have compared groups depending on institutional definitions of vulnerability: for example, using the EPA demographic index (Campa and Muehlenbachs 2023) or the "disadvantaged community" definition used by the California EPA (Cushing et al. 2018; Hernandez-Cortes and Meng 2023). The designation of a community as disadvantaged comes from a pollution index developed by the State of California—the CalEnviroScreen—which estimates relative pollution burdens across census tracts in California OEHHA 2017). The publicly available scores allow researchers to compare total pollution burdens across communities.

The White House recently published a similar tool, allowing practitioners to identify census block groups that are particularly polluted (White House 2022).

Deciding how to make comparisons in this research is not trivial. For example, should one control for income in a comparison of exposures by race? Should groups be based on race, ethnicity, national origin, or linguistic isolation? EPA's definition of environmental justice offers a helpful perspective: "Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. This goal will be achieved when everyone enjoys: The same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work" (EPA 2023).

This definition underlines that environmental injustice exists wherever there are gaps in fair treatment and meaningful involvement across all people. Accordingly, well-done comparisons across many different demographic and socioeconomic characteristics can contribute to our understating of environmental injustice. Still, the researcher needs to be fastidious in interpreting results across models, being cognizant of how seemingly small methodological decisions (e.g., whether to control for demographic characteristics in econometric analysis) change the interpretation of their results.

Mechanisms

Making predictions is a key weakness in studies that only quantify the pollution exposure gap. And understanding the mechanisms that contribute to environmental injustice is necessary to move beyond program evaluation. Banzhaf, Ma, and Timmins (2019b) outline four general mechanisms, all of which also appear in Mohai, Pellow, and Roberts's (2009) review. These mechanisms include residential sorting, firm sorting, discriminatory policy or discriminatory enforcement of regulations, and the relationship between firm and household sorting. "Sorting" refers to the process by which firms and households choose where to locate, including any factors that limit their choices. The mechanisms studied over the last decade follow a similar categorization. We list papers studying residential sorting and firm sorting in rows one and two of table 2. We group papers studying discriminatory policies and enforcement as relating to procedural justice, listed in row three of table 2. We add a fourth category of papers studying markets and market-based policy in row four. Individual welfare impacts are discussed in this section; however, because papers in this area span multiple categories, they are listed in table 1.

Residential sorting

Economic intuition tells us that households make residential location decisions by trading off their preference for better amenities with costly housing. Yet formulating environmental injustice as the equilibrium result of standard economic models of residential sorting can greatly obscure the mechanisms generating the injustice. Recent empirical work demonstrates the poor suitability of several of the standard assumptions included in these models. For example, a standard sorting model would ignore pure discrimination faced by those searching for housing, whereas the results of Christensen and Timmins (2022) demonstrate the bias introduced by such an assumption. The authors combine a large-scale experiment in renters'

Table 2 Papers studying mechanisms in environmental justice

Mechanism	Papers	Count
Residential sorting	Downey and Hawkins 2008; Gamper-Rabindran and Timmins 2011; Grainger 2012; Pais, Crowder, and Downey 2014; Abel and White 2015; Depro, Timmins, and O'Neil 2015; Bayer et al. 2016; Haninger, Ma, and Timmins 2017; Voorheis 2017b; Keenan, Hill, and Gumber 2018; Aizer and Currie 2019; Bakkensen and Ma 2020; Christensen, Sarmiento-Barbieri, and Timmins 2020; Hausman and Stolper 2021; Heblich, Trew, and Zylberberg 2021; Wang 2021;Christensen and Timmins 2022; Melstrom and Mohammadi 2022	18
Firm-side sorting	Wolverton 2009; Currie et al. 2015; Collins, Munoz, and JaJa 2016; De Silva 2016; Morehouse and Rubin 2021; Wang et al. 2021	6
Procedural justice	Morello-Frosch, Pastor, and Sadd 2001; Adams and Charnley 2018; Paolella et al. 2018; Fowlie, Walker, and Wooley 2020; Hoffman, Shandas, and Pendleton 2020; Campa and Muehlenbachs 2023; Sager and Singer 2022	7
Markets and market-based policy	Fowlie, Holland, and Mansur 2012; Cushing et al. 2015, 2018; Andaloussi and Isaksen 2017; Grainger and Ruangmas 2018; Goulder et al. 2019; Simeonova et al. 2021; Pizer and Sexton 2019; Dauwalter and Harris 2023; Davis and Hausman 2021; Mansur and Sheriff 2021; Shapiro and Walker 2021; Timmins and Vissing 2022; Hernandez-Cortes and Meng 2023; Hernandez-Cortes, Meng, and Weber 2023	15

housing search with a structural sorting model and identify race-based discrimination in rental housing markets, demonstrating that sorting models that exclude this form of discrimination would yield significantly biased estimates of households' willingness to pay for environmental quality. For instance, Christensen, Sarmiento-Barbieri, and Timmins (2020) find that renters with African American and Hispanic/Latino names are less likely than renters with white names to receive responses to rental inquiries for properties in locations that have low exposure to pollution.

