Racial Disparities in the Health Effects from Air Pollution: Evidence from Ports

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Introduction and Background

- Both the economic literature and the epidemiological literature have shown that air pollution negatively affects human health by e.g., contributing to respiratory and cardiovascular diseases.
- Maritime ports are a major source of air pollution.
- Marine ships, trucks, and cargo-handling equipment often burn highly polluting fossil fuels, e.g. diesel fuel.
- Maritime ports tend to be located in urban areas with high population density, surrounded by low-income, minority neighborhoods.

Environmental Inequalities

- Health effects of air pollution are unevenly distributed across the population.
- Some groups face higher pollution exposures: low-income, minority groups more likely than other groups to live adjacent to environmental risks.
- Previous studies also provide estimates of heterogeneous marginal damages of pollution exposure.
- Contributions:
  - Estimate the contemporaneous effects of port activity-related air pollution on physical and mental health, using variation in port activities driven by distant tropical cyclones;
  - Evidence of racial inequality in health outcomes due to air pollution around maritime ports;
  - Use a regression discontinuity design and dynamic simulation to analyze a regulation that reduces fossil fuel use in ports.

Instrumental Variable - Lagged Distant Cyclones

- Monotonicity:
  - These cyclones often disrupt travel for marine vessels, delaying their arrival into ports, leading to fewer ships and less tonnage in ports several days later (in primary specification, distance = 500 miles, lag = 7 days).
- Exclusion Restriction:
  - Remove the observations during the days when cyclones appear within a 300-mile radius of ports, and observations two days prior and after;
  - Figure 4: weather in the ports is no different when there are tropical cyclones in the distant ocean seven days prior than when there are not;
  - Figure B.6: lagged distant cyclones do not have any notable effect on the composition of vessel types.

Empirical Setting and Data

- Focus on 27 major ports in the US, six of which are in California.
- Port traffic: daily vessel tonnage or number of vessels.
- Air pollution: daily pollution concentrations for five air pollutants at the pollution monitoring site level.
- Weather: dew point, temperatures, precipitation, wind speed and wind direction at the weather station level.
- Cyclones: dates, central location, wind radii, etc. of historical cyclones.
- Health outcomes: visits to hospitals, emergency departments and ambulatory surgery centers related to respiratory, mental and cardiovascular illnesses in California.

