Comments to the Texas Commission on Environmental Quality on the 2023 Amendment to the Concrete Batch Plant Standard Permit (Non-Rule Project No. 2022-033-OTH-NR)

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Attention Non-Rule Project No. 2022-033-OTH-NR

On behalf of myself and my colleagues Alex Hollingsworth and David Konisky, I am pleased to share with you the attached comments on the Texas Commission on Environmental Quality (TCEQ) 2023 Amendment to the Concrete Batch Plant Standard Permit.

My colleagues and I have completed a research paper (attached as part of this public comment and available on-line at `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4470152`) examining concrete batch plant emissions and siting in Harris County. We are compelled by our expertise to comment on the agency's proposed amendment to revise the Air Quality Standard Permit for Concrete Batch plants.

Based on our research, we believe that the agency's proposed amendment does not address the substantial threat to air quality imposed by Concrete Batch Plants in Harris County. In addition, the amendment fails to consider the disproportionate burden that Concrete Batch Plant siting imposes on low income and minority communities in Harris County.

If you have any questions or would like additional information please contact me at `nzirogia@indiana.edu`.

Sincerely,

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1 Key findings

- Concrete Batch Plants in Harris County are collectively a major pollution source, contributing between 38-111 tons of primary $PM_{2.5}$ emissions and between 109-493 tons of primary PM_{10} emissions. Estimates from an integrated assessment model suggest health damages from the $PM_{2.5}$ emissions alone amount to $29 million annually.
- Concrete Batch Plants in Harris County are disproportionately located in census tracts with more low-income, Hispanic, and Black populations, thereby raising important environmental justice concerns.
- The 2023 Proposed Amendment does not address important limitations in Concrete Batch Plant permitting and operations. TCEQ should mandate air quality monitoring and emissions reporting from Concrete Batch Plants. In addition, the agency should consider cumulative environmental and health impacts of those facilities as part of the permitting process.

2 Concrete Batch Plants in Harris County are collectively a major pollution source

There is substantial uncertainty around the environmental impacts of Concrete Batch Plants (CBPs) operating in Texas, in part because TCEQ has no emissions reporting requirements for CBPs in the state. So long as CBPs remain below the maximum allowable emissions thresholds listed on their permit, and as long as that limit is below 100 tons of Particulate Matter (PM_{10} and $PM_{2.5}$) emissions per year, they are not required to report their emissions to the Texas Emissions Inventory. As a result, emissions from only three Concrete Batch Plants are included in the Environmental Protection Agency's National Emissions Inventory. In addition, emissions from CBPs in Texas are not included as part of ”Area Source” emissions in the National Emissions Inventory. At the same time, the 2017 US Economic Census lists 534 CBPs operating in Texas. The large discrepancy (3 Texas CBPs in the National Emissions Inventory vs. 534 in the Economic Census) highlights the vast uncertainty that exists around the impact of CBPs on air quality. The Air Quality Analysis (AQA) conducted by TCEQ to support the 2023 Amendment therefore relies on modeling estimates that fail to account for the actual implications of concrete batch plant operations.

To address this uncertainty, we collected PM_{10} and $PM_{2.5}$ emissions thresholds from the air permits of all 131 Concrete Batch Plants that were active in Harris County as of 2021. Based on our analysis, detailed in section 2.1 and 3.1 of Zirogiannis et al. (2023) we find that all CBPs in Harris County are, collectively, a major pollution source, contributing between 38-111 tons of primary $PM_{2.5}$ emissions (between 26%-76% of $PM_{2.5}$ from the median Texas oil refinery) and between 109-493 tons of primary PM_{10} (between 64%-290% of PM_{10} from the median Texas oil refinery).

To estimate how those emissions affect human health, we use the Estimation of Air pollution Social Impact Using Regression (EASIUR) model, a reduced complexity integrated assessment model developed by Heo, Adams and Gao (2016). Using the direct emissions of $PM_{2.5}$ from CBPs in Harris County, the EASIUR model predicts two premature mortalities a year, amounting to $29 million in annual health damages.

3 Concrete Batch Plants in Harris County are disproportionately located in census tracts with low-income and minority populations

To examine the siting patterns of CBPs in Houston, we perform a statistical analysis that examines the correlations between census tract sociodemographic attributes and the number of nearby plants. Our analysis considers the number of CBPs within a 5 mile radius of a each of the 786 US Census tract centroids in Harris County. We also conduct additional analyses that considers a 0.5, 1, 2, 3 and 4 mile radii as alternatives. Controlling for proximity to highways and population density, we find that CBPs tend to be consistently located near census tracts with a higher share of low-income, Black, and Hispanic residents. The 2023 proposed amendment does not address the incidence of disproportionate siting of CBPs close to those communities. Given the nature of CBP operation and the fact that PM_{10} and $PM_{2.5}$ emissions are released close to ground level, it is very likely that low income and minority communities experience the largest share of the health impacts of pollution exposure.

4 The 2023 Proposed Amendment does not address important permitting and operational limitations

Based on the findings of our research we believe that CBP operations pose significant risks to the health and well-being of nearby communities. Moreover, TCEQ has very limited information to fully evaluate the extent of those risks. The agency should add air quality monitoring and reporting as part of CBP permitting, something the proposed amendment does not consider. It is important to note that the current network of regulatory-grade PM monitors in the United States is scattered and intermittent (Zou 2021), and unable to capture neighborhood-level effects of small sources. This is evident in the Air Quality Analysis that accompanies the proposed Amendment which is based on a single PM_{10} and $PM_{2.5}$ air quality monitor for each TCEQ region, failing to capture geographically-granular ambient pollution effects. In addition, the amendment does not require air quality modelling as part of the CBP permitting process. This makes the estimation of CBP-specific and industry-wide cumulative air quality impacts infeasible. EPA has recently acknowledged this problem and highlighted the need for estimation of cumulative impacts of exposure as part of the permitting process of industrial facilities (Reilly 2022). We urge TCEQ to consider the findings outlined above and conduct a thorough inventory of CBP emissions as well as mandate detailed recording keeping and reporting emissions requirements from CBPs. In addition, the agency should carefully consider the environmental justice implications of CBP siting and protect communities that are overly exposed to CBP emissions.

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Polluting under the radar: Emissions, inequality, and concrete batch plants in Houston

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Abstract

Small industrial sources collectively release large amounts of pollution, including particulate matter (PM) contributing to air quality problems in the United States and elsewhere. We study one such type of industrial facility, concrete batch plants, and analyze PM emissions and siting patterns of 131 plants located in Harris County, Texas. We find that concrete batch plants in Harris County are collectively a major pollution source, contributing between 38-111 tons of primary $PM_{2.5}$ emissions (between 26%-76% of $PM_{2.5}$ from the median Texas oil refinery) and between 109-493 tons of primary PM_{10} (between 64%-290% of PM_{10} from the median refinery). Estimates from an integrated assessment model suggest health damages from the $PM_{2.5}$ emissions alone amount to $29 million annually, reflecting two additional premature deaths per year. We further find that concrete batch plants in Harris County are disproportionately located in census tracts with more low-income, Hispanic, and Black populations, thereby raising important environmental justice questions. On the basis of these findings, we argue that small pollution sources require more air quality monitoring and emissions reporting and that regulatory agencies should consider cumulative environmental and health impacts of these sources as part of the permitting process.

Keywords: concrete batch plants, air pollution, Houston, particulate matter

Synopsis: Concrete batch plants have faced little scrutiny from environmental regulators even though collectively they are large emitters of particulate matter.

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1 Introduction & Background

Exposure to air pollution is a leading cause of premature mortality across the world. According to the World Health Organization, outdoor ambient air pollution resulted in 4.2 million premature deaths worldwide in 2016, with fine particulate matter ($PM_{2.5}$) being the main driver of pollution exposure (1). Various studies have examined the global premature mortality impacts of $PM_{2.5}$, reporting estimates ranging from 3.2 million (2) to over ten million deaths annually (3).

Although most of these deaths occur in low- and middle-income countries, poor air quality also results in substantial premature mortality in many high income countries like the United States. Studies have estimated that U.S. excess deaths attributable to $PM_{2.5}$ are over 100,000 annually (4; 5). Moreover, exposure to $PM_{2.5}$ and other air pollutants is not evenly distributed across the population, often disproportionately affecting people of color and those experiencing poverty (6; 7; 8). Economists have estimated the monetized health damages from PM pollution to be over $1 trillion or 5% of U.S. gross domestic product (9).

Given the strong evidence that exposure to PM not only results in premature mortality but extensive morbidity, it is no surprise that particulate pollution is a central focus of air pollution policy in the United States. The U.S. Environmental Protection Agency (EPA), for example, has authority under the U.S. Clean Air Act (CAA) to set national ambient air quality standards for PM, and the agency does so separately for $PM_{2.5}$ and PM_{10} (10). EPA also regulates sources that emit primary PM and precursor pollutants on a facility-by-facility basis. These programs (e.g., New Source Performance Standards), however, tend to focus on large industrial point sources (e.g., power plants, oil refineries, incinerators) and mobile sources, particularly those that emit large quantities of precursor pollutants such as sulfur dioxide and nitrogen oxides.

Operating largely under the radar are small industrial sources of primary PM pollution. These facilities are typically managed under general, as opposed to facility-specific, permits that require comparatively less documentation and undergo less rigorous review by regulatory agencies.

Existing research has demonstrated that small industrial emissions sources can diminish nearby air quality and increase adverse health risks. Researchers for example, have studied metal recycling facilities (11; 12; 13; 14), urban oil wells (15; 16), dry cleaners (17), and restaurants (18; 19; 20). In most studies, researchers use either stationary or mobile sensors to measure ambient concentrations of pollutants at different distances from the point sources of emissions, often focusing on race- and income-based disparities in exposure (15; 16; 20). Related work takes a "hot spots" approach whereby researchers identify areas of high pollution concentration, which can then be attributed to sources (21). In general, however, work in this area remains sparse compared to studies of larger industrial emissions sources for which data are more plentiful.

The focus of this study is concrete batch plants (CBPs), which are one such small source of primary PM. CBPs are facilities that collect, store, and combine ingredients - aggregate, cement, sand, water, and other raw materials - to create ready-mix concrete, which is then loaded on to mixer-trucks and delivered to construction sites. CBPs as pollution sources are important to study for several reasons. First, although individual plants emit modest amounts of PM (at least compared to sources such as power plants or oil refineries), as an industrial category, their aggregate emissions are quite substantial. Second, CBPs can be located in close proximity to population centers, particularly in places without stringent zoning and setback requirements. And, third, CBPs are regulated primarily at the local or state level where decision-making is often less transparent.

CBPs have received some attention in the environmental science literature. One analysis performed by the California Air Resources Board (CARB) examined the distribution of PM size of concrete batching, finding that 40 percent of the total PM emitted from CBPs is PM_{10}, and 6 percent is $PM_{2.5}$, with the rest of the PM being coarser and larger size (22). Other research examines water, and waste pollution from CBPs (23; 24; 25), as well as air emissions of sulfur dioxide and hydrogen sulfide (26) and the health impacts of $PM_{2.5}$ emissions on workers employed in a CBP in Indonesia (27). Only a couple of published studies evaluate PM pollution from these industrial facilities in the United States. As part of a community health and air quality monitoring study in a neighborhood of Washington, DC, one study measured PM pollution with a stationary monitor in an area with a couple of CBPs, finding levels below EPA standards (28). In a study of urban air pollutants in Houston, Texas, researchers using mobile air quality monitors for black carbon, particulates, and nitrogen oxides, found elevated concentrations of these pollutants in close proximity to four of seventeen CBPs in the 24 census tracts sampled (29). These studies provide important insights into PM emissions around these industrial sites, but, to date, there are no studies that have systematically investigated emissions from all CBPs in a large geographic area, which is the objective of this work.

A main reason for the gap in our understanding of the environmental impacts of CBP operation is the lack of reporting requirements. The National Emissions Inventory (NEI), the main EPA database that keeps track of annual emissions levels of criteria air pollutants, has reporting requirements only for facilities with "the potential to emit" at least 100 tons of PM per year (30). Overall, according to the NEI there were 1,124 CBPs operating in 32 U.S. states in 2017, with 84% of those facilities located in just six states (Kansas, Kentucky, North Carolina, Colorado, California, and Illinois). A different source of data on the number of CBPs is the U.S. Economic Census. This source provides a more accurate picture of the total count of facilities, since all businesses with a tax identifier are required to report their operation (31). According to the 2017 Economic Census, there were 5,579 active CBPs in the US, with the median state having 93 facilities. Figure 1 highlights the large discrepancy between the NEI and the Economic Census in the number of CBPs by state. For example, Texas, the state with the highest number of CBPs (534) in the country according to the Economic Census, reports data only on 3 plants to the NEI.

There is considerable variation in the way states regulate CBP operation and permitting. Almost all states classify CBPs as minor sources as long as they emit less than 100 tons of criteria pollutants per year. Many states have specific permitting programs targeted at CBPs exempting them from permitting requirements or allowing them to simply register with the state in lieu of obtaining an air quality permit. Section S.1 in the Supporting Information summarizes the results of 31 Freedom of Information Act (FOIA) requests to state Environmental Agencies with data on various permitting aspects of CBPs. Table S1 in the Supporting Information, highlights descriptive statistics for the total (across all CBPs) and median (per CBP) amount of PM_{10} and $PM_{2.5}$ emissions from states that report to the NEI.