Several methodological developments over the last decade have improved the ability of sorting models to provide insights on environmental justice–related research questions. Bishop and Murphy (2011) and Bayer et al. (2016) demonstrate the potential bias that occurs from ignoring the dynamic components of the sorting decision. Bishop and Murphy (2011) develop a simplified dynamic estimator to estimate people's willingness to pay to avoid violent crimes. They find that a myopic model—one that includes only short-term considerations—underestimates the willingness to pay for this amenity over the long run. Similarly, Bayer et al. (2016) develop a dynamic structural model of neighborhood choice and apply it to estimate willingness to pay for environmental amenities by forward-looking households—those that consider the future impacts of today's choices. They find that a static (nondynamic) model underestimates willingness to pay to avoid pollution and crime over the long term, with the size of the underestimation varying by income level. Hausman and Stolper (2021) study the role of known and unknown information in the sorting decision and show that the residential sorting process results in more environmental injustice when there is a correlation between observable and unobservable environmental problems. Complicating the role of information in environmental justice outcomes, Wang et al. (2021) find indirect evidence that information-based interventions in the form of disclosures can aggravate equity outcomes due to varying community pressure. Depro, Timmins, and O'Neil

(2015) study the contribution of household mobility to pollution disparities, estimating differences in willingness to pay for clean air across race groups and demonstrating how residential mobility contributes to differences in environmental health risks, which may work against policies intended to address environmental injustice. Gamper-Rabindran and Timmins (2011) find evidence of a related unintended consequence of an environmental cleanup, where the remediation of Superfund sites benefits the rich households that migrate to the cleaned-up areas rather than the households that were originally exposed to the contamination. Heblich, Trew, and Zylberberg (2021) study the persistence of both pollution and neighborhood effects, finding that temporary industrial and coal pollution has long-run implications on pollution and segregation, explaining up to 20 percent of neighborhood sorting 40 years later. Bakkensen and Ma (2020) use a research design based on differences occurring at a boundary (discontinuity design) to study sorting and flood risk, finding evidence that low-income minority residents are more likely to move to high-risk flood zones. Advances in data access have allowed researchers to study longer-term disparities in exposure across location decisions. Voorheis (2017a) uses new longitudinal data—in which individuals are tracked over time—to study environmental gentrification, where amenity improvements result in increased housing prices, leading disadvantaged individuals to move out of newly improved regions. The study finds that longer-term environmental gentrification results in greater reduction to pollution exposure among socioeconomically advantaged individuals compared with initially disadvantaged individuals. Pais, Crowder, and Downey (2014) study exposure and residential location over two decades, finding that exposure differences are only partially explained by racial differences in people moving to suburban neighborhoods, socioeconomic status, and the frequency of interneighborhood moves.

Many of the sorting models in empirical economics simply add up environmental costs and benefits, ignoring both cumulative pollution effects and the ways in which pollution may interact with other disadvantages. For instance, a lower-income person with asthma may suffer worse health effects from the same level of air pollution compared with a higher-income person who has access to health care and can take precautions to avoid pollution exposure—for example, by purchasing a home air filter. Or a person who cannot read English may not find out about an unhealthy air warning. Some of these effects are studied in environmental and health-oriented research, including calculating population risk, measures of cumulative pollution (Morello-Frosch, Pastor, and Sadd 2001), and generating vulnerability indices that account for exposure to multiple sources of pollution and other risks (Su et al. 2009; Sadd et al. 2011). Hsiang, Oliva, and Walker (2019) discuss a related dimension—the differences between exposure and vulnerability—highlighting that differences in location-based exposure predicted by sorting models may tell an incomplete story of environmental justice due to differences in vulnerabilities to the environmental hazards across race and socioeconomic demographics. Future economics research in this area would do well to consider the potentially interactive effects of environmental hazards, as well as the differences and connections between exposure and vulnerabilities and their unique contributions to environmental injustice.

Welfare impacts

The aforementioned literature highlights that at least some component of choosing where to live involves trading off housing prices for amenities. If households are to be compensated for environmental hazards, then what are the impacts of environmental injustice on the welfare of households and society? Answering this question requires accurate estimates of individuals' willingness to pay for environmental amenities, which is done by Bento, Freedman, and Lang (2015), Depro, Timmins, and O'Neil (2015), Cropper, Krupnick, and Raich (2016), and Wang (2021). Discussions of the connection between environmental inequalities and individual or social welfare are found in almost one-fourth of the surveyed papers. Yet many of the existing methodological approaches are unable to distinguish willingness to pay from all other potential discriminatory forces affecting the household sorting decision. Further, Greenstone and Jack (2015) discuss four possible reasons why estimates of marginal willingness to pay among low-income individuals are seemingly low. Future research and continued innovation in modeling residential location decisions are needed to better connect environmental justice to individual welfare. In table 1, we list the subset of papers in our review that discuss individual welfare impacts and/or estimate willingness to pay.