Descriptive Statistics

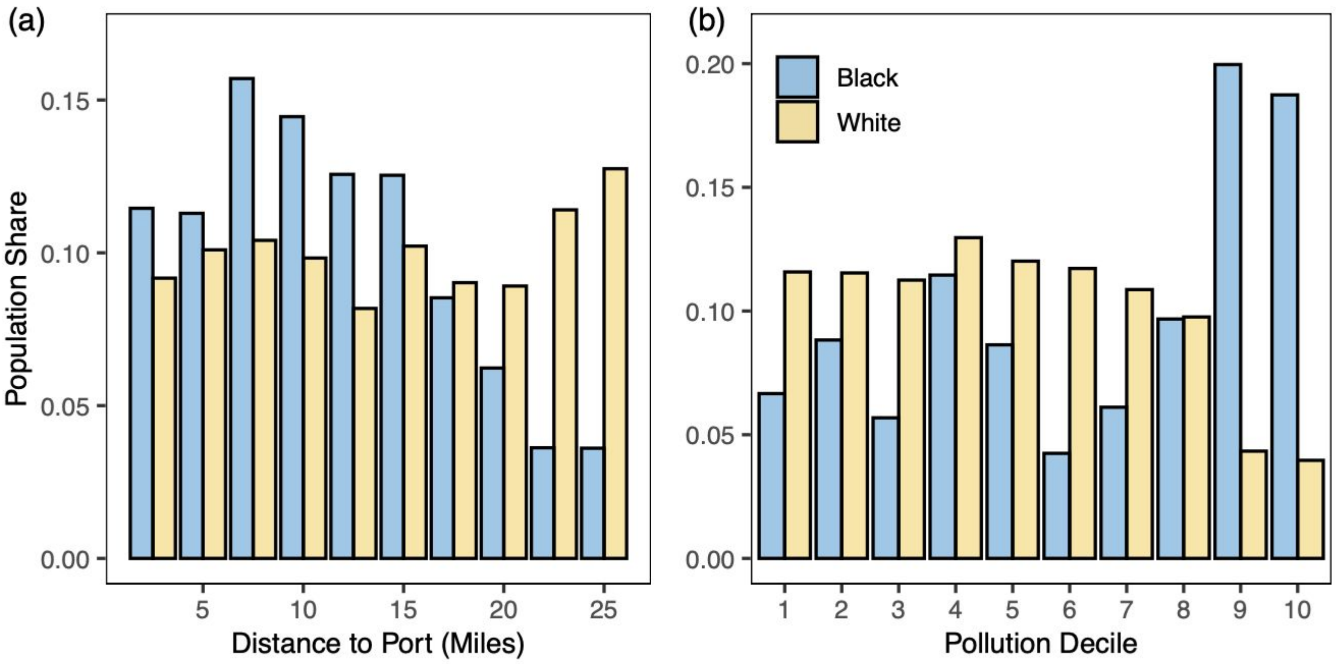

Figure 2(a): Distribution of population by distance to major California ports; 2(b): Distribution of the population in California port areas by decile of $PM_{2.5}$ concentration.

Descriptive Statistics

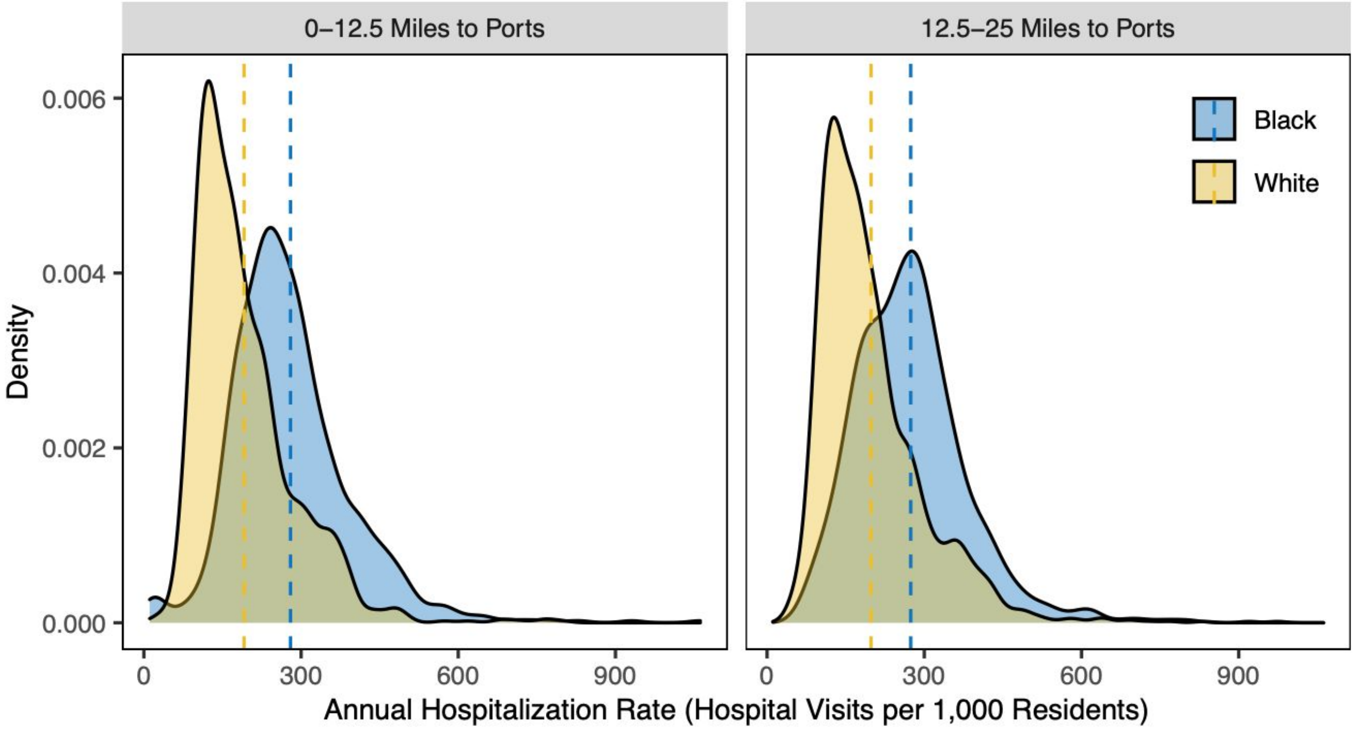

Figure 3: Distribution of annual hospitalization rates in California port areas.