In this study, we analyze CBPs located in Harris County, Texas, home to the Houston metro area. Houston is the fourth largest city in the United States and provides a useful empirical setting for studying CBPs because they are numerous and the city as a general practice does not use zoning ordinances. Those facilities are a major source of concern for communities that live close to them, a fact that has led to calls for action by local advocacy organizations and has resulted in legislative efforts from Texas state representatives. A detailed list of those efforts is provided in section S.2 of the Supporting Information.

Within Texas, CBPs are of particular concern in Houston because it is the only city in the US without a formal zoning policy. Houston does have some city-wide regulations that dictate development standards (e.g., minimum lot sizes, minimum parking requirements, street width and street block length) and subdivision-specific restrictive covenants may be used to separate residential and commercial uses (32). More detail on those regulations is provided in Section S.2 of the Supporting Information. However, as a consequence of the lack of city-wide zoning restrictions, CBPs (as well as other small pollution sources) have a less restricted set of siting locations compared to most other US cities where siting options are limited. This flexibility has both benefits and costs. On the one hand, a less restrictive set of siting locations can be beneficial for economic development since it allows CBPs to be placed near development projects, decreasing the costs of concrete delivery and, subsequently, the costs of construction. However, unrestricted siting can bring CBPs much closer to residential communities, city parks, schools, retirement homes or hospitals increasing exposure of vulnerable segments of the population to harmful PM emissions, noise and frequent traffic from concrete trucks (33; 34; 35).

We find that CBPs in Houston are collectively a major pollution source, contributing between 38 to 111 tons of primary $PM_{2.5}$ emissions per year (between 26%-76% the $PM_{2.5}$ emissions of the median Texas oil refinery) and between 109 to 493 tons of primary PM_{10} (between 64%-290% the PM_{10} of the median refinery). Integrated assessment models estimate the annual health damages of $PM_{2.5}$ emissions to be $29 million (in 2023 dollars), reflecting about two additional premature deaths per year. Second, we show that CBPs in Houston are disproportionately located in census tracts with more low-income, Hispanic, and Black populations, thereby raising important environmental justice questions about the siting and permitting process. In the concluding section of the paper, we discuss the implications of these findings and argue for the need of more air quality monitoring and emissions reporting from CBPs and other small sources of PM. In addition, we argue that regulatory agencies should consider not only facility-by-facility emissions releases but also the cumulative environmental and health impacts of minor sources of pollution as part of the permitting process.

2 Materials and Methods

Our analysis consists of two methodological approaches. The first approach is to assess the amount of PM emissions released from CBPs in Houston. The second approach is to examine whether the siting of CBPs disproportionately burdens low income and minority communities. Each approach makes unique contributions to the literature. First, we address the lack of information about CBP emissions in Texas, by compiling a novel dataset of permitted CBP emissions in Houston. Second, our analysis examining the environmental justice implications of CBP siting adds to the existing literature on pollution exposure from small sources. For each of those two approaches we discuss important limitations and ways we address them.

2.1 Estimated PM emissions

To analyze PM emissions from currently operating CBPs in Houston, we collected and processed emissions data from the permits of all 131 active (as of 2021) plants. These permits vary in the amount and type of information presented, but, in most cases, they include a facility's rate of PM emissions (in pounds per hour) – separately for PM_{10} and $PM_{2.5}$, the annual total amounts released (in tons per year) and their production capacity for concrete.

The permitting process for a new CBP varies substantially by state and is often contingent on the plant's operating capacity (more detail on state regulations is provided in Section S.1 of the Supporting Information). The Texas Commission on Environmental Quality (TCEQ) allows plants with capacity of $300\frac{yd^3}{hr}$ of concrete or lower to operate with a "standard" permit (also referred to as "permit by rule" or an "exempt" permit) (36). These types of general permits are applicable to facilities that "*will not make a significant contribution of air contaminants to the atmosphere*", a determination that is based on the $300\frac{yd^3}{hr}$ production capacity threshold alone (37). Because these permits are intended for minor sources of pollution, firms are neither required to perform air quality modeling as part of their permit application nor to report their annual emissions to the Texas Emissions Inventory. Regardless of the production capacity of a proposed CBP, TCEQ does not review the potential cumulative effects of having an additional pollution source to an area (38; 39). This is an important limitation of the permitting process, and EPA has recently acknowledged the need for incorporating cumulative impact assessments as part of the permitting process of industrial facilities (40).

Given the lack of an annual emissions reporting requirement for CBPs in Texas, the emissions thresholds data we collected from TCEQ permits are the only source of information for estimating CBP emissions. This presents a limitation, however, since there is no way of knowing if Houston CBPs emit below, at or over the threshold listed in their permit. To address this limitation we combine information on permitted emissions from Illinois CBPs (obtained through a FOIA request) and annual reported emissions to the NEI. Using those two sources of information, we are able to estimate the ratio of reported annual emissions to permitted emissions for Illinois CBPs. We use this ratio as an alternative approach to predict annual reported emissions of Texas CBPs.

To estimate how emissions affect human health, we use the Estimation of Air pollution Social Impact Using Regression (EASIUR) model, a reduced complexity integrated assessment model developed by Heo, Adams and Gao (41). The output of the model provides a monetized estimate of how damaging an additional ton of particulate matter from a particular place is with respect to human health. EASIUR estimates these marginal damages over the continental United States in 36 km square grids. The model allows for three different release heights (ground-level, 150 meter, and 300 meter), seasonality, choice of the value of a statistical life, and custom concentration-response relationships. The model accounts for mortality induced damages from particulate matter and other pre-cursors to particulate matter. Particulate matter represents the vast majority of damages from all pollution sources (over 90 percent) with non-mortality and non-particulate matter damages composing the remainder (42; 43, p. 7-15). The EASUIR model is based on the Comprehensive Air Quality Model with Extensions (CAMx) model. CAMx is an air quality model that simulates where pollutants released into the atmosphere will travel and how these emissions will affect pollution concentrations elsewhere, accounting for meteorological conditions, chemical reactions, atmospheric transport, dispersion, and removal. The EASIUR model produces comparable damage estimates to other chemical transport models and reduced complexity models, both directly used and coupled with BenMAP, including CAMx, AP2, AP3, InMAP, and SA Direct (44; 45).

Broadly the model takes reduced form estimates from CAMx of how releases of pollution in one place will affect concentrations of pollution elsewhere. Then these changes in ambient particulate matter concentrations are mapped into expected changes in mortality using a dose-response relationship estimated by Krewski et al. (46). The model can easily be adapted to account for the dose-response estimated by Lepeule et al. (47). These expected changes in mortality are then monetized using a Value of Statistical Life of $12.32 million (2023 $). While the underlying relationship between exposure and mortality is thought to be non-linear across the entire range of pollution exposure, EASUIR uses a linear approximation since the marginal damages are approximately linear over the observable range of particulate matter exposure (41).

2.2 Patterns of Concrete Batch Plant Siting

An extensive social science literature on environmental injustice demonstrates that various types of industrial facilities are more likely to be located in communities with higher proportions of people of color and low-income (48; 49; 50). The co-location of these types of facilities in these marginalized communities often results in disproportionate pollution burdens and their associated adverse health effects. To examine if this type of pattern exists with CBPs in Houston, we perform a statistical analysis that examines the correlations between census tract sociodemographic attributes and the number of nearby plants.

Figure 2 shows the location of 131 plants in Houston, overlayed on census tracts that each have, on average, a population of 4,000 people. To determine the number of active plants we obtained original permits and subsequent permit renewal documents from TCEQ's online dataset, for all CBPs (irrespective of size or permit type) that have a registered air permit in Harris County (51; 52). Once issued, standard permits are valid for 10 years. If in the course of those 10 years, a plant stops producing (goes out of business or otherwise ceases to operate) the owner is not required to inform TCEQ. As a result, TCEQ does not maintain a list of active and currently operating plants (53). News stories in the local media have reported the total number of CBPs in Harris County between 121 (35) and 188 plants (33), emphasizing the uncertainty around the exact count of these facilities. To address this uncertainty our analysis relies on the original permit documents, coupled with a visual inspection of aerial images of each plant, to determine the ones that are still active. Figure S4 in the Supporting Information provides two examples of our aerial image verification process.

The map in Figure 2 reveals a few patterns. First, CBPs are often located near highways and other major roadways, which makes practical sense because, once water, sand, and aggregate are added to cement, it needs to be delivered quickly to its end use location before it hardens and becomes unusable. Second, the plants tend to be located in more densely populated areas (reflected by the higher concentration of plants in geographically smaller census tracts). Third, there are few CBPs in the west central part of Houston, the part of the city with the highest average income and lowest percentages of Black and Hispanic residents, also known as the Houston "*Arrow*" (54). This last point is suggestive of disproportionate siting patterns, and has recently led EPA to investigate TCEQ permitting procedures for CBPs (55).

We run five OLS regression models that estimate the correlation between a series of socio-demographic variables and proximity to CBPs. The functional form of our models is the following:

$$\begin{aligned} \text{CBP}_{ir} = \; & \beta^{dem}\text{Demographics}_i + \beta^{den}\text{Population Density}_i \\ & + \beta^{highway}\text{Highway access}_{ir} + \beta^{inc}\text{Income}_i + \epsilon_i \end{aligned} \tag{1}$$

CBP_{ir} is the number of CBPs within r miles of census tract i centroid. To construct this dependent variable we identify the centroid of all 786 census tracts in Harris County (based on the 2010 census) and add up the number of CBPs within r miles (as the crow flies) of each tract's centroid (where r takes the value of 0.5, 1, 2, 3, 4 and 5 miles in separate regression models). β^{dem} is the main regression coefficient of interest, capturing the correlation between the number of CBPs and three different demographic variables, namely percent White, percent Black and percent Hispanic, all measured at census tract i. We run three separate models, where $Demographics_i$ captures either percent Black, percent Hispanic or percent White. Each of those three models controls for population density, proximity to highways and median household income of tract i. We control for population density to account for the fact that CBPs are more likely to be sited near densely developed areas where more construction sites are present. Similarly, given the importance of getting concrete (once poured) to the end user before it hardens, CBPs are more likely to be located near highway entry/exit ramps. Our Highway access_{ir} variable adds up the number of entry/exits ramps within r miles of census tract i centroid. We also control for median household income in all three models to account for the fact that CBPs are more likely to be sited in low income areas. We run an additional model where we drop our $Demographics_i$ variable to more accurately capture the correlation between median household income and CBP proximity, unconditional on racial and ethnic characteristics. Our fifth and final model, also drops $Demographics_i$ and replaces median household income with median home value.

Positive correlations between CBP_{ir} and our socio-demographic variables, if present, would be consistent with a pattern of disproportionate siting and permitting in Harris County, but our research design does not enable us to infer the cause of any such association. Siting of industrial facilities is determined by multiple factors including land value, proximity to raw materials and end users, access to transportation infrastructure, etc. In addition, discriminatory siting closer to marginalized communities, if present, could be a result of several factors. Regulators might choose to site noxious facilities near these communities, responding to pressure from citizen groups with political power to influence those decisions. CBP owners might also choose to locate near marginalized communities anticipating less opposition during the permitting process. These are mechanisms that our research design cannot address. Furthermore, our approach examines the correlation between the contemporaneous socio-demographic characteristics of census tracts and CBP siting. Our results might be different if we were to instead examine the same relationships at the time of siting (56). Those limitations aside, we believe it is important to document the incidence of environmental injustices in CBP siting, even if we cannot address the causes of those injustices.

To provide additional leverage, we perform a similar analysis for Cook County, Illinois (i.e., the Chicago metro area). Chicago is a good comparison for Houston in terms of overall population size, though it has fewer CBPs, higher population density, and a lower percentage of Hispanics. Table 1 compares Harris County and Cook County on several sociodemographic dimensions including race (percent Black, percent White) and ethnicity (percent Hispanic). Importantly, Chicago differs from Houston in that it has zoning which restricts the location choice set of CBPs. CBPs in Chicago are less likely to be located close to residential areas, given the presence of industrial zoned areas in the city. That said, Chicago has a long history of past discriminatory zoning regulations that affect minority communities (57).

3 Results and Discussion

3.1 Estimated PM emissions

To estimate the environmental impact of CBPs in Houston we begin by assuming that all plants emit at their permitted limit, an assumption that we will subsequently relax using our Illinois CBPs estimates discussed later in this section. Of the 131 CBPs that we have identified as currently in operation in Houston, 101 have information in their permit on production capacity and PM emissions. An additional 23 plants have production capacity thresholds but no emissions limits listed in their permits. We interpolate the emissions thresholds for those 23 plants based on the median level of emissions in plants with similar operating capacity (the details of the interpolation process and descriptive statistics of emissions are provided in section S.3 of the Supporting Information). We drop 7 plants that do not list operating capacity or emissions in their permits from this part of our analysis.