Firm sorting

Other work studies how firm location decisions affect the distribution of environmental hazards. Morehouse and Rubin (2021) find that power plants strategically locate near borders so that pollution disperses downwind of the local or state authority. Wolverton (2009) reviews the role of timing in the firm siting decisions—the difference in matching firms to communities at the time of making the location decision versus the demographics of a community once the firm is located there. Although focusing on the latter helps explain which communities are expected to see pollution from firms, the former approach is more instructive for understanding how polluting firms decide where to locate (Wolverton 2009; Abel and White 2015; Currie et al. 2015; Collins, Munoz, and JaJa 2016; De Silva 2016; Mikati et al. 2018; Wang 2021; Wang et al. 2021; Timmins and Vissing 2022). In addition, there are potential interactions between firm sorting and residential sorting. Heblich, Trew, and Zylberberg (2021) show that historical pollution and residential sorting with respect to firm locations can explain current residential segregation patterns. Ho (2022) studies the location of solid waste disposal, finding that NIMBY-motivated bans on waste disposal could lead to substitution of waste from facilities near white residents to facilities near Hispanic residents.

Procedural justice

As the EPA definition above discusses, environmental justice is not solely about fair treatment but also about meaningful involvement, which has been studied recently through the lens of procedural justice and makes up a small share of the work in our review. Procedural justice concerns the fairness of the processes that resolve disputes and allocation of resources (Department of Justice 2022). Bell and Carrick (2018) highlight that the decisions that change the environment are usually made by people who enjoy the benefits of the decisions rather than those who bear the burdens. Hamilton (1993) shows that communities that are better able to organize politically are less likely to see local firms expand hazardous waste processing. Gray and Shadbegian (2004) and Shadbegian and Gray (2012) study the determinants of regulatory stringency in communities near polluting facilities and find that collective action is an important determinant of stringency. Timmins and Vissing (2022) study outcomes from leases signed between shale operators and households in Texas, finding that race and English-speaking are correlated with lease terms and royalty compensation. Campa and Muehlenbachs (2023) study outcomes when companies negotiate with local communities as to whether to pay a monetary fine or undertake a local environmental project as a penalty for breaking an environmental law. They find empirically that richer communities are more likely to settle with in-kind transfers such as an environmental project. They also find that fewer in-kind settlements occur than would be optimal in an analogous theoretical model of welfare maximization. Fowlie, Walker, and Wooley (2020) study the connections among climate change policy, local air pollution policy, and environmental justice by evaluating recent legislative experiences, and they find that a community-driven process to address pollution hotspots is likely to be a "political prerequisite" for policy in environmental justice and climate, a finding that implicitly highlights the role of procedural justice in shaping historical outcomes.

Government Intervention

Another body of work examines the impact of regulations and policies on disproportionate exposures and damages from environmental hazards. The papers that fall in this category are listed in table 1.

Market based

Within this literature, recent attention has been paid to whether market-based policies, such as emissions trading programs and pollution taxes, exacerbate inequities. Market-based programs put a price on the emission of pollutants, as an incentive for firms to reduce pollution. Under market-based regulation, firms with lower costs of abatement (pollution reduction) will reduce emissions relatively more than firms with higher abatement costs. Thus, households near and downwind of firms that can reduce pollution at a relatively low cost are expected to benefit more from market-based programs, compared with households living near and downwind of firms with high abatement costs.

Some market-based regulations allow polluters to buy and sell the rights to emit a unit of pollution; again, this is intended to create an incentive for cleaner production. Shapiro and Walker (2021) study offset trading in the Clean Air Act (CAA), a program that includes market-based elements but is distinct from cap-and-trade programs. They find little evidence that emissions offsets are more likely to be bought and sold in places with a larger share of Black or Hispanic population or with lower mean income.

Similarly, Fowlie, Holland, and Mansur (2012) investigate the impact of Southern California's emissions trading program (RECLAIM) on local air pollution, assuming uniform pollution dispersal around point sources (fixed sources of pollution, as opposed to dispersed sources such as automobiles). They do not find evidence of disproportionate impact by demographics. However, when Grainger and Ruangmas (2018) replicated the study but relaxed the assumption of uniform pollution dispersion, they did find evidence that high-income areas benefited from emissions trading more than low-income areas and that predominantly Black communities benefited from emissions trading relative to Hispanic communities. The difference in findings highlights the importance of the chosen method of modeling the movement of pollutants, a methodology further discussed in "Discussion."

Market-based regulations to address global climate change have recently come under scrutiny, at least in part due to their impacts on copollutants emitted alongside greenhouse gases (GHGs). Although these policies regulate GHG emissions, they also have an impact on the location and quantity of copollutants emitted alongside GHGs, which have human health effects for the exposed populations. Hernandez-Cortes and Meng (2023) study this question in the context of California's cap-and-trade program; they find that pollution has not increased in vulnerable communities following the regulation, and find evidence of a gap narrowing. On the other hand, Cushing et al. (2018) study the same program in California and find descriptive evidence of increases in pollution exposure among heavily polluted communities following the program's implementation. Overall, research on emissions trading programs and environmental justice effects is beginning to establish that the anticipated environmental justice impacts from these types of policies cannot be predicted without considering the empirical setting—specifically, the spatial distribution of abatement costs and communities.