Descriptive Statistics

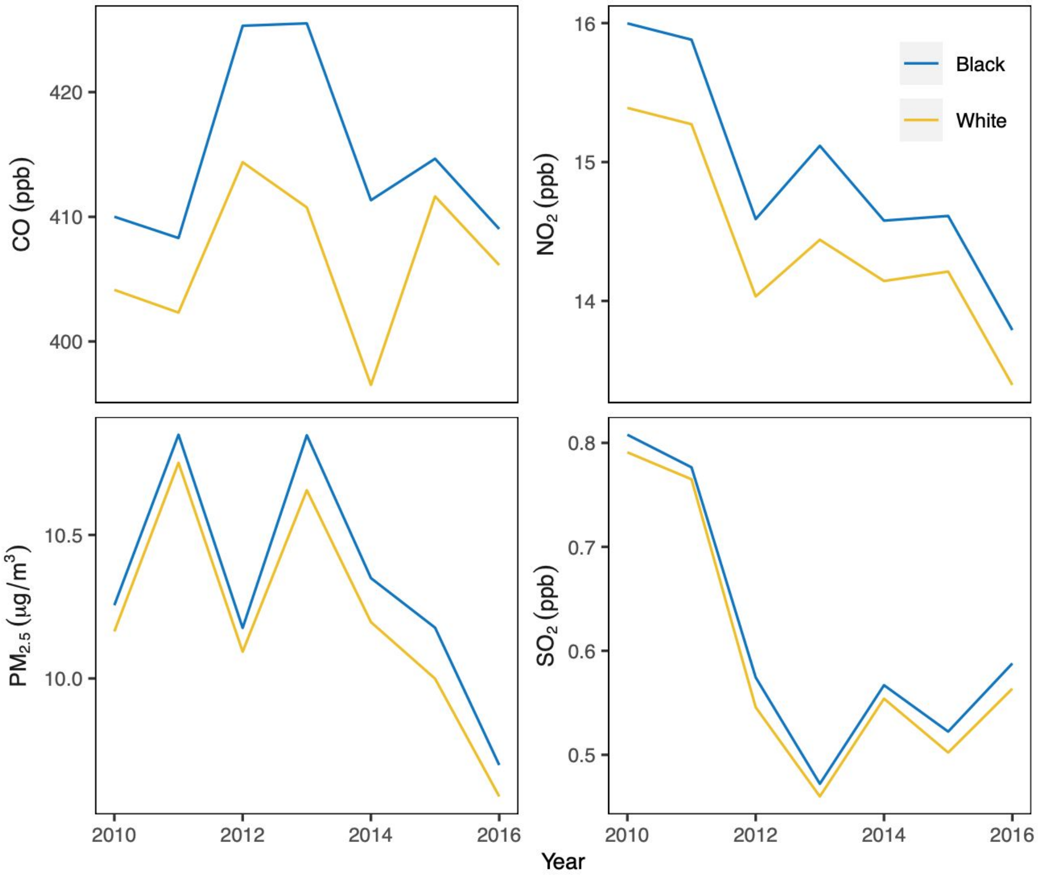

Figure B.4: Annual air pollution exposure for individuals visiting hospitals by race.

Effect of Vessels in Ports on Air Pollution

- Primary specification:

$$P_{ipt} = \beta V_{pt} + \mathbf{X}_{it}\theta + \delta_t + \mu_{ip} + e_{ipt}$$

- P = pollutant concentration, V = measure of port traffic, X = weather controls
- Use the existence of lagged tropical cyclones far out in the ocean to instrument for port traffic
- First Stage:

$$V_{pt} = \alpha TC_{t-m} + \mathbf{W}_{ipt}\lambda + \epsilon_{ipt}$$

Results: First Stage

$$V_{pt} = \alpha TC_{t-m} + \mathbf{W}_{ipt}\lambda + \epsilon_{ipt}$$

Table A.11: First-stage relationship between tropical cyclones and port traffic

	Dependent variable: port traffic			
	(1)	(2)	(3)	(4)
Panel A: Log of vessel tonnage				
Tropical Cyclone	−0.04***	−0.04***	−0.05***	−0.04***
	(0.01)	(0.01)	(0.01)	(0.01)
First-Stage F Stat.	32.88	37.42	36.52	30.89
Anderson-Rubin Stat. P-val	0.0021	0.0402	0.0080	0.0268
Stock-Wright S Stat. P-val	0.0012	0.0216	0.0066	0.0154
Observations	502,631	587,833	423,200	431,574
Panel B: Number of vessels				
Tropical Cyclone	−0.54***	−0.48***	−0.48***	−0.45***
	(0.13)	(0.10)	(0.13)	(0.12)
First-Stage F Stat.	16.69	20.78	12.96	13.64
Anderson-Rubin Stat. P-val	0.0021	0.0402	0.0080	0.0268
Stock-Wright S Stat. P-val	0.0012	0.0216	0.0066	0.0154
Observations	502,631	587,833	423,200	431,574

Notes: Panel A presents the first-stage results for the instrumental variable estimation in Panel A in Table 1, where the port traffic is measured as log of daily vessel tonnage. Panel B presents the the first-stage results for the instrumental variable estimation Panel B, using the number of vessels as the variable of interest. Each entry orresponds to an individual regression. The instrument is an indicator of seven-day lagged and 500-mile distant cyclones in the ocean. All regressions include weather controls, such as the quadratics of maximum temperature, minimum temperature, dew point temperature, precipitation, wind speed, and relative wind direction between a monitor-port pair. All regressions also include county-by-year, month, day-of-week, holiday, and monitor-port pair fixed effects. An observation is a monitor-port-day. Standard errors are clustered by monitor-port pair and day. Significance levels are indicated by *** 1%, ** 5%, and * 10%.

Strong first stage suggesting that **the existence of lagged distant tropical cyclones results in 0.4-0.5% less tonnage (or 0.5 fewer vessels) in ports per day.**

Each column = a different lag *m;*
main spec has *m* = 7.

Results: Second Stage

$$P_{ipt} = \beta V_{pt} + \mathbf{X}_{it}\theta + \delta_t + \mu_{ip} + e_{ipt},$$

Table 1: Effect of vessels in ports on air pollutant concentrations in the United States, instrumental variable estimation

	Dependent variable: log of pollution concentration			
	CO	NO_2	$PM_{2.5}$	SO_2
	(1)	(2)	(3)	(4)
Panel A: Vessel tonnage				
Log of Vessel Tonnage	0.37***	0.25**	0.43**	0.43**
	(0.13)	(0.12)	(0.17)	(0.19)
Adjusted R^2	0.50	0.72	0.27	0.47
Observations	502,631	587,833	423,200	431,574
Panel B: Number of vessels				
Number of Vessels	0.030**	0.023**	0.043**	0.042**
	(0.012)	(0.012)	(0.019)	(0.021)
Adjusted R^2	0.54	0.74	0.37	0.48
Observations	502,631	587,833	423,200	431,574

Notes: Panel A presents the instrumental variable estimation of the effect of log vessel tonnage on air pollutant concentrations within a 25-mile radius of ports in the United States. Panel B presents the same instrumental variable estimation using the number of vessels in ports as the variable of interest. Each entry presents an individual regression on a local air pollutant. The endogenous variables, vessel tonnage and the number of vessels, are instrumented by an indicator of seven-day lagged cyclones at least 500-mile distant from ports. All regressions include weather controls, such as the quadratics of maximum, minimum, and dew point temperature, precipitation, wind speed, and relative wind direction between a monitor-port pair. All regressions also include county-by-year, month, day-of-week, holiday, and monitor-port fixed effects. An observation is a monitor-port-day. Standard errors are clustered by monitor-port pair and day. Significance levels are indicated by *** 1%, ** 5%, and * 10%.

Significant effect of both measures of port traffic on pollution concentrations within a 25-mile radius of the port.

- **100% increase in vessel tonnage leads to ~40% increase in CO and SO2**, in range of U.S. EPA's 7-61% estimate of the contribution of ocean-going vessels to SOx and NOx emissions.

This includes both the **direct effect** of extra emissions from the additional ships and the **indirect effect** of the complementary activities associated with handling goods from the ship e.g. trucks.