The cumulative total of $PM_{2.5}$ emissions from the 101 CBPs in our dataset that list PM thresholds in their permits – assuming that the plants are emitting at their maximum permitted level – is 111 tons annually. By comparison, annual $PM_{2.5}$ emissions from the median Title V source in Texas are 1.9 tons. Title V facilities are considered "*major*" sources of pollution for regulatory purposes according to the CAA. Considered in this way, Houston CBPs, collectively, rank as the 58th most emitting polluter in Texas out of a total of 1,752 Title V facilities reporting to the Texas Emissions Inventory (see Figure 3; since the distribution of $PM_{2.5}$ emissions is skewed to the right, Figure 3 uses a log-scale on the x-axis to illustrate $PM_{2.5}$ emissions). To place this estimate in context, these 111 tons of emissions are akin to almost one oil refinery's worth of directly emitted $PM_{2.5}$ in Harris County (median $PM_{2.5}$ emissions for a Texas refinery is 145 tons in 2019). PM_{10} emissions from the 101 plants that list emissions thresholds in their permits are 493 tons, which is equivalent to 290% of the PM_{10} emissions of the median Texas oil refinery. Additional results that include the 23 plants for which we interpolated emissions rates based on their production capacity are provided in section S.4 of the Supporting Information.

Our assumption so far has been that CBPs in Harris county emit at the maximum allowable level. This, however, might be implausible since plants might be operating below capacity. We use an alternative approach based on the ratio of reported (annual) to permitted emissions from Illinois CBPs discussed in section 2.1. We run an OLS regression of permitted thresholds for emissions on reported actual emissions for 316 CBPs in Illinois. We find that for every ton increase in the threshold, reported emissions of $PM_{2.5}$ increase by 0.037 tons/year. A detailed discussion of the data collection process in Illinois and associated regression models for $PM_{2.5}$ and PM_{10} emissions is provided in section S.4 of the Supporting

Information. We use this estimated regression coefficient and predict that reported $PM_{2.5}$ emissions for Houston CBPs are 38 tons/year or 34% of their maximum permitted emissions. The black dotted line in Figure 3 illustrates the logged value of the 38 tons/year estimate, ranking Houston CBPs as the 172nd most polluting facility in Texas (out of a total of 1,752 Title V facilities reporting to the Texas Emissions Inventory).

To help put these emissions in context, we use the EASIUR integrated assessment model to simulate the health damages attributable to these $PM_{2.5}$ emissions (58; 59). Using the direct emissions of $PM_{2.5}$ from CBPs in Harris County, the EASIUR model predicts two premature mortalities a year, amounting to $29 million in annual health damages. To account for both estimation uncertainty and uncertainty in the dose-response function, we have added four different 95% confidence intervals in Table S8 of the Supporting Information. Each confidence interval accounts for uncertainty in the dose-response relationship used in the EASIUR run. Two of the four confidence intervals also account for uncertainty in our estimation procedure of amount of emissions from batch plants. The first two confidence intervals use dose response estimates from Krewski et al. (46) and the second two use estimates from Lepeule et al. (47). Across all the confidence intervals the widest range of damages is from 7.6 to 49.4 million dollars (2023 $).

3.2 Patterns of Concrete Batch Plant Siting

The left column panels in Figure 4 show the estimated relationship between median household income, percent Hispanic, and percent Black and the number of CBPs within five miles of census tract centroids in Harris County, respectively. We also conduct sensitivity analyses using alternative buffers of 0.5, 1, 2, 3 and 4 miles that do not substantively affect our main results as illustrated in Figure S5 of the Supporting Information. We find that, as median household income increases, there are fewer plants in close proximity to the census tract [b = -7.4, p-value = 0.00]. A similar relationship holds when using median home value as an alternative measure of census tract wealth. The full sets of regression results for the 5-mile buffer are provided in Table S6 of the Supporting Information. In the case of percent Black and Hispanic, all else equal, the estimates suggest a positive association; more Hispanic [b = 2.8, p-value = 0.00] and Black [b = 4.1, p-value = 0.00] residents in a census tract is positively correlated with higher counts of nearby CBPs. The effect for percent Black is driven by 39 census tracts in Harris County with a share of Black population greater than 66%. When we exclude those 39 tracts from the analysis, the regression coefficient of Percent Black is still positive but no longer statistically significant. Taken as a group, therefore, CBPs in Harris County are disproportionately located in communities of color and low-income, which is consistent with expectations from the environmental justice literature. An analysis that uses the total amount of emissions released from CBPs as the dependent variable (as opposed to the count of CBPs within 5 miles of the census tract centroid) produces very similar results.

By comparison, we consider these same factors in Chicago. The regression estimates presented in the right column panels of Figure 4 suggest a similar negative relationship between median household income and the count of CBPs [b = -0.64, p-value = 0.00] – that is, as the median household income increases, the predicted number of nearby plants decreases. However, this result is not robust to alternative specifications of buffer size as illustrated in Figure S6a of the Supporting Information. Note that the magnitude of that coefficient is substantially lower in Cook County compared to Harris County, which is, in part, driven by the lower number of plants in the Chicago area. Using median home value as an alternative measure suggests a similar pattern, but the estimated coefficient is not statistically significant (see Table S7) nor is it robust to different buffer sizes (see Figure S6b). Moreover, the findings in Cook County are different than Harris County with respect to census tracts with more Hispanic and Black residents. Controlling for income, population density and highway access, the location of CBPs in Cook County is unrelated to the percentage of these population groups at the census tract level [Hispanics: b = -0.004, p-value = 0.978]; Black [b = -0.009, p-value = 0.947].

4 Conclusion

In this study, we examine the emissions and location patterns of CBPs in Houston, Texas. We find that these small industrial facilities are important sources of directly emitted PM pollution, and, collectively, generate substantial amounts of both PM_{10} (between 109 to 493 tons) and $PM_{2.5}$ (between 38 to 111 tons) emissions annually. Results from an integrated assessment model that monetizes the annual health damages from the $PM_{2.5}$ pollution alone yield an estimate of $29 million, reflecting two additional premature deaths a year. Moreover, our siting analysis reveals CBPs are more likely to be located in census tracts with lower median household incomes and higher percentages of Hispanic and Black residents. An analogous evaluation of CBP locations in Cook County shows that the findings for Hispanic and Black residents in Harris County differ from those of a similarly large U.S. city. An important difference between those two cities is the availability (Chicago) or lack (Houston) of zoning policies that restrict the location choice set of industrial facilities. Though our analysis is not able to identify the causal impact of zoning on CBP siting, it offers suggestive evidence that lack of zoning could be a contributing factor to disproportionate siting near minority communities. Collectively, these findings demonstrate that many historically marginalized populations in Harris County live in closer proximity to the PM_{10} and $PM_{2.5}$ emissions from CBPs, which is of particular concern in Houston because the city does not have the type of zoning ordinances that in other locations provide some safeguards from exposure to these emissions. Moreover, it is important to emphasize that while the analysis here focuses on just PM pollution, there are other implications of CBPs being in close proximity to populations, including noise, dust, and pollution from truck traffic.

The findings from this study underscore the importance of accounting for the impacts of small industrial sources of pollution, both in terms of their emissions and their proximity to vulnerable populations. However, our work is limited to just one type of pollution source in a single US geographic location. Additional research is needed to both analyze CBPs in other locations and consider other small sources of PM pollution, such as metal recycling facilities, dry cleaners, rock crushing plants, etc. These small sources are regulated in a similar fashion to CBPs, and are often permitted and sited without detailed air quality modeling, consideration of cumulative effects, and transparent community outreach processes.

Analysis of these small sources of PM (and other pollutants) would further benefit from localized air quality monitoring. The current network of regulatory-grade PM monitors in the United States is scattered and intermittent (60), and unable to capture neighborhood-level effects of small sources. In addition, local and state regulatory agencies engage in strategic behavior when siting and operating air quality monitors in order to avoid falling out of compliance with the National Ambient Air Quality Standards (61; 62). The availability of reliable, low-cost PM monitors (63; 64) enables the potential for real-time monitoring, and creates an opportunity for government agencies to require companies to perform such monitoring as a condition of operation. This type of monitoring is especially important in places like Houston, where the lack of zoning can place pollution sources in very close proximity to homes, schools, and other places of businesses.

In addition to more facility-level air quality monitoring, the tracking and understanding of small sources of pollution would benefit from more robust reporting requirements. For example, of the 131 currently operating CBPs in Harris County, Texas, only 1 is included in EPA's NEI. In fact, while 5,759 CPBs are identified in the 2017 Economic Census, only 1,124 appear in the NEI. This lack of reporting, coupled with TCEQ's lack of requiring air quality monitoring as part of a CBP permit application, makes the estimation of plant-specific and industry-wide cumulative air quality impacts infeasible. EPA has recently acknowledged this problem and highlighted the need for estimation of cumulative impacts of exposure as part of the permitting process of industrial facilities (40). A policy change by EPA to require more reporting from CBPs and other small sources of pollution, as well as more detailed air quality monitoring, would provide valuable information to communities, regulators, and other stakeholders.

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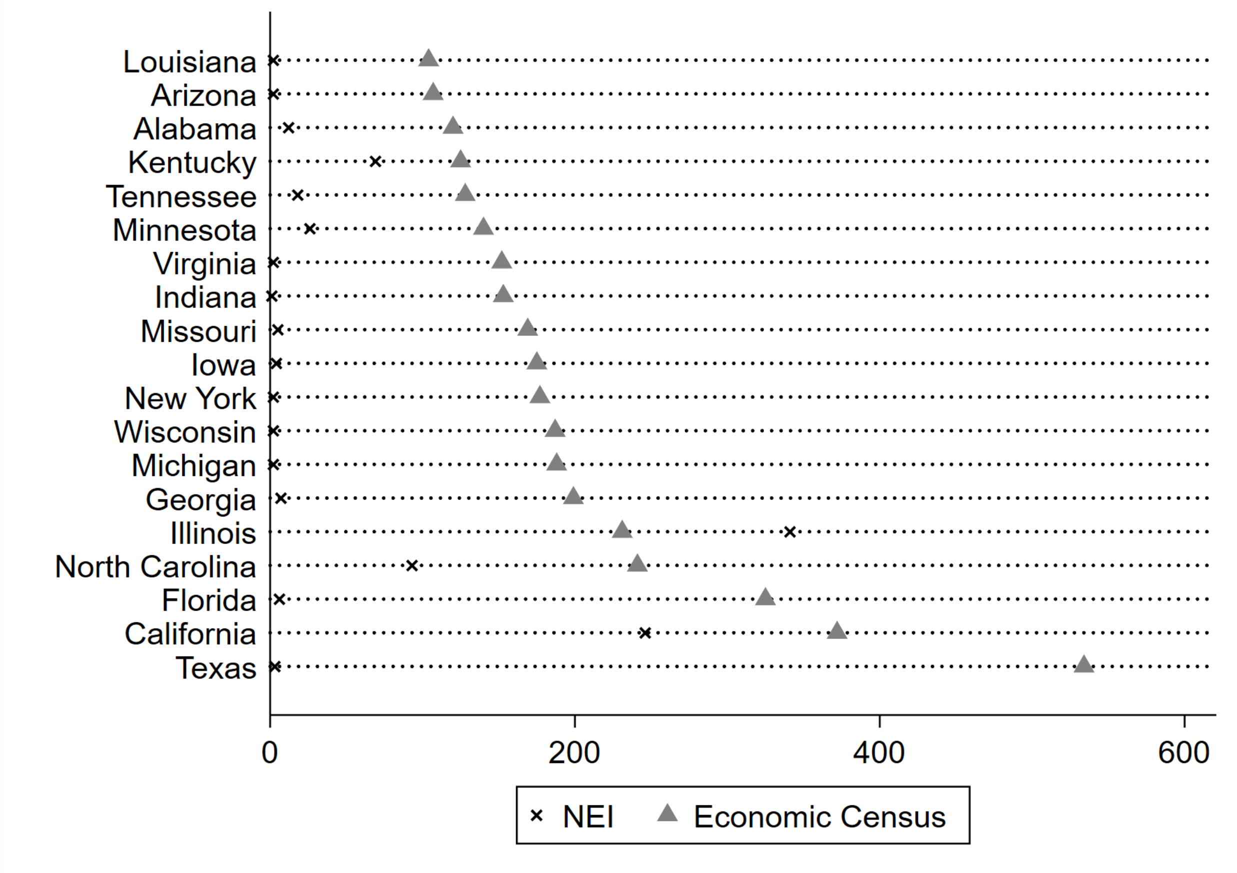
Table 1: Comparison of key demographic characteristics between Cook county, IL and Harris county, TX

	Cook County	Harris County
Total population (millions)	5.2	4.6
Land area (square miles)	945	1,703
Number of Concrete Batch Plants	32	131
Number of census tracts	786	1319
Percent Black	23.4	19
Percent White	56.7	62.5
Percent Hispanic	25.1	43