Nonmarket based

Among the literature studying non-market-based regulations, an extensive body of work documents the welfare impacts of pollution decreases induced by the 1970 CAA amendments.[1] The CAA amendments of 1970 and 1977 were based on a command-and-control approach for local air pollutants (Currie and Walker 2019). Distinct from a market-based approach, these command-and-control regulations required that counties that exceed emissions standards create their own air quality improvement plans. The CAA amendments of 1990 established similar standards for toxic emissions. Studies examining the effects of the CAA have found that improvements in air quality due to the CAA amendments caused significant health benefits (Isen, Rossin-Slater, and Walker 2017; Aizer et al. 2018; Aizer and Currie 2019; Colmer et al. 2020).

Currie, Voorheis, and Walker (2020) show that pollution concentrations throughout the United States have decreased in the last few decades, with concentrations in predominantly Black neighborhoods decreasing more than those in predominantly white neighborhoods. The authors examine whether the gaps closed due to the implementation of the CAA amendments—specifically, the revised standard $PM_{2.5}$ (particulate matter that is 2.5 microns or less in diameter) in 2006. The authors find that the CAA accounts for more than 60 percent of the relative improvement between Black and white pollution concentrations. The authors also find that this decline in the gap cannot be explained by changes in mobility, individual, or neighborhood characteristics, which allows them to attribute the change in the gap to the CAA $PM_{2.5}$ standard. Sager and Singer (2022) also shows that the 2005 $PM_{2.5}$ CAA standards contributed to narrowing urban–rural and Black–white $PM_{2.5}$ exposure disparities.

Other non-market-based regulations involve the disclosure of information about pollution sources. For example, the information disclosure provided by the Toxics Release Inventory (TRI) in 1990 provided information on existing pollution sources across communities

[1]These amendments established the maximum level of pollution concentrations of six pollutants: carbon monoxide, nitrogen dioxide, ozone, particulate matter, lead, and sulfur dioxide.

in the United States. Although toxic emissions fell after the disclosure of the TRI (Wang et al. 2021; Environmental Protection Agency 2016), studies have found that these reductions are not evenly distributed across communities. In particular, toxic emissions fell more in high-income counties compared with low-income counties (Kalnins and Dowell 2017), and African American communities experienced a smaller decrease in toxic pollution compared with other communities (Ard 2015). Releasing information about existing pollution sources might exacerbate pollution exposure depending on how and to what extent this information causes individuals to move to different places (Banzhaf and Walsh 2008; Hausman and Stolper 2021) or causes firms to relocate their facilities (Wolverton 2009; De Silva 2016). A study by Wang et al. (2021) finds that TRI facilities located in communities with higher population density and higher education levels were more likely to relocate to lower-income and lower-educational-attainment communities.

Cleanup programs such as the Brownfield Program and the Superfund Program are other examples of non-market-based policies. Superfund sites are high-risk areas that pose a significant threat to human and environmental health, whereas areas designated as brownfields are currently low-risk areas that have been previously used for industrial or commercial purposes. Haninger, Ma, and Timmins (2017) examine whether the US EPA Brownfield Grants Program, designed to provide economic support to redevelop brownfields, had positive impacts on property values. The Brownfields Program cleanups increased property values by 5–11.5 percent; however, the authors find that these impacts were highly localized near these areas. Moreover, Melstrom and Mohammadi (2022) find that Black residents are more likely to be displaced after a Brownfield cleanup, suggesting that the program contributed to environmental gentrification. Wang (2021) finds a similar result when looking at environmental improvements following the installment of abatement technologies in gas-fired power plants in Los Angeles following the California electricity crisis in 2000, finding that environmental improvements can benefit housing owners but have a negative impact on renters.

EPA's Supplemental Environmental Projects constitute another non-market-based policy and allow firms to address noncompliance with environmental regulation through environmental and community projects. Campa and Muehlenbachs (2023) find that these in-kind transfers can be beneficial for the violating firms and that such projects are more likely to occur in communities that are high income and predominantly white. Another nonmarket government intervention occurs in the siting and permitting of polluting facilities and, more broadly, land-use planning. Not much research has been done in this area since Hamilton (1995), which studied how differences in the probability that residents would engage in collective action to oppose expansions of hazardous waste facilities affected the locations of these expansions.