Results: OLS

Table A.13: OLS estimation of the effect of vessel tonnage in port on air pollution

	Dependent variable: log of pollution concentration			
	CO	NO_2	$PM_{2.5}$	SO_2
	(1)	(2)	(3)	(4)
Log of Vessel Tonnage	0.001	0.01***	0.01	0.01*
	(0.003)	(0.004)	(0.003)	(0.01)
Adjusted R^2	0.57	0.75	0.46	0.50
Observations	502,631	587,833	423,200	431,574

Notes: This table presents the OLS estimation of the effect of vessel tonnage in port on air pollution. Each column presents an individual regression on a local air pollutant. All regressions include weather controls, such as the quadratics of maximum temperature, minimum temperature, dew point temperature, precipitation, wind speed, and relative wind direction between a monitor-port pair. All regressions also include county-by-year, month, day-of-week, holiday, and monitor-port pair fixed effects. An observation is a monitor-port-day. Standard errors are clustered by monitor-port pair and day. Significance levels are indicated by *** 1%, ** 5%, and * 10%.

Magnitudes of coefficients are more attenuated and not all significant.

Effect of Air pollution on Health

- Specification:

$$y_{ipt} = \beta P_{ipt} + \mathbf{X}_{it}\theta + \delta_t + \mu_{ip} + e_{ipt}$$

- y = hospital visits.
- Instrument pollution concentrations with vessel tonnage in ports, predicted by distant oceanic storms several days prior, and local wind speed and direction
-

Effect of Air pollution on Health

- Specification:

$$y_{ipt} = \beta P_{ipt} + \mathbf{X}_{it}\theta + \delta_t + \mu_{ip} + e_{ipt}$$

- First Stage:

$$P_{ipt} = \alpha_1 \widehat{V}_{pt} + \alpha_2 WS_{it} + \sum_{s=1}^{7} \alpha_{3s} WD_{it}^{s} + \alpha_4 \widehat{V}_{pt} \times WS_{it} + \sum_{s=1}^{7} \alpha_{5s} \widehat{V}_{pt} \times WD_{it}^{s} + \sum_{s=1}^{7} \alpha_{6s} WS_{it} \times WD_{it}^{s} + \sum_{s=1}^{7} \alpha_{7s} \widehat{V}_{pt} \times WS_{it} \times WD_{it}^{s} + \mathbf{W}_{ipt}\lambda + \epsilon_{ipt}.$$

$$V_{pt} = \sum_{p} \gamma_p \mathbb{1}_p \times TC_{t-m} + \xi_{pt}$$

Results: Second Stage

Panel A: Significant effects of all four pollutants on hospital visits for the overall population.

Panels B + C: The effects on rate of hospital visits are **more than double for Blacks than for whites** in nearly all categories of pollutants. All statistically significant except for psychiatric visits (which is significant in the overall sample).

<u>Important</u>: These estimated effects are contemporaneous. **What's the mechanism?**

Table 2: Effect of air pollution on hospitalizaton rates in California port areas, instrumental variable estimation