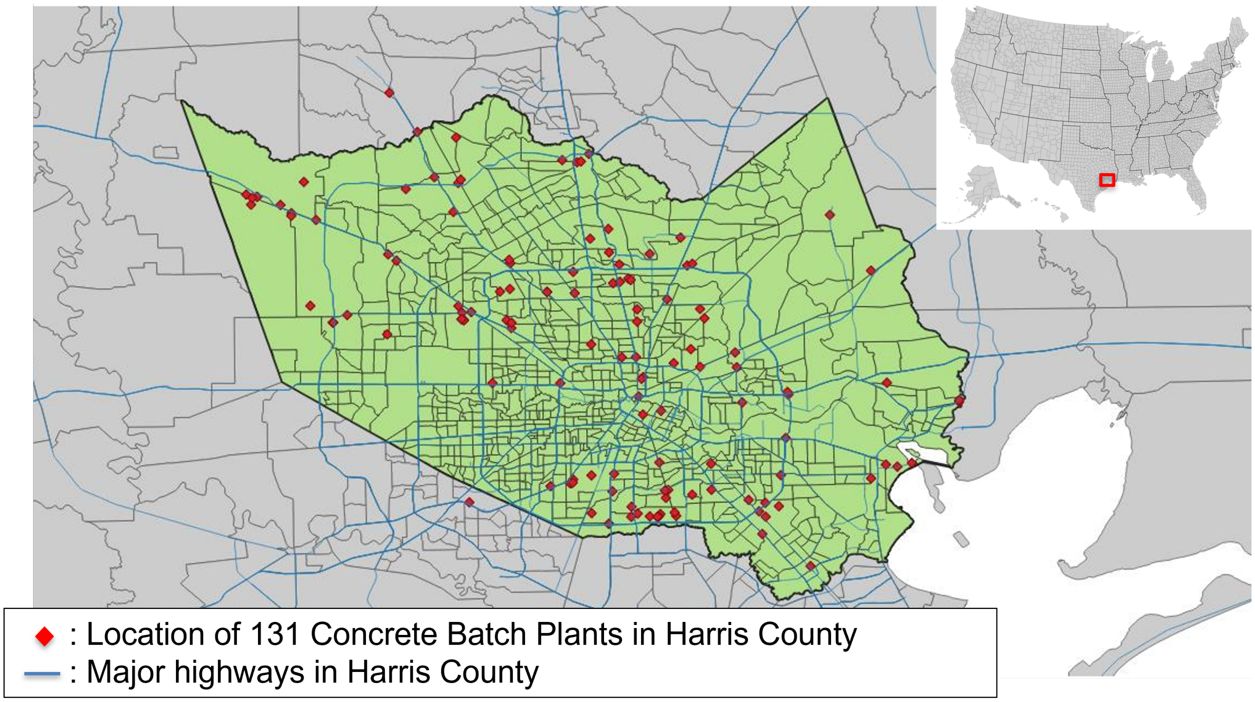
Source: American Community Survey, National Emissions Inventory, Texas Commission on Environmental Quality (65; 66; 51).

Figure 1: Number of concrete batch plants by state in the 2017 NEI vs. 2017 Economic Census



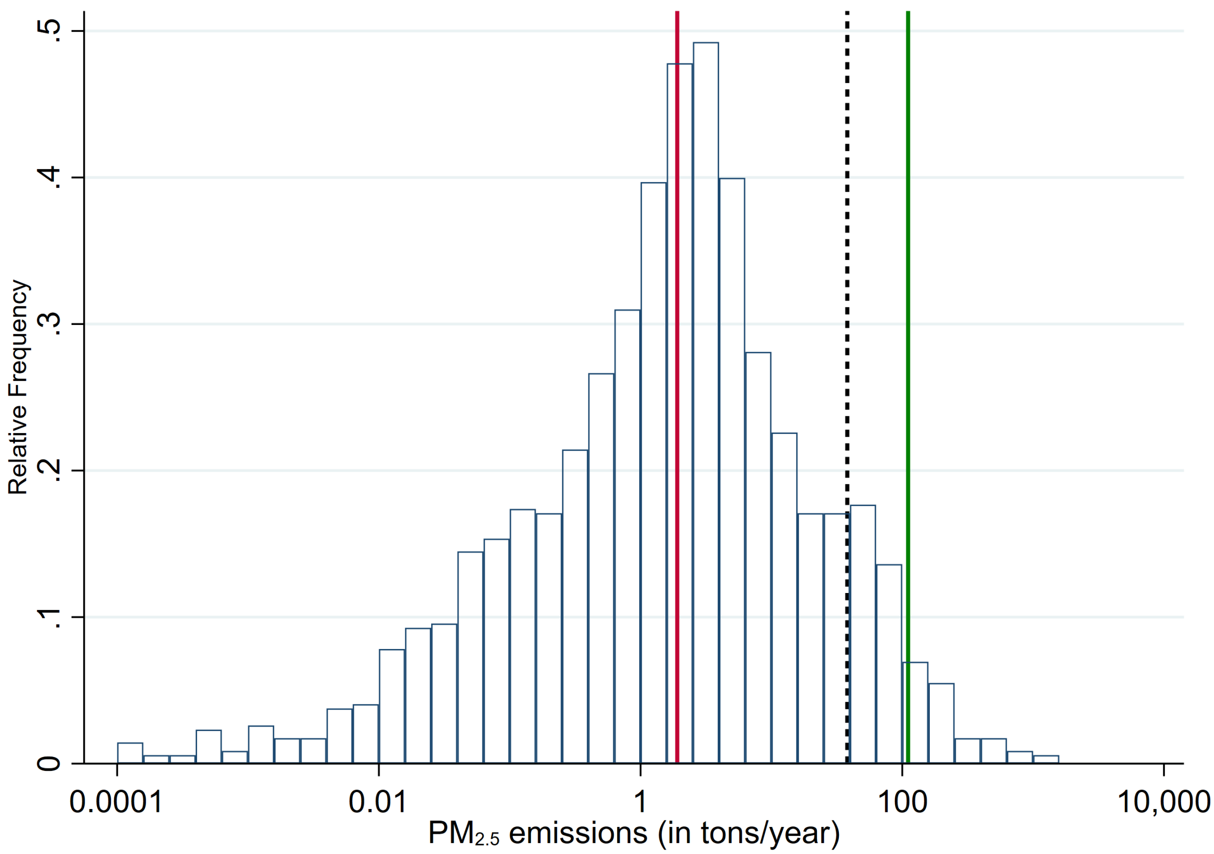
Note: States listed above are the ones reporting at least one concrete batch plant to the NEI and at least 100 plants in the Economic Census. Source: US Economic Census, National Emissions Inventory (31; 66)

Figure 2: Active Concrete Batch Plants in Harris County, Texas, 2021



Note: Data compiled by the authors using information from the Texas Commission on Environmental Quality (52). Three of the 131 plants illustrated on the map are just outside the border of Harris County, but we still include them in our siting analysis in section 3.2 given their close proximity to county borders. Removing those three plants from the analysis does not affect our results.

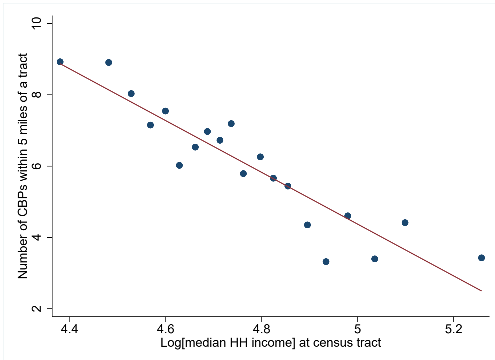
Figure 3: Distribution of $PM_{2.5}$ emissions by Title V facilities in Texas



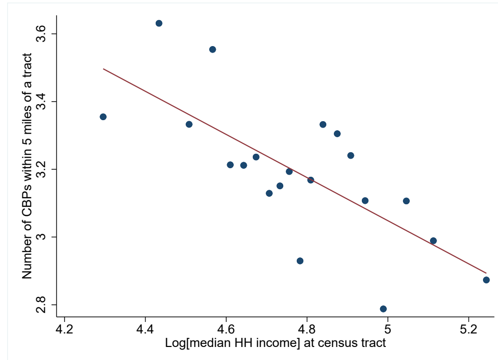
Note: Green line represents 111 tons of cumulative $PM_{2.5}$ emissions from 101 CBPs in Houston (based on the maximum allowable emissions threshold listed on CBP permits). Red line represents 1.9 tons of $PM_{2.5}$ emissions of the median TX Title V facility. Black dotted line is an alternative estimate of 38 tons of cumulative $PM_{2.5}$ emissions from Houston CBPs using the reported to permitted ratio of emissions from Illinois CBPs (discussed in section S.4 of the Supporting Information).

Figure 4: Binned scatter plots of proximity to CBPs in Harris and Cook counties by demographic characteristics

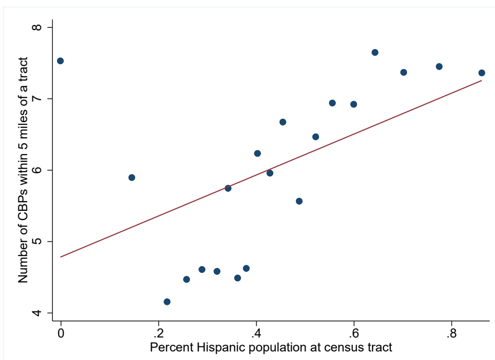
(a) Harris county; Median income



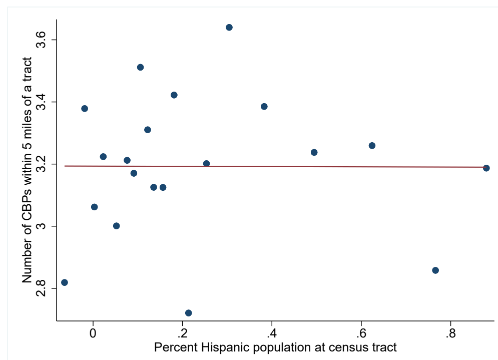
(b) Cook county; Median income



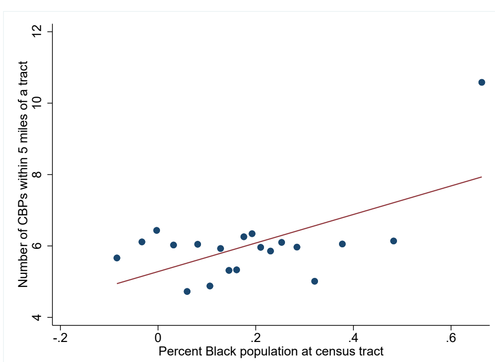
(c) Harris county; Hispanic



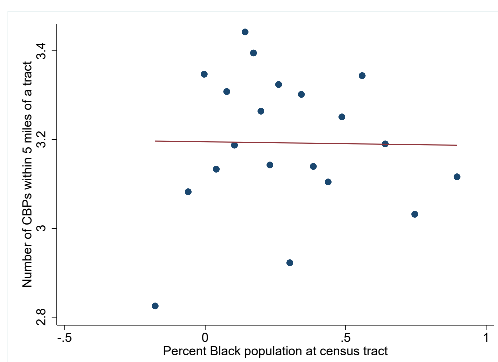
(d) Cook county; Hispanic



(e) Harris county; Black



(f) Cook county; Black



Note: All six panels control for population density and highway access. In addition, panels 4c-4f control for median household income.

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Supporting Information

Polluting under the radar:
Emissions, inequality, and concrete batch plants in Houston

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S.1 Permitting of CBPs in the US

In order to examine Concrete Batch Plant (CBP) permitting requirements and activity across multiple states, we submitted Freedom of Information Act (FOIA) requests to the state environmental protection agencies of 31 states. We submitted FOIA requests to states that had at least 1% of the total number of CBPs in the US (i.e. over 50 CBPs in the state) based on the information from the 2017 US Economic Census.[1] For each state, we asked to receive information on the number of CBPs that have received a permit since 1990, their permit status, their production capacity, reported emissions, type of permit and, more importantly, the maximum allowable emissions threshold for each CBP. Almost all states classify CBPs as minor sources as long as they emit less than 100 tons of criteria pollutants per year. Many states have specific permitting programs targeted at CBPs exempting them from permitting requirements or allowing them to simply register with the state in lieu of obtaining an air quality permit. Below we list all states that offer such programs along with the emissions or production thresholds that apply to their CBPs.

1. Alabama: The response to our FOIA request indicated that: *"There isn't any case by case or general air permits issued by [the Alabama Department of Environmental Management] ADEM for concrete batch plants.*"

2. Arizona: The state offers a Concrete Batch Plant General Permit to CBPs that have a throughput (production) rate of concrete at or below 2,000 yd^3/day. Larger CBPs that are considered minor sources and emit less than 100 tons of criteria pollutants per year must obtain a Class II permit (1; 2). Through our FOIA request we obtained information on 86 active CBPs in Arizona, 67% of which had a General Permit with the remaining 33% having a Class II permit.

3. Arkansas: While there is no specific permit type for CBPs, the state requires a minor source permit from facilities emitting between 25-100 tons/year of PM, or 15-100 tons/year of PM_{10}, and a simple Registration from facilities emitting 15-25 tons/year of PM, or 10-15 tons/year of PM_{10} (3). The Arkansas Department of Environmental Quality did not provide us with information on the permit type of CBPs.

4. California: The response to our FOIA request indicated that: *"The search for responsive records is complete. No documents were found responsive to this request. Clean Air Act permitting in California is the shared responsibility of the California Air Resources Board (CARB), its 35 air pollution control agencies (districts) and EPA Region 9.*

[1] We did not submit FOIA requests to Tennessee or Virginia. Those states require FOIA requests be made only by residents of the state.

Generally, CARB plays an oversight role for permitting and does not issue any pre-construction or operating permits. The information you are requesting may be found by contacting the local air districts themselves."