Finally, another non-market-based approach for EPA to regulate environmental injustice may come through new and evolving interpretations of the agency's legal authority under Title VI of the Civil Rights Act of 1964 (Title VI). A recent report by EPA notes that, as discussed in Executive Order 12898, "existing environmental and civil rights statutes [Title VI] provide many opportunities to ensure that all communities live in a safe and healthful environment." The report also highlights that all EPA funding recipients are required to comply with Title VI (US Environmental Protection Agency: Office of General Counsel 2022). Although developments on the legal authority of EPA in the context of Title VI are ongoing, recent updates indicate potential expansions in EPA's legal tools to address environmental injustice.

Climate Justice

Climate impacts

Recent research increasingly connects environmental injustice to climate-induced environmental hazards. Urban "heat islands" have been found to disproportionately affect non-white and lower-income populations (Hsu et al. 2021). Heat-related disparities have also been linked to historical discrimination in housing markets through the practice of redlining. In an analysis of 108 American urban settings, Hoffman, Shandas, and Pendleton (2020, p. 1) found that "94% of studied areas display consistent city-scale patterns of elevated land surface temperatures in formerly redlined areas," finding that the main mechanisms are disparities in tree canopy coverage, landscape features, and the types of construction in these areas.

Climate-related natural disasters such as floods and wildfires have also been shown to disproportionately affect low-income and minority communities. Bakkensen and Ma (2020) find that housing prices lead low-income and minority households to be disproportionately likely to move into high-risk zones in south Florida. Keenan, Hill, and Gumber (2018) use Miami-Dade County, Florida, as a case study to describe climate gentrification, finding that housing prices are higher at higher elevation levels, which are less likely to flood. Hardy and Hauer (2018) project sea-level risk in coastal Georgia out to 2050, finding that women and Hispanic/Latino populations face disproportionate increases in the risks caused by rising sea levels. There is also documented evidence of differences in the capacity to adapt to climate risks and to mitigate those risks—for instance, through preventive measures or insurance. Bin, Bishop, and Kousky (2017) consider whether the National Flood Insurance Program is progressive (relatively beneficial to lower-income people) or regressive (relatively beneficial to higher-income people). They find that, although payouts tend to be progressive, both coverage and net premiums divided by coverage are regressive. Anderson, Plantinga, and Wibbenmeyer (2023) show that fire control agencies increase the use of preventive measures in communities with higher income, more education, and a higher share of white population.

Climate policy costs and incidence

More recent policy discussions around the equity impacts of decarbonization policies have invigorated the debate around how regulating GHG emissions will affect equity outcomes. Existing studies show that increases in electricity bills associated with the energy transition to a decarbonized economy are likely to affect low-income groups. Pizer and Sexton (2019) provide an extensive summary of the existing evidence on the distributional impacts of energy taxes and discuss the main findings. They find that energy taxes tend to be regressive and that much of the regressivity is driven by electricity consumption, given that households in the United States in the lowest 10 percent of income spend a higher share of income on electricity than wealthier households. Other studies have found that these taxes are not necessarily regressive, as the distributional impacts also depend on the redistribution of the revenue generated by these policies (Chen, Goulder, and Hafstead 2018). Doremus, Jacqz, and Johnston (2022) find that energy expenditures for low-income consumers are about half as responsive to extreme temperatures as all other households, indicating disparities in climate adaptation options available across income.

A report on electricity rates (Borenstein, Fowlie, and Sallee 2022) finds that half to two-thirds of consumers' electricity expenditures in California are residual costs, akin to a tax, covering activities outside of the cost of supplying electricity, including activities related to the state's climate and environmental goals. Because electricity bills account for a larger share of income for low-income households, the effective tax turns out to be more regressive than the state's sales tax. Other work finds that an increase in electrification and substitution from fossil fuels such as natural gas might affect low-income and minority consumers chiefly because of the structure of capital cost recovery—the way capital costs for producers are passed through to consumers in electricity rates (Davis and Hausman 2021). Dauwalter and Harris (2023) show that there are variations in environmental benefits from rooftop solar installation, that these environmental benefits increase with income, and that minority households receive higher environmental benefits per capita.

Holland et al. (2016) study the environmental benefits of electric vehicles, including not only the climate-related benefits but also the air quality costs from the electricity produced to fuel electric vehicles. They find great variation in different communities in the environmental benefits from subsidizing electric vehicles. Holland et al. (2020) find that electric vehicles only recently switched from being cleaner than the average gas-powered vehicle, over the period 2010–2017, though with heterogeneity across locations. Holland et al. (2019) study the distributional consequences of electric vehicle adoption and find that, on average (without census region fixed effects), Asian and Hispanic residents receive positive environmental benefits from electric vehicles, whereas white and Black residents see environmental costs. These findings underline that the future impacts of increasing electrification of the transportation sector are likely to be highly heterogeneous across space and thus may come with mixed implications for environmental justice.

Study Design and Methodological Considerations

The work reviewed in the previous section includes an array of methodological decisions at various stages, from formulating the study question to calculating the outcomes of interest. The differences in study designs and approaches prevent a quantitative meta-analysis of pollution inequities, in which the analytical results of numerous studies are combined for an aggregate analysis. Perhaps more importantly, the different approaches highlight a need to carefully consider how and why these methodological decisions are made. In many cases, decisions stem from data and methodological limitations. Recent advances in both dimensions provide an opportunity to relax some of these constraints. Below, we discuss several methodological areas in which the research over the last decade has advanced: modeling of pollution transport, use of new data sources from satellites and crowdsourced pollution monitors, and use of new administrative data sets to study long-run trends in exposure.

Pollution Transport

How can economists take into account the science of how pollution travels? Early literature in this field assigned pollution to people using the "unit-hazard coincidence" approach. This approach involves selecting predefined geographic units, determining which units contain environmental hazards, and comparing demographics of geographic units with and without those hazards. A key weakness of this approach is that it assigns environmental burdens equally to all people within the same unit, regardless of the size of the unit, people's distance to the hazard, how the pollution is transported, and variation among populations in terms of their vulnerabilities, as well as differences in the behaviors and investments that they undertake to defend themselves against risks from pollution. In 2006, Mohai and Saha describe unit-hazard coincidence as the "classic" and "most widely used" approach for assessing environmental disparities at the time. A related issue concerns the "ecological fallacy," whereby an individual unit might have a different exposure from the assigned exposure after adding up these units to some spatial scale. Banzhaf, Ma, and Timmins (2019a) discuss how the ecological fallacy creates bias when assigning individuals to hazards using grouped data.

Since then, increasingly sophisticated methods have been developed to model the transport of air pollutants, allowing for the assignment of people to air quality at finer spatial levels (see table 3). Some new models embed the physical and chemical properties of pollutants into the transport models, though with different methodologies and assumptions. For example, dispersion models based on planetary boundary layers include Gaussian dispersion models such as AERMOD or ADMS, or Lagrangian dispersion models such as HYSPLIT or HyAD. Other pollution transport models consider the primary release of pollutants along with secondary chemical atmospheric reactions; for instance, $PM_{2.5}$ concentrations are a function of

Table 3 Pollution transport models and new data sources

Pollution measure	Model type	Model name example	Papers example
Pollution transport models	Dispersion model based on planetary boundary layers	AERMOD	Sullivan 2017
		HYSPLIT	Grainger and Ruangmas 2018; Morehouse and Rubin 2021; Hernandez-Cortes and Meng 2023
	Reduced complexity air quality modeling	EASIUR	Heo and Strauss 2020
		AP2/AP3/APEEP	Holland et al. 2016; Chan et al. 2018
		InMAP	Auffhammer 2021; Tessum et al. 2021; Hernandez-Cortes, Meng, and Weber 2023
	Eulerian photochemical models	CAMx	Marshall, Swor, and Nguyen 2014
		CAMQ	Bravo et al. 2016
		WRF-Chem and GEOS-Chem	
	Toxics exposure	RSEI	Sheriff 2024
Satellite data	AOD	MODIS	Zou 2021
	Satellite data and machine learning/ chemical transport	Neural network (Di et al. 2016)	Fowlie, Rubin, and Walker 2019
		Chemical transport modeling and geographic-weighted regression (Hammer et al. 2020)	Fowlie, Rubin, and Walker 2019; Currie, Voorheis, and Walker 2020

Note: Papers listed are examples of papers that use these models for environmental justice–related research. They are not intended as an exhaustive list.

direct $PM_{2.5}$ releases and other chemicals that are directly emitted and their chemical reactions in the atmosphere (SO_x and NO_x). Examples of these models are WRF-Chem and GEOS-Chem. Models like AERMOD or HYSPLIT can be less computationally intensive than WRF/GEOS-Chem, though WRF/GEOS-Chem models chemical reactions that are important for the formation of secondary $PM_{2.5}$.

Reduced-complexity models (RCMs) for air pollution modeling have surged in popularity, as they avoid the computational burdens required for full chemical transport models discussed above. Examples of these RCMs are EASIUR, AP3, and InMAP (Gilmore et al. 2019). These models calculate total $PM_{2.5}$ from precursor pollutants, including primary $PM_{2.5}$, NO_x, SO_x, and NH_3, at different resolutions: EIASUR at a 36 × 36-km pixel, AP3 at the county level, and InMAP at a varying grid of 1 km × 1 km in urban areas and 48 km × 48 km in rural areas. These models have improved researchers' overall access to more sophisticated pollution transport models, though caveats and inconsistencies of the RCMs have been documented (see Gilmore et al. 2019).

Satellite Data

Recent advances in satellite data availability have also allowed for research at finer spatial scales and various time resolutions. Most of these satellite products measure aerosol optical depth (AOD), which measures aerosol optical thickness based on how the atmosphere reflects both visible and infrared light. Di et al. (2016) use MODIS AOD data together with a neural network to predict daily $PM_{2.5}$ concentrations in the United States at a 1 × 1-km grid cell-level resolution. Di et al. (2019) use machine learning algorithms such as random forests, gradient boosting, and neural networks to estimate $PM_{2.5}$ levels at a 1 × 1-km resolution across the United States. Hammer et al. (2020) use a combination of satellite remote-sensing data with chemical transport modeling and geographically weighted regression to predict annual $PM_{2.5}$ concentrations at a 1 × 1-km resolution.