5. Colorado: CBPs in the state can obtain an Air Pollutant Emission Notice (APEN) as a substitute to an air quality permit. So long as the uncontrolled actual emissions (i.e. emissions that do not account for a pollution control device the facility might be using) are between 2 and 5 tons of criteria pollutants, the facility must submit an APEN and does not have to obtain an air pollution permit. Facilities emitting less than 2 tons of criteria pollutants don't have to submit any information to the state agency (4). Of the 219 CBPs that are active in Colorado (based on our FOIA request data) 216 were registered with the APEN program.

6. Florida: So long as CBPs emit less than 100 tons of PM, PM_{10} or $PM_{2.5}$ they can operate under an Air General Permit and are not required to submit any information on their production capacity or emissions rates to the state (5). Our FOIA request identified 736 CBPs registered with the Florida Department of Environmental Protection, 96% of which had an Air General Permit.

7. Georgia: CBPs can obtain a Minor Source permit as long as their PM emissions are less than 100 tons/year, which the state calculates based on emissions factors to correspond to a production capacity below 800,000 yd^3/year (6). Based on the response to our FOIA request, all 455 CBPs that are registered in Georgia have a minor source air permit.

8. Illinois: In 2012 the state implemented a Registration of Small Source (ROSS) program. The goal was to reduce the regulatory burden placed on small facilities that, following the implementation of the ROSS program, would simply need to register with the Illinois Environmental Protection Agency, instead of obtaining an air permit. The main requirement for inclusion in the ROSS program is that facilities have a combined amount of actual emissions for all criteria pollutants (PM, CO, NOx, SO2 and VOC) below 5 tons/year (7). We received information on 343 CBPs currently operating in IL through our FOIA request. Of those, 289 (84.2%) have a ROSS permit with the remaining 54 having a lifetime (non-ROSS) permit.

9. Indiana: CBPs in the state can obtain a Source Specific Operating Agreement (SSOA) so long as their PM and PM_{10} emissions are below 25 tons/year and their production capacity is below 300,000 yd^3/year (8). Our FOIA request returned 849 CBP permits in Indiana, all of which were registered under the SSOA program.

10. Iowa: The state issues operating permits only to Title V facilities. Facilities with the potential to emit at levels below those of Title V facilities (including CBPs) can obtain a Construction Permit so long as they emit less than 0.1 gr/dscf (grains per dry standard cubic foot) of PM (9). The Iowa Department of Natural Resources did not provide us with information on the permit type of CBPs.

11. Kansas: The response to our FOIA request indicated that: "*The Kansas Department of Health and Environment-Bureau of Air is only required to provide public records that already exist. There is no requirement for the agency (KDHE) or the bureau (Bureau of Air) to create a record upon request. The Kansas Open Records Act does not require an agency to provide raw data, answer questions or create reports.*"

12. Kentucky: The state has in a place a tiered system for permitting. No permit or registration is required for sources emitting less than 10 tons/year of criteria air pollutants. Facilities emitting between 10 to 25 tons/year are required to register with the state. A combined construction and operating permit for minor sources (state origin permit) is required for facilities emitting between 25 to 100 tons/year of criteria air pollutants (10). Based on our FOIA request data, 84% of the 296 CBPs that have been permitted in the state have a Minor Source operating permit, 13% are a Registered Source, and 3% are listed as unknown classification or insignificant source.

13. Louisiana: The state has a Regulatory Permit program specifically designed for Concrete Manufacturing Facilities under Section III-315 of the Louisiana Administrative code. The program lists specific requirements for pollution control device installation, but has no emissions rates thresholds other than a 20% opacity threshold for PM. Louisiana's Minor Source permits (also referred to as State permits) apply to facilities emitting more than 5 tons of any criteria pollutant (or more than 15 tons of combined criteria pollutant emissions) but with potential emissions less than 100 tons (11). Our FOIA request to the state resulted in 242 permits, 16% of which fell under the Section III-315 Regulatory Permit program. The remaining 84% were all Minor Source (or State) Permits.

14. Maryland: The state provides an Air Quality General Permit to Construct Concrete Batch Plants, with the goal of streamlining and facilitating the permitting process. CBPs can apply for a General Permit to construct if their PM emissions are less than 0.03 gr/dscf (grains per dry standard cubic foot) in Baltimore City and 6 other counties. In the rest of the state the threshold is 0.05 gr/dscf (12). Of the 52 active CBPs in our FOIA request, 46 had a General Permit to Construct.

15. Michigan: The state has a "Permit to Install" application, specifically tailored to concrete batch plants that lists specific limits for PM emissions rates based on the amount of production capacity. CBPs with capacity below 200,000 yd^3/year are exempt from obtaining a Permit to Install (13). Our FOIA request resulted in a list of 158 operational CBPs in the state but without any permit related identifiers.

16. Minnesota: CBPs in the state can obtain an Option D Registration Permit as long as their annual PM or PM_{10} emissions are below 50 tons/year each. The permit has specific requirements for pollution control devices and record keeping of annual or monthly emissions (14). Our FOIA request resulted in 102 CBP permits in Minnesota, 89% of which were Option D Registration Permits.

17. Mississippi: CBPs in the state can obtain a Ready Mix Concrete General Permit (RMCGP) so long as their production capacity does not exceed 1,000,000 y^3/year of concrete. The permit includes requirements for the use of baghouses, but there are no thresholds for PM emissions (15). All 160 CBPs that have been permitted in Mississippi (listed in our FOIA request) had an RMCGP.

18. Missouri: The vast majority of CBPs in the state operate under a Minor Construction Permit (246 of the 249 CBPs that hold an active permit). This permit is provided to facilities that exceed the state's "de minimis" emissions levels (25 tons/year PM, 15 tons/year PM_{10}, 10 tons/year $PM_{2.5}$) but are below Title V emissions thresholds (16).

19. Nebraska: The state provides an Air Quality General Construction Permit, designed specifically for CBPs that do not exceed 2,500 yd^3/hour and 900,000 yd^3/year of concrete production. For reference, the hourly threshold in Nebraska is eight times higher than the hourly threshold for Texas CBPs. Concrete facilities in Nebraska that operate using the General Construction Permit cannot exceed 45.53 tons of PM_{10} and 10.92 tons of $PM_{2.5}$ total emissions (including fugitive emissions). CBPs can alternatively obtain a Low-Emitter permit if their actual (as opposed to potential) emissions are below 50 tons/year for any criteria pollutant (17; 18). Our FOIA request to Nebraska resulted in 127 CBP permits, 76% of which were Air Quality General Construction Permits, with the remaining 24% being Low Emitter permits.

20. Nevada: CBPs in the state can apply for a Class II General Air Quality Operating Permit, so long as they meet specific PM emissions limits that are determined based on minimum setback requirements and maximum daily hours of operation (19). CBPs that do not qualify for a General Air Permit can obtain a Class II Air Quality Operating

Permit, so long as they can be considered minor sources (emissions lower than 100 tons/year of criteria pollutants). Of the 92 CBP permits we received through our FOIA request, 47% were Class II Air quality operating permits, 35% were General Permits, and the remaining 18% did not have a permit type identifier.

21. New Jersey: Our FOIA requests resulted in a list of 33 CBPs without any identifying information on the permit type. While the state offers a General Permit for Minor Source Facilities we were unable to identify any permit or registration program specifically targeted at CBPs (20).

22. New York: The state denied to respond to our FOIA request citing the following reason: "*Please note that FOIL pertains to existing records and states, in general, that an agency need not create a record in response to a request for information. Similarly, nothing in FOIL requires an agency to supply information in response to questions. The Committee on Open Government has repeatedly emphasized that FOIL is to be used as a tool for gaining access to existing records. Accordingly, your request is denied pursuant to NYS Public Officers Law.*"

23. North Carolina: The state operates a three-tiered permitting system that is applicable to CBPs. A General Permit for CBPs is available for facilities with production rates ranging from 327,000-1,358,000 yd^3/year (for central mix operations). The capacity range varies with the minimum distance of the mixing operation to the property line of the facility. Facilities that are not required to obtain a General Permit can simply register with the North Carolina Department of Environmental Quality so long as their combined emissions of criteria pollutants, Hazardous Air Pollutants (HAPs) and Toxic Air Pollutants (TAP) are between 5-25 tons/year. Facilities emitting less than 5 tons/year of any pollutant and less than 10 tons/year of combined criteria, HAPs and TAPs are exempt from permitting (21; 22). Based on our FOIA request data, of the 281 CBPs that are active in North Carolina, 73% are exempt from permit, 27% have a General Permit, and only 1 CBP has a registration.

24. Ohio: CBPs can obtain a Minor Source - Permit to Install and Operate (PTIO), also referred to as a non-title V permit (23). The state requires specific abatement methods be implemented (eg. fabric filters on fly ash and slag silos) so that particulate emissions do not exceed 5.31 tons/year from central mix facilities (where the ready mixed concrete is poured into the concrete truck) and 11.4 tons/year from truck mix facilities (where the dry materials are placed unmixed into the concrete truck). Truck mix facilities have a production threshold of 200 y^3/hr (250,000 y^3/year) while central

mix plants have a production threshold of 300 y^3/hr (300,000 y^3/year). Based on our FOIA request, the vast majority (85%) of the 379 CBPs that have at some point operated in Ohio received a Non-Title V permit (15% of plants did not have a permit classification).

25. Oklahoma: There are four different types of permits available for CBPs in Oklahoma: 1) Individual Minor Source Permit for sources emitting less than 100 tons/year of criteria pollutants, 2) General Permit for Nonmetallic Mineral Processing Facilities (GP-NMPF) with emissions of any regulated pollutant below 100 tons/year, 10 tons/year of any individual HAP and 25 tons/year of all HAPs, 3) General Permit for Area Source and Small Facilcities (GP-ASNF/SNF) with emissions of any regulated pollutant below 40 tons/year, 10 tons/year of any individual HAP and 25 tons/year of all HAPs, and 4) Applicability Determination for facilities that are not required to obtain an air permit, and have actual emissions of any regulated pollutant below 5 tons/year (24). The break down of the 72 currently active CBP permits in Oklahoma across those four categories is as follows: 45 permits under Applicability determination, 2 GP-ASNF/SNF permits, 1 GP-NMPF permit, 24 Individual Minor Source Permits.

26. Oregon: The state offers three types of permits for concrete manufacturing: 1) Basic Air Contaminant Discharge Permit (ACDP) for CBPs with a production capacity between 5,000 to 25,000 y^3/year, 2) General ACDP for CBPs with a production capacity above 25,000 y^3/year and PM_{10} ($PM_{2.5}$) threshold below 14(9) tons/year, 3) Simple ACDP with the same thresholds as the General ACDP, but given to portable CBPs or cement treated base CBPs (25). All 194 CBP permits obtained from our FOIA request to Oregon were General ACDP permits.

27. Pennsylvania: Minor sources can obtain a State-Only Operating Permit so long as their emissions are below 100 tons/year for any criteria pollutant. Pennsylvania offers exemptions from State-only permit to facilities emitting (among others) less than 3 tons/year of PM_{10} (26). CBPs can obtain an exemption as long as their PM emissions are below 0.01 gr/dscf (grains per dry standard cubic foot). Our FOIA request resulted in a list of 62 operational CBPs in the state but without any permit related identifiers.

28. South Carolina: Most CBPs in South Carolina operate under a General State Operating permit, targeted towards minor sources emitting less than 100 tons/year of PM_{10} and having a maximum production rate of 294 yd^3/hour. The state also has a Conditional Major permit applicable to facilities with the capacity to emit above Title V thresholds but that have invested in pollution control equipment that allows them to

stay below those emissions thresholds. Finally, CBPs can be exempt from permitting if their uncontrolled emissions are below 1lb/hour of PM (27; 28; 29). Based on the results of our FOIA request, of the 259 CBPs currently permitted in South Carolina, 13% have a Conditional Major Permit, 85% have a General State Operating Permit and only 4 facilities are exempt from permitting.

29. Texas: The Texas Commission on Environmental Quality (TCEQ) allows plants with capacity of $300\frac{yd^3}{hr}$ of concrete or lower, to operate with a "standard" permit (also referred to as "permit by rule" or an "exempt" permit) (30). These types of general permits are applicable to facilities that "will not make a significant contribution of air contaminants to the atmosphere", a determination based on the $300\frac{yd^3}{hr}$ production capacity threshold alone (31). A recent proposed amendment to the CBP standard permit, lowers this capacity threshold to $200\frac{yd^3}{hr}$ for some counties in the state and adds setback requirements for all plants (32). Because these permits are intended for minor sources of pollution, firms are neither required to perform air quality modeling as part of applications, nor do they have to report their annual emissions to the Texas Emissions Inventory. CBPs with an exempt permit do not have to inform abutting neighbors of the proposed siting during their application process. There is, however, a requirement to announce the submission of the permit application in the local press. Moreover, TCEQ is not required under state law to address any community concerns that arise, such as frequent noise (about half of the plants in the Houston area operate 24-hours/day), dust, or truck traffic and idling (33; 34).The permitting process for a new CBP with a production capacity greater than $300\frac{yd^3}{hr}$ falls under the CAA's New Source Review program, which TCEQ implements in Texas. Proposed plants at this scale must demonstrate (at minimum) the use of "Best Available Control Technology," which may include the installation and proper disposal of fabric filter baghouses when handling and reloading concrete as well as prewashing all aggregate material prior to delivery (35). In addition, there are some setback requirements, such as a standard that plants be at least 3,000 feet away from schools (34). Our FOIA request to the state resulted in a list of 9,336 CBP-related permits (issued to a total of 2,305 CBP facilities). Of those, 1,805 permits (issued to 1,652 facilities) appear as "issued" or "effective" (i.e. not listed as void or canceled). This highlights the uncertainty that exists within TCEQ as to the exact number of CBPs that are currently in operation, considering that the 2017 Economic Census lists 534 active operating CBPs. 96% of those 1,805 permits are either Standard Permits, Permits by Rule or Exempt.