These satellite products have been validated using monitoring station data; however, they can also underestimate total $PM_{2.5}$ concentrations in some areas (Fowlie, Rubin, and Walker 2019). One potential problem with these pollution products is that the construction and training of the data are based on the location and data availability of the existing pollution monitoring networks. However, monitoring can depend on demographic characteristics; for example, disadvantaged areas may be less thoroughly monitored (Grainger and Schreiber 2019; Mu, Rubin, and Zou 2021; Zou 2021). For example, Grainger and Schreiber (2019) find that regulators tend to avoid monitoring pollution in pollution hotspots, especially in poor areas. Although improvements in satellite data can provide opportunities for measuring pollution concentrations in spatially disaggregated areas, finding nonbiased approaches to calibrating the data remains an important area for future research.

Crowdsource Pollution Monitoring

The recent deployment of "consumer" air quality monitors provides opportunities to observe air qualities at finer geographies in a wider array of places. However, residents of disadvantaged areas may be less likely to adopt those monitors. Singer and Delp (2018) compare air quality measurements from these monitors, including AirBeam, AirVisual, Foobot, and PurpleAir. They find that, although the estimated concentrations of particles at a given time were similar for all four of these measurements, all of the consumer monitors and both research monitors that were studied substantially underreported emissions for particles smaller than 0.3-μm diameter.

Short- and Long-Run Outcomes

Another decision point occurs in this literature when connecting a particular environmental burden to the policy-relevant outcome of interest. Examples of outcomes of interest include pollution concentration, population-weighted pollution concentration or exposure, or human health damages from pollutants. Differences in this choice reflect different research questions and will include or exclude different dimensions of environmental justice. For example, differential pollution concentrations across population groups may ignore differential abilities to adapt to pollution across these groups, which has an impact on health outcomes. Studies focusing on characterizing disparities in concentrations and exposure (Colmer et al. 2020; Currie, Voorheis, and Walker 2020) calculate the exposure gaps as the difference in pollution concentrations (weighted or unweighted) across demographic groups. Studies characterizing exposure gaps in damages calculate the differences in hospitalizations, mortality, and morbidity by race or income groups (Gillingham and Huang 2021).

For some of the environmental hazards being studied, notably, air pollution, human health, and socioeconomic impacts, are expected from long-term exposure rather than short-term shocks. Further, people are mobile, and their location choices may change over time. In these cases, understanding disparities in human health impacts from environmental hazards requires tracking people's exposure to pollution over time, while incorporating changes in residential locations. Recently, the availability of long-term panel data has made such research designs possible. In several first-of-their-kind studies,[2] Voorheis and coauthors use newly linked survey and administrative records to create long panel data that facilitate studies of pollution exposure over time (Voorheis 2017a, 2017b; Colmer and Voorheis 2020).

Voorheis (2017a) connects these administrative records to satellite measurements of ground-level concentrations of fine particulate matter to study longitudinal trends in pollution exposure from 2000 to 2014. The work confirms that environmental inequality has been declining but finds that this result masks patterns over time. On average, pollution reductions over this period are larger among whiter and richer individuals than they are for minority and poorer individuals. Long panel data also allow for the study of intergenerational pollution exposure. Voorheis (2017b) uses administrative data to study the impact of pollution exposure at birth on outcomes as an adult, finding that pollution exposure at birth has significant effects on high school completion, college attendance, and incarceration. Colmer and Voorheis (2020) develop a data set that links parents and children, finding that air quality improvements induced by regulations while children are in utero increase second-generation college attendance, a result that appears to stem from parents' resources and investments rather than biological channels.

[2]Other papers have also used administrative data to study longer-term pollution exposure effects, though without a focus on distributional impacts by race and income. These include Bishop, Ketcham, and Kuminoff (2018) and Deryugina et al. (2019).

These longitudinal studies, made possible through the application of newly linked long panel data, provide novel insights into the intergenerational effects of pollution exposure, opening the door for further research into the intergenerational consequences of environmental injustice.

Discussion

A key development in the last decade of work in this area regards the documentation of underlying selection and bias in off-the-shelf data sources. Pollution monitors, for example, can be strategically located by decision makers. Or they can have systematically less coverage across minority or poor communities. Improvements in satellite data availability and the use of atmospheric transport models have allowed researchers to use finer-scale pollution exposure measures, without being limited to the administrative geographic units of strategically placed pollution monitors. Strategic placement is an example of selection bias, which occurs when the data are limited or biased due to choices that people make in providing information or participating in an activity. Economists are well versed in the perils of selection in biasing their estimation of effects. Our profession needs to continue to apply these fundamental tools to estimation in the environmental justice arena. Likewise, administrative agencies can play a role in refining state and federal reporting requirements to promote either more comprehensive data collection or randomized data collection. Research has also demonstrated the pitfalls of aggregating sociodemographic characteristics to larger geographic boundaries (Baden, Noonan, and Turaga 2007). And recent increases in data availability have allowed researchers to make use of finer-scale pollution and demographic data, overcoming at least some of the aggregation issues in earlier work. Further, the recent availability of longitudinal pollution and demographic data has allowed for burgeoning work in intergenerational pollution exposure.