30. Washington: CBPs can obtain a General Order Permit so long as their production

capacity is below 74,500 y^3/year (for truck mix plants) or 246,000 y^3/year (for central mix plants). Emissions thresholds for central mix (truck mix) plants that qualify for the General order permit are 36.33 (34.88) tons/year of PM, 7.32 (10.32) tons/year of PM_{10} and 0.2 (0.06) tons/year of $PM_{2.5}$ (36). The Washington Department of Ecology has 13 regional office. We only received responses from the Central and Eastern Regional Offices to our FOIA request. As a result we do not have a holistic view of the share of Washington CBPs that have a General Order permit.

31. Wisconsin: The state offers nine different permit types to CBPs, ranging from Major Source permits (for Title V facilities) to exempting facilities from any permit requirements, so long as they emit less than 10 tons/year of criteria pollutants (37). Our FOIA request resulted in permits of 21 CBPs only. This is a particularly low number, considering the fact that the 2017 Economic Census listed 187 CBPs in the state. In response to a question highlighting this discrepancy, the Wisconsin Department of Natural Resources suggested that: "*Other concrete batch plants may not be required to be permitted and therefore are not on the spreadsheet.*"

Table S1 highlights descriptive statistics for the total (across all CBPs) and median amount of PM_{10} and $PM_{2.5}$ emissions (per CBP) from states that report data on CBPs to the National Emissions Inventory (NEI). A small number of states (Illinois, California, Colorado and North Carolina) report large numbers of CBPs.

Table S1: Descriptive statistics (PM_{10} and $PM_{2.5}$ are measured in tons/year)

State	Economic Census Facilities	NEI facilities	Total PM_{10}	Median PM_{10}	Total $PM_{2.5}$	Median $PM_{2.5}$
Texas	534	3				
California	372	246	400	0.55	158	0.11
Florida	325	6	31	3.24	26	1.2
North Carolina	241	93	67	0.23	31	0.1
Illinois	231	341	449	0.66	132	0.22
Georgia	199	7				
Ohio	188	0				
Pennsylvania	188	0				
Michigan	188	2	1	0.68	.35	0.35
Wisconsin	187	2	15	7.41	5	2.4
New York	177	2				
Iowa	175	4				
Missouri	169	5				
Indiana	153	1				
Virginia	152	2				
Minnesota	140	26	50	1.86	19	0.79
South Carolina	135	0				
Oklahoma	134	0				
Tennessee	128	18	48	1.66	15	0.49
Kentucky	125	69	228	0.51	89	0.18
Alabama	120	12	52	2.65	28	1.23
Arkansas	108	0				
Arizona	107	2				
Louisiana	104	2				
Colorado	96	133	300	1.6	103	0.5
Washington	90	7				
Mississippi	84	0				
Nebraska	81	19	44	2.7	23	1.53
Oregon	76	3				
Kansas	74	59	11	1.18	4	0.41
New Jersey	68	0				

State	Economic Census Facilities	NEI facilities	Total PM_{10}	Median PM_{10}	Total $PM_{2.5}$	Median $PM_{2.5}$
Maryland	61	4				
Utah	51	3	22	22	4	4
South Dakota	49	0				
Nevada	48	21	49	0.31	3	0.12
West Virginia	48	0				
Massachusetts	41	21	19	1.04	15	0.64
North Dakota	39	0				
Wyoming	38	2	1	0.39	0.04	.002
Montana	37	0				
New Mexico	37	0				
Idaho	35	1				
Connecticut	29	0				
Maine	26	0				
New Hampshire	19	0				
Alaska	16	0				
Hawaii	14	0				
Vermont	12	0				
Delaware	10	1	0.06	.06	.06	.06
Rhode Island	0	4	1	0.2	0.33	0.07

S.2 Houston Zoning Policies and CBP related policy developments in Texas

Houston is the only major city in the US that does not have a formal zoning policy. However, a series of city wide regulations mandate standards that place some restrictions on development. Examples include minimum lot sizes, minimum parking requirements, street width and street block length requirements that inhibit high density residential areas from emerging. In addition, restrictive covenants are used as a means of separating residential and commercial uses. Those covenants are subdivision specific and created via contract (not through city regulations) by a simple majority vote of subdivision residents (38). The unique element of restrictive covenants in Houston is that following a 1962 referendum, the state legislature authorized the use of municipal funds in enforcing private deed restrictions (39). This made the enforcement of deed restrictions in Houston, similar to the enforcement of local zoning ordinances in other Texas municipalities.

In response to citizen concerns about pollution exposure from CBPs, local and state representatives in Texas have pursued several legislative initiatives. In 2014, the Austin city council, responding to citizen complaints about construction noise, issued a temporary ban on overnight concrete pouring in the city's central business district. The ban was extended several times and was eventually revoked in 2016, allowing overnight pouring with certain restrictions. Industry representatives voiced concerns about the ban and it's effects on crew safety. Since Austin experiences high temperatures during the day, concrete pouring in the city is best suited for the cooler night time temperatures that allow for better curing. The overnight ban led to higher levels of truck traffic during the day, as contractors attempted to increase amounts poured outside of the banned hours (40; 41).

In 2021 the city of Houston announced the "*Houston Inspires/Houston Inspira*" campaign funded through an EPA environmental justice grant. The goal of the campaign is to raise awareness about air quality and pollution issues in parts of Houston particularly burdened by pollution. $PM_{2.5}$ exposure from operation of CBPs is one of main focus points of the campaign (42).

In the 2021 session of the Texas Legislature (session 87), several House and Senate bills attempted to increase the restrictions on CBP permitting. HB 56 (as well as companion bills HB 3604 and SB 953) proposed an increase in setback requirements for CBPs from 440 yards (0.25 miles) to 880 yards (0.5 miles) between a CBP and a residence, school, or church. In addition, the bill proposed to extend the definition of who is considered an "*affected person*" due to the operation of a CBP by the same distance (880 yards); based on existing CBP permitting regulations only "*affected persons*" have the right to request a hearing during the permitting process of a CBP (43). HB 1627 would allow Harris County or the city of Houston to reject permit application of CBPs, thereby prohibiting TCEQ from issuing the permit (44). None of these proposed bills passed in the 87th legislative session.

S.3 Interpolation of PM emissions and descriptive statistics

For each of the 131 CBPs that are active in Harris county we record their reported emissions limits and operating capacity based on the information listed in their permit. We begin by estimating ratios of PM_{10}/PM and $PM_{2.5}/PM_{10}$ for plants that report their emissions limits. We find a median ratio of $PM_{10}/PM=0.48$ and a median ratio of $PM_{2.5}/PM_{10}=0.17$. For plants that only report PM we use those ratios to interpolate their PM_{10} and $PM_{2.5}$ emissions. For plants that do not report any emissions limits (23 plants total) we make interpolations based on their operating capacity. That is, for the group of plants that report emissions limits, we calculate the median PM_{10} and $PM_{2.5}$ emissions for three groups of operating capacities, namely plants with capacity: 1) at or below $100\frac{yd^3}{hr}$, 2) between 100-200$\frac{yd^3}{hr}$ and 3) between 200-300$\frac{yd^3}{hr}$. The resulting values are illustrated in Table S2. Those values are used to interpolate PM, PM_{10} and $PM_{2.5}$ emissions for plants that only report operating capacity. Table S3 provides descriptive statistics on PM emissions for the 124 active CBPs in Houston.

Table S2: Median values of PM, PM_{10} and $PM_{2.5}$ in tons/year by plant operating capacity

Operating capacity	PM	PM_{10}	$PM_{2.5}$
$< 100\frac{yd^3}{hr}$	3.12	1.3	0.27
$100\frac{yd^3}{hr} < 200\frac{yd^3}{hr}$	6.6	3.29	0.54
$200\frac{yd^3}{hr} < 300\frac{yd^3}{hr}$	7.76	4.2	0.76

Source: Authors' calculations using data from TCEQ (45)

Table S3: Descriptive statistics of PM, PM_{10} and $PM_{2.5}$ emissions (measured in tons/year) for 124 active CBPs in Houston.

Pollutant	Min	Q1	Median	Q3	Max
PM	0.018	3.4	7.3	9.8	67
PM_{10}	0.18	1.6	3.6	5.5	27
$PM_{2.5}$	0.03	0.28	0.65	0.92	7.1

Source: Authors' calculations using data from TCEQ (45)

S.4 Predicting reported emissions of Houston CBPs using ratio of reported to permitted emissions from Illinois CBPs

The information we collected from TCEQ CBP permits provides data on the maximum allowable emission thresholds at the plant level. However, in the absence of any emissions reporting requirements for Texas CBPs, it is not possible to know whether actual emissions are below, at or above those thresholds. As an alternative to assuming that Houston CBPs emit at their permitted levels, we implement an approach based on data from our FOIA requests, discussed in section S.1. Of the 25 responses we received from the 31 FOIA requests, the only state that provided data on maximum allowable emissions thresholds was Illinois. We combined NEI data on reported emissions from Illinois CBPs with the emissions thresholds data we got from our Illinois FOIA request to estimate how far below the maximum allowable threshold CBPs in Illinois emit.

Illinois implemented the Registration of Small Source (ROSS) Program in 2012 in order to reduce the regulatory burden on small facilities. Under the ROSS program, facilities that emit less than 5 tons of criteria pollutants per year can simply register with the Illinois Environmental Protection Agency, instead of obtaining an air permit. From our IL FOIA request we received information on 343 Illinois CBPs, 289 of which have a ROSS permit. We merged the information on maximum allowable emissions of those facilities with the reported emissions from the NEI and obtained 316 successful facility merges (259 of which are ROSS permits). Many of the ROSS facilities in our dataset obtained their original permit prior to 2012, before the implementation of the ROSS program. As a result, their maximum allowable emissions thresholds in the FOIA data reflect the thresholds in their original, pre-ROSS permit. To account for that discrepancy, we adjusted the maximum allowable threshold of ROSS facilities to 5 tons of PM_{10} or $PM_{2.5}$, which is the threshold specified in the ROSS permit. We then run an OLS regression of the maximum allowable threshold on the NEI reported emissions of those 316 Illinois CBPs from 2012-2018 (since our NEI data are not available after 2018). We used 2012 as the first year in our regressions since it marks the beginning of the ROSS program. The results in Table S4 below illustrate the relationship between allowable and reported emissions for Illinois CBPs.

Variables "$PM_{2.5}$ original threshold" and "PM_{10} original threshold" in Table S4 are the maximum allowable threshold of $PM_{2.5}$ and PM_{10} emissions (respectively) for IL CBPs. In many cases, CBPs with a Registration of Small Sources (ROSS) had maximum allowable emissions limits far exceeding the 5 tons/year threshold, which is the requirement for facilities to be included in the ROSS program. For those cases (6 facilities for $PM_{2.5}$ emissions and 171 facilities for PM_{10} emissions) the variables "$PM_{2.5}$ adjusted threshold" and "PM_{10} adjusted

Table S4: Reported vs. Max allowable PM emissions in IL CBPs

	All CBPs b/se	All CBPs b/se	All CBPs b/se	All CBPs b/se
$PM_{2.5}$ original threshold	0.037***			
	(0.01)			
$PM_{2.5}$ adjusted threshold		0.068***		
		(0.01)		
PM_{10} original threshold			0.056***	
			(0.01)	
PM_{10} adjusted threshold				0.283***
				(0.01)
Constant	0.335***	0.281***	0.808***	0.003
	(0.02)	(0.02)	(0.07)	(0.06)
N	2022	2022	2062	2062

Standards errors in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

threshold" include an adjusted maximum allowable emissions limit, revising the original threshold downward to 5 tons of $PM_{2.5}$ and PM_{10} respectively. The dependent variable in all regressions is the reported $PM_{2.5}$ and PM_{10} emissions from the NEI data.

The results presented in Table S4 indicate that a one ton increase of the adjusted maximum PM_{10} ($PM_{2.5}$) emissions threshold increases reported emissions by 0.283 (0.068) tons. Next, we apply the estimated coefficients of Table S4 to our Texas CBP data, collected from the TCEQ air permits. The goal of this exercise is to move away from the assumption that Texas CBPs emit at their permitted limit. Instead, we predict reported (actual) Texas CBP emissions using the regression coefficients from IL CBPs. Based on the regression results presented in Table S4, IL CBPs release lower amounts of PM_{10} and $PM_{2.5}$ compared to what their permits allow them to. Predicting Texas CBP reported (actual) emissions using the regression coefficients in Table S4 provides a plausible alternative estimate, deviating from the assumption that Harris county CBPs emit at the permitted threshold. Figures S1 and S2 present the distribution of estimated CBP emissions in Texas using the IL CBP coefficients.

Table S5 shows the results in terms of total PM_{10} and $PM_{2.5}$ from this estimation exercise and compares those totals with the maximum allowable thresholds in Texas. Results in Table S5 are broken down by whether or not Texas CBPs maximum allowable thresholds were interpolated or not. The top segment of Table S5 shows predictions for the 101 CBPs for which PM_{10} or $PM_{2.5}$ maximum emissions threshold were not interpolated based on production capacity. The bottom panel shows predictions for an additional 23 CBPs (124 CBPs total) for which maximum emissions thresholds were interpolated based on reported production capacity. Figure S3 is an alternative version of Figure 3 from the manuscript,

Table S5: Predicted Houston CBP emissions

Data	Prediction based on:	PM_{10} emissions in (tons/year)	$PM_{2.5}$ emissions in (tons/year)
Non-interpolated Texas data (101 CBPs)	TCEQ maximum allowable emissions threshold	493	111
	Original IL emissions threshold	109	38
	Adjusted IL emissions threshold	140	36
Interpolated Texas data (124 CBPs)	TCEQ maximum allowable threshold	580	126
	Original IL emissions threshold	133	46
	Adjusted IL emissions threshold	164	43

illustrating the distribution of PM_{10} (instead of $PM_{2.5}$) emissions.

This exercise has a series of limitations, namely that facility size is endogenous and not randomly distributed. That is, because of the presence of the ROSS program, IL CBPs have an incentive to decrease their output in order to stay below the 5 ton emissions threshold mandated by the ROSS program. Therefore our IL results might not be applicable to TX given this systematic difference in state regulatory policy governing CBP operation. However, considering the absence of data on CBP emissions and, more importantly, maximum allowable emissions, this is the best approximation we can apply.

Figure S1: Texas PM_{10} emissions based on IL estimation

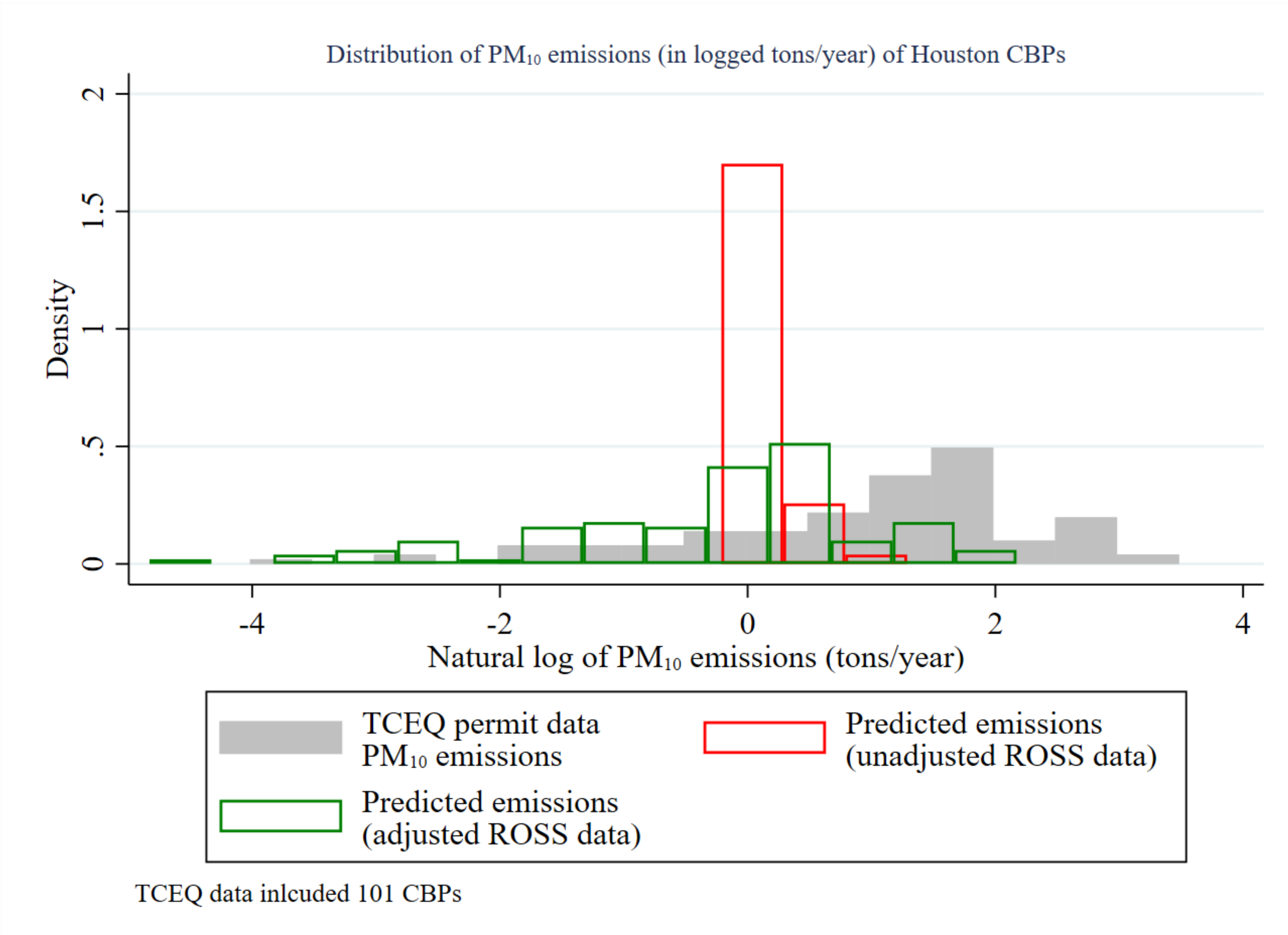

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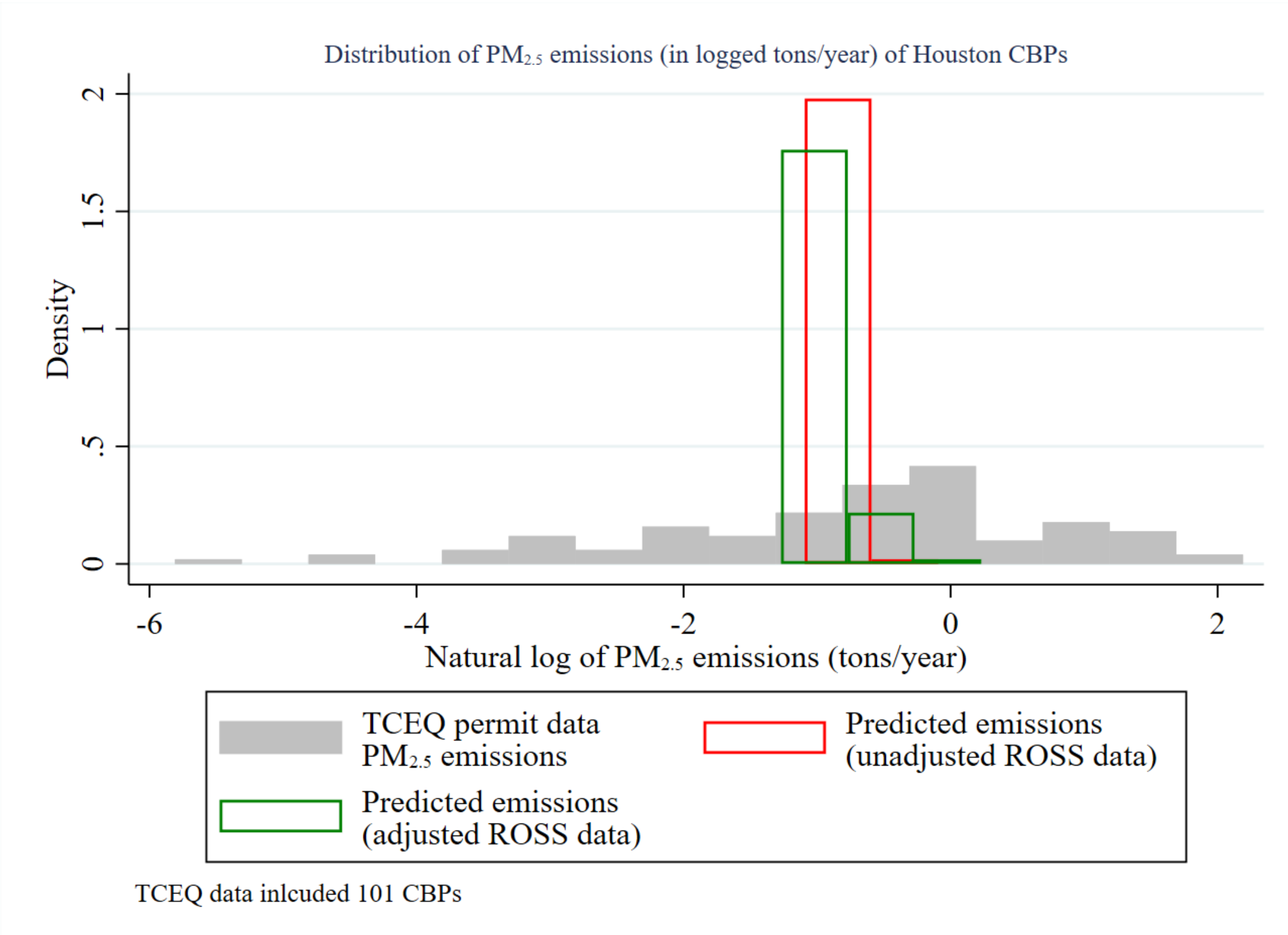
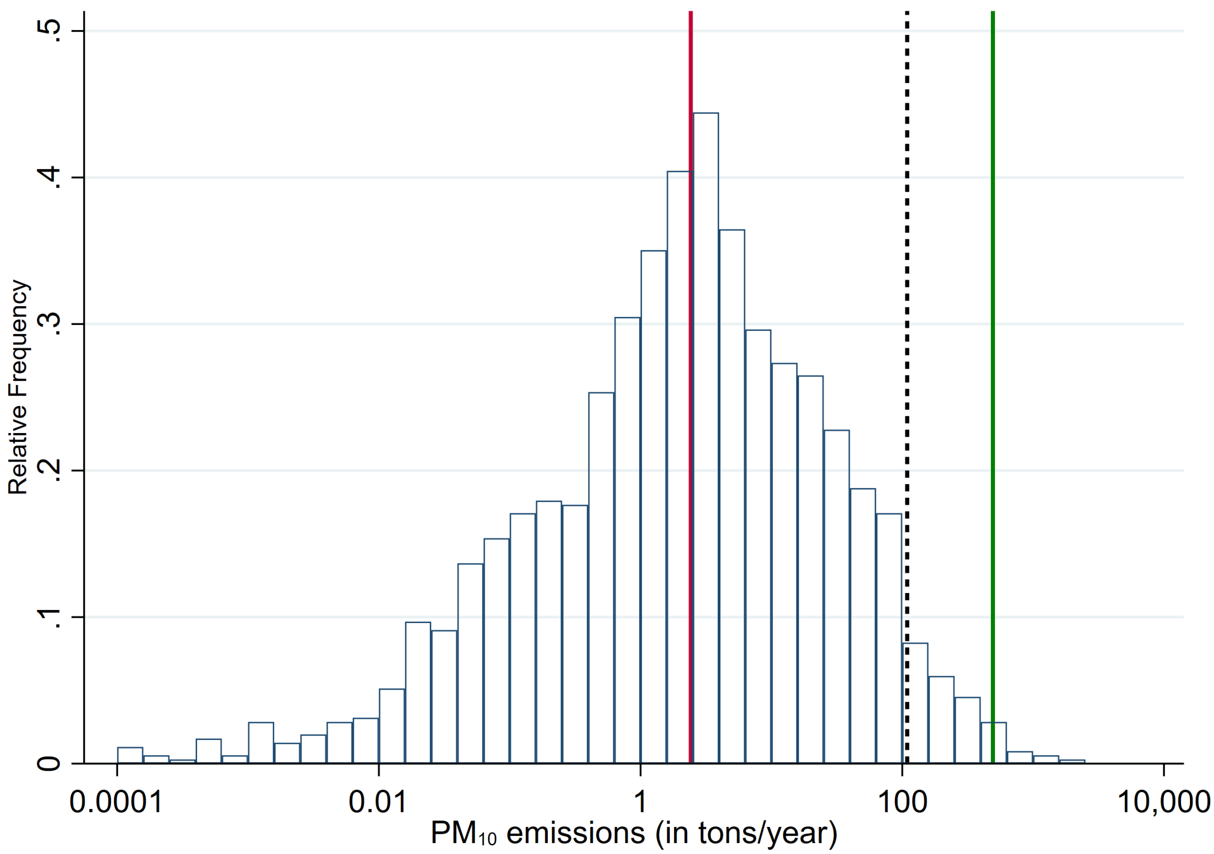
Figure S2: Texas $PM_{2.5}$ emissions based on IL estimation



S17

Figure S3: Distribution of PM_{10} emissions by Title V facilities in Texas



Note: Green line represents 493 tons of cumulative PM_{10} emissions from 101 CBPs in Houston (based on maximum allowable threshold). Red line represents 2.4 tons of PM_{10} emissions of the median TX Title V facility. Black dotted line is an alternative estimate of 109 tons of cumulative PM_{10} emissions from Houston CBPs using the reported to permitted ratio of emissions from Illinois CBPs (discussed in section S.4 of the Supporting Information.