Meanwhile, the literature continues to lack consensus on the objective function, or the goal of, environmental justice policy, which is likely in part due to difficulty of connecting pollution exposure to individual measures of welfare. Studies have instead taken an array of approaches to defining environmental inequality and disparities in pollution exposure. Some calculate the average difference across minority groups or income levels (Fowlie, Holland, and Mansur 2012; Currie, Voorheis, and Walker 2020), whereas others have calculated the concentration distribution of pollution exposure across demographic groups using measures of inequality such as the Gini coefficient or the Atkinson index (Clark, Millet, and Marshall 2014; Boyce, Zwickl, and Ash 2016; Holland et al. 2019). Studies using inequality indexes estimate the extent to which existing pollution concentrations deviate from equal distributions of pollution concentrations. Notably, Clark, Millet, and Marshall (2014) find that the inequality in pollution exposure to NO_2 is larger than the income inequality in the United States. Boyce, Zwickl, and Ash (2016) show that the Gini coefficient for toxic exposure in 2010 was even more unequal than income equality measured by the Gini coefficient. Moreover, analyzing inequality coefficients in pollution exposure can yield different policy implications than when looking at average pollution exposure across groups. Holland et al. (2019) find large differences in inequality of damages associated with different pollution sources—when comparing the Gini coefficients, damages from gasoline vehicles are more concentrated compared with damages from electric vehicles. Mansur and Sheriff (2021) use alternative methodologies derived from the income inequality literature to estimate the distributional impacts of a cap-and-trade program in Southern California. Using representations of inequality known as generalized Lorenz curves and equally distributed equivalents, the authors rank policies in terms of pollution distributions across groups. Their methodology allows preferences to be included when characterizing trade-offs across different policies.

Much of the recent literature studies environmental justice in the context of air pollution, with less research on other types of pollution, such as water pollution. However, studies have estimated the impact of other types of pollution, such as water pollution, on infant health (Currie et al. 2013, Flynn and Marcus 2021). To our knowledge, the impact of water pollution on environmental justice remains a gap in the literature. Linking water pollution to affected communities is difficult because it requires modeling the catchment area of rivers, streams, and sources of drinking water. Keiser and Shapiro (2019) and Andarge (2020) use the National Hydrography Dataset, which delineates a network of all surface waters in the United States and describes the flow direction of rivers and streams; this allows the authors to characterize whether a location is upstream or downstream from rivers and streams. Hill and Ma (2021) create a novel data set from several administrative data sources to study the impact of fracking on water quality. These empirical approaches offer guidance to future research studying disparities in access to safe drinking water. Policy makers and state and federal agencies can also help here—expanding the data collection processes on air pollution to other types of pollution would offer a pathway for the next decade of research to study other environmental hazards.

Studies measuring pollution impacts on disadvantaged communities often associate pollution exposure based on individuals' place of residence. However, depending on the occupation and commuting patterns for work and school, location of residence may be a poor indicator of total pollution exposure. Yet filling in the research gap characterizing differences in exposure to pollution at home, school, and work has been stalled by data availability. Because these differences can have important implications for anticipating the effects of place-based policies, the research community would do well to work with regulators on methods to fill in these gaps. The EPA has also developed methods for assessing environmental justice, publishing a *Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* in 2016, which describes methodological practices to consider when assessing environmental justice concerns. Among other contributions, the guidance proposes a set of best practices, which relate to several topics discussed throughout this article, such as the selection of a comparison group, the selection of the geographic unit of analysis, the measurement of cumulative or interacting impacts, and other methodological decisions to examine environmental justice in EPA decisions.

Conclusion

The last 10 years have seen a marked increase in the documentation of many dimensions of environmental justice, as well as improvements in data collection and methodologies. Increasingly sophisticated pollution transport models have allowed for improvements in linking pollution sources to places and people. And the use of administrative records to observe location decisions over time and more sophisticated ways to model pollution distributions over space have both been key advancements in connecting residential choices to pollution exposure. Yet empirical researchers can only study what they observe, and much of the work in this review is focused on air pollution, due to the availability of data. Environmental justice research in water pollution, for example, is notably lagging. Expanding pollution monitoring across places and types of pollution would be a straightforward way to make progress on environmental justice goals in the near term. Finally, a small but growing share of the recent literature studies the causal mechanisms that determine disparities in pollution exposure. Analyzing the impacts of future policies on environmental justice will require a continued focus on understanding where the injustice comes from.

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