Table S6: Proximity to Concrete Batch Plants in Harris County by sociodemographic characteristics

	Hispanics	Blacks	Whites	Income	Home value
Percent hispanic	2.795***				
	(0.718)				
Percent black		4.091***			
		(0.858)			
Percent white			–1.352*		
			(0.818)		
Log of median HH income	–5.549***	–5.615***	–6.784***	–7.378***	
	(0.842)	(0.788)	(0.791)	(0.705)	
Log of median home value					–6.632***
					(0.524)
Tract population density	–741.252***	–656.300***	–725.732***	–724.203***	–684.103***
	(96.191)	(96.691)	(96.858)	(96.962)	(112.670)
Highway proximity	0.005***	0.005***	0.005***	0.005***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Adj. R^2	0.18	0.18	0.16	0.16	0.21
Observations	782	782	782	782	760

Note: Each column in this Table shows regression results where the dependent variable is the number of CBPs within a 5 mile radius of a census tract centroid. Highway proximity is defined as the number of highway exit and entry ramps within that same 5 mile buffer.

Table S7: Proximity to Concrete Batch Plants in Cook County by sociodemographic characteristics

	Hispanics	Blacks	Whites	Income	Home value
Percent hispanic	–0.004				
	(0.138)				
Percent black		–0.009			
		(0.131)			
Percent white			0.094		
			(0.170)		
Log of median HH income	–0.637***	–0.645***	–0.727***	–0.637***	
	(0.157)	(0.201)	(0.225)	(0.155)	
Log of median home value					–0.221
					(0.149)
Tract population density	35.990***	35.865***	35.321***	35.969***	37.177***
	(6.916)	(7.050)	(6.970)	(6.869)	(6.975)
Highway proximity	0.014***	0.014***	0.014***	0.014***	0.014***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Adj. R^2	0.46	0.46	0.46	0.46	0.46
Observations	1314	1314	1314	1314	1301

Note: Each column in this Table shows regression results where the dependent variable is the number of CBPs within a 5 mile radius of a census tract centroid. Highway proximity is defined as the number of highway exit and entry ramps within that same 5 mile buffer.

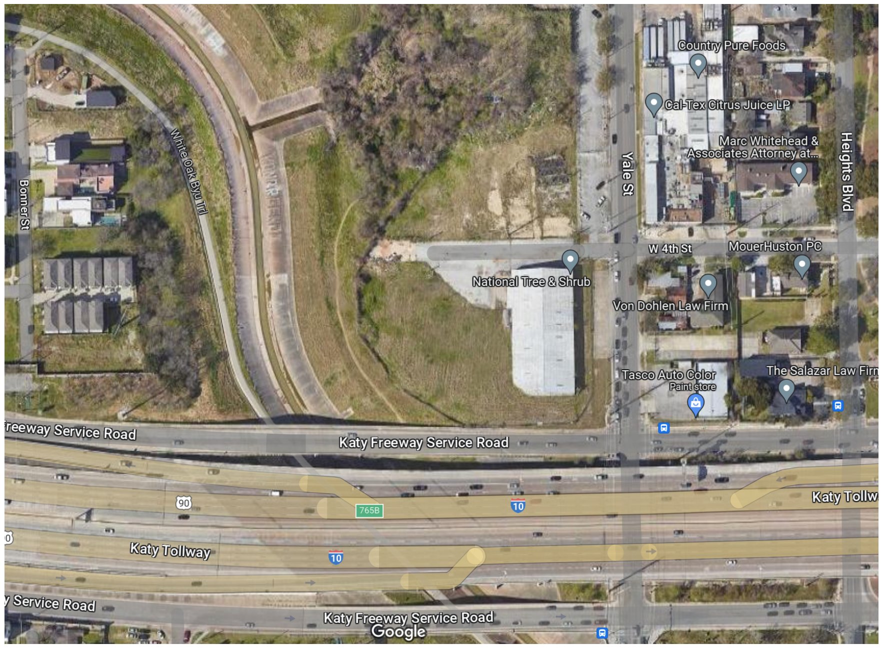
Table S8: Damage estimates using different dose-responses and accounting for estimation uncertainty (in 2023 million $s)

Dose-response used	Estimation uncertainty	Damage estimate	95% CI
Krewski et al. (2009) (46)	No	12.36	[8.3 to 16.4]
Krewski et al. (2009) (46)	Yes	12.36	[7.6 to 17.9]
Lepeule et al. (2012)(47)	No	28.8	[14.5 to 45.4]
Lepeule et al. (2012)(47)	Yes	28.8	[13.2 to 49.4]

Note: The first two confidence intervals (rows 1 and 2) use dose response estimates from Krewski et al. (46) and the second two (rows 3 and 4) use estimates from Lepeule et al. (47). Rows 1 and 3 use the point estimate of 38 tons of $PM_{2.5}$ emissions reported in Table S5 and the uncertainty around the Krewski et al. (46) and Lepeule et al. (47) dose response functions to estimate confidence intervals. Rows 2 and 4 use the standard errors in column 1 of Table S4 to include estimation uncertainty around the point estimate of 38 tons of $PM_{2.5}$ to the confidence intervals.

Figure S4: Google maps aerial images of concrete batch plants

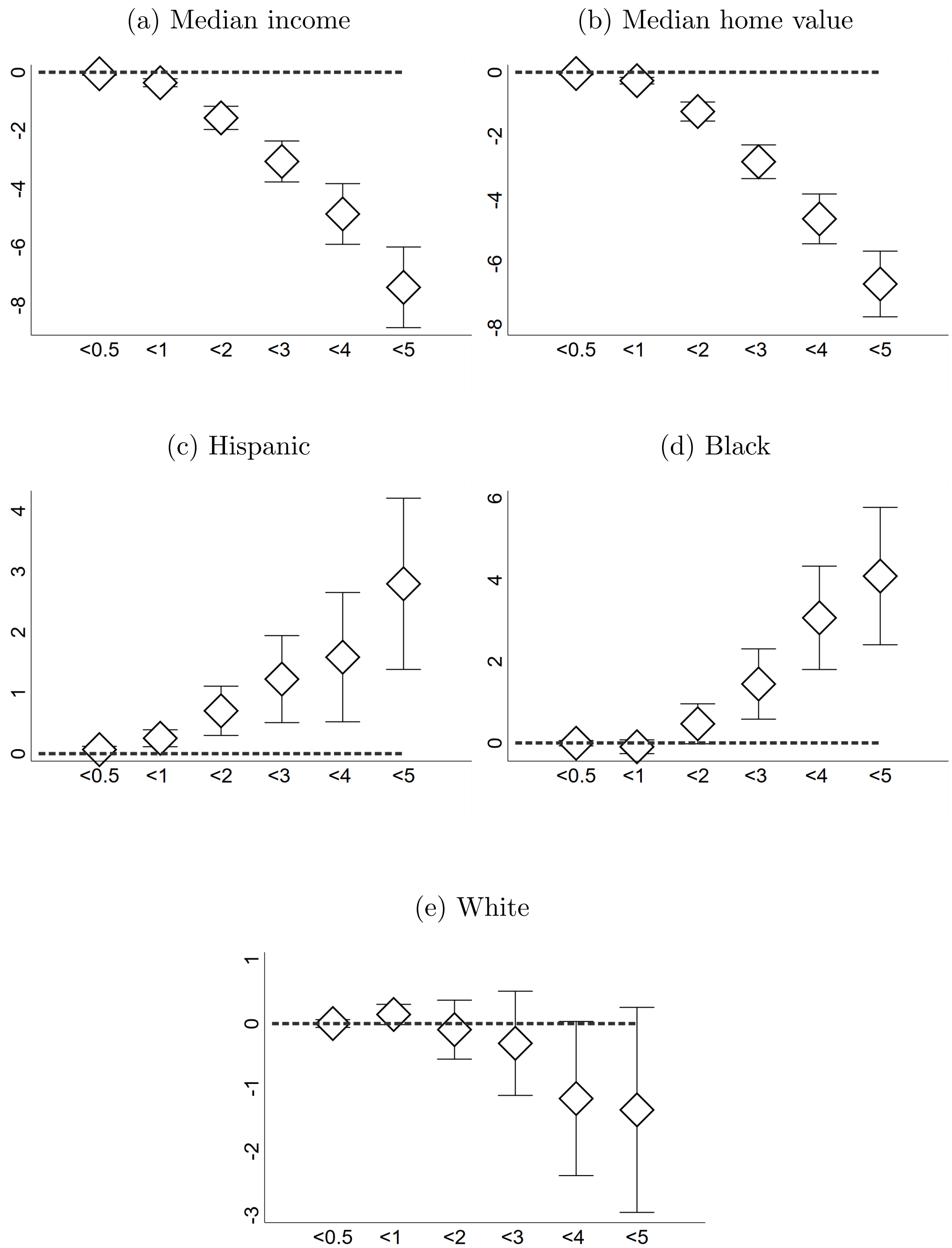
(a) Example of an inactive CBP



(b) Example of an active

Note: Panel S4a on the top, shows the location of an inactive CBP (Regulated Entity number: 102895224; permit# 42843) located on 357 Yale Street, Houston, TX-77007. According to TCEQ records, that CBP has a permit with an effective date of February 25th 2000 and no ending permit date. It is clear from the aerial image that no CBP is operating in that location. We do not include that CBP in our analysis. Panel S4b on the bottom, shows the location of a active CBP (Regulated Entity number: 102897451; permit# 24193C) located on 2020 Fellows Road, Houston, TX-77047. According to TCEQ records, that CBP has a permit with an effective date of March 19th 1997 and no ending permit date. The aerial image shows clear evidence of the existence of a CBP in that location. Several key features of a CBP (concrete trucks, aggregate stockpiles, mixing silos) are visible in the areal image. Source: google.com/maps.

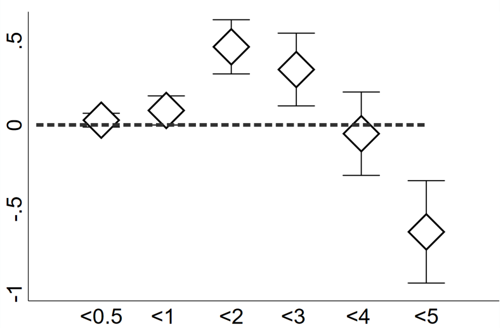
Figure S5: Sensitivity analysis of proximity to CBPs in Harris county by demographic characteristics.



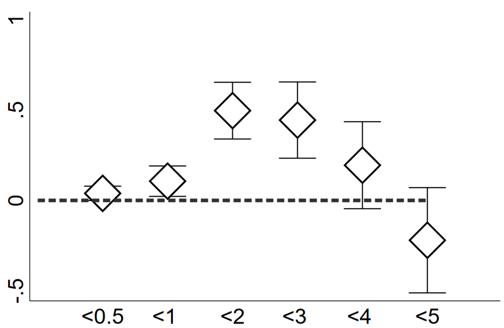
Note: The vertical axis shows estimated coefficients for the main explanatory variable of interest (listed in the title of each panel) from multiple regression models. Each regression model uses the number of CBPs within different distance buffers of a tract centroid (i.e. $< 0.5 = 0.5$ mile buffer, $< 1 = 1$ mile buffer, etc.) as the dependent variable. All five panels control for population density and highway access. In addition, panels S5c-S5e control for median household income.

Figure S6: Sensitivity analysis of proximity to CBPs in Cook county by demographic characteristics.

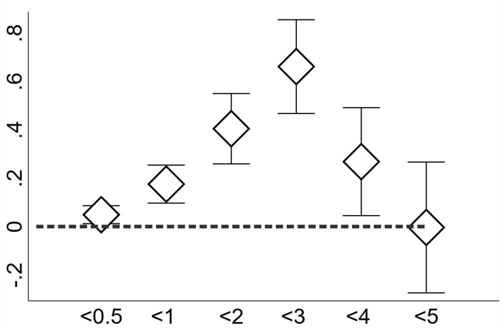
(a) Median income



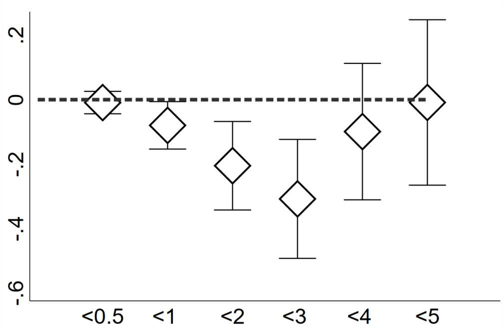
(b) Median home value



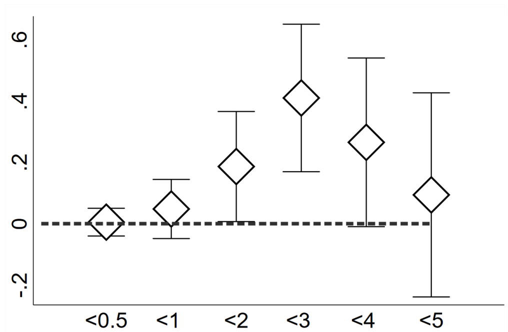
(c) Hispanic



(d) Black



(e) White



Note: The vertical axis shows estimated coefficients for the main explanatory variable of interest (listed in the title of each panel) from multiple regression models. Each regression model uses the number of CBPs within different distance buffers of a tract centroid (i.e. $< 0.5 = 0.5$ mile buffer, $< 1 = 1$ mile buffer, etc.) as the dependent variable. All five panels control for population density and highway access. In addition, panels S6c-S6e control for median household income.

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