	Dependent variable: hospital visits/million residents					
	Respiratory			Heart	Psychiatric	
	Asthma	Upper Respiratory	All Respiratory	All Heart	Anxiety	All Psychiatric
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Overall population						
CO (ppb)	0.01***	0.01***	0.05***	0.01***	0.003***	0.01***
	(0.002)	(0.003)	(0.01)	(0.003)	(0.001)	(0.003)
NO_2 (ppb)	0.28***	0.34***	1.04***	0.37***	0.09***	0.23***
	(0.05)	(0.07)	(0.19)	(0.07)	(0.03)	(0.07)
$PM_{2.5}$ ($\mu g/m^3$)	0.35***	0.42***	1.28***	0.43***	0.10**	0.26***
	(0.06)	(0.10)	(0.26)	(0.09)	(0.04)	(0.09)
SO_2 (ppb)	7.36***	9.25***	27.47***	9.99***	2.68***	6.95***
	(1.36)	(2.11)	(5.57)	(1.98)	(0.85)	(2.04)
Panel B: Black						
CO (ppb)	0.04***	0.03***	0.09***	0.03***	0.004	−0.0001
	(0.01)	(0.01)	(0.02)	(0.01)	(0.004)	(0.01)
NO_2 (ppb)	0.83***	1.03***	2.73***	0.71***	0.14	0.08
	(0.20)	(0.17)	(0.50)	(0.22)	(0.10)	(0.23)
$PM_{2.5}$ ($\mu g/m^3$)	1.07***	1.22***	3.45***	0.73***	0.07	−0.09
	(0.24)	(0.22)	(0.62)	(0.27)	(0.12)	(0.28)
SO_2 (ppb)	23.44***	35.53***	85.74***	17.99***	4.50	4.55
	(5.28)	(5.13)	(14.16)	(6.11)	(2.80)	(6.34)
Panel C: White						
CO (ppb)	0.01***	0.01***	0.04***	0.02***	0.001	0.01**
	(0.002)	(0.002)	(0.01)	(0.01)	(0.002)	(0.01)
NO_2 (ppb)	0.21***	0.21***	0.80***	0.42***	0.03	0.29**
	(0.05)	(0.05)	(0.17)	(0.12)	(0.06)	(0.13)
$PM_{2.5}$ ($\mu g/m^3$)	0.29***	0.28***	1.04***	0.55***	0.05	0.37**
	(0.08)	(0.07)	(0.24)	(0.17)	(0.08)	(0.19)
SO_2 (ppb)	4.68***	5.23***	18.26***	10.01***	1.22	8.12**
	(1.47)	(1.24)	(4.48)	(3.17)	(1.46)	(3.43)

Notes: This table presents the instrumental variable estimation of the effect of air pollution on contemporaneous hospitalization rate for the overall population, Blacks, and whites. Each entry presents an individual regression of an air pollutant on an illness category. Pollution concentrations are instrumented by fitted vessel tonnage in ports, wind direction, wind speed, and their interactions. All regressions include weather controls, such as the quadratics of maximum, minimum, and dew point temperature, and precipitation. All regressions also include county-by-year, month, day-of-week, holiday, and zip code-port pair fixed effects. An observation is a zip code-port-day. Standard errors are clustered by zip code-port pair and day. Estimates are weighted by the zip code-specific population. Significance levels are indicated by *** 1%, ** 5%, and * 10%.

Results: Heterogeneity by Age and Sex (Optional)

- Larger effects on children for respiratory illnesses.
- Larger effects on the elderly for heart and psychiatric diseases.
- **Consistently larger (but slight) effects on females than males for all categories of visits.**

Table shown for effects by sex.

Question: Why is this the case, when we might expect the local male residents to hold jobs in closer proximity to the ports/pollution than do the female residents?

Table A.21: Effect of air pollution on hospitalizaton rates in California port areas by sex

	Dependent variable: hospital visits/million residents in each sex group					
	Respiratory			Heart	Psychiatric	
	Asthma	Upper Respiratory	All Respiratory	All Heart	Anxiety	All Psychiatric
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Male						
CO (ppb)	0.01***	0.01***	0.04***	0.01***	0.003***	0.01***
	(0.002)	(0.003)	(0.01)	(0.004)	(0.001)	(0.003)
NO_2 (ppb)	0.22***	0.28***	0.89***	0.33***	0.07***	0.22***
	(0.04)	(0.07)	(0.18)	(0.08)	(0.03)	(0.07)
$PM_{2.5}$ ($\mu g/m^3$)	0.27***	0.34***	1.10***	0.35***	0.08**	0.23***
	(0.06)	(0.09)	(0.25)	(0.11)	(0.03)	(0.09)
SO_2 (ppb)	5.24***	7.17***	22.98***	8.52***	2.16***	6.22***
	(1.32)	(2.02)	(5.24)	(2.40)	(0.73)	(1.92)
Panel B: Female						
CO (ppb)	0.02***	0.02***	0.05***	0.02***	0.004**	0.01**
	(0.002)	(0.003)	(0.01)	(0.003)	(0.002)	(0.004)
NO_2 (ppb)	0.34***	0.41***	1.18***	0.40***	0.10**	0.25***
	(0.06)	(0.08)	(0.21)	(0.07)	(0.04)	(0.09)
$PM_{2.5}$ ($\mu g/m^3$)	0.43***	0.49***	1.46***	0.50***	0.12**	0.29**
	(0.08)	(0.11)	(0.29)	(0.09)	(0.06)	(0.12)
SO_2 (ppb)	9.44***	11.28***	31.83***	11.42***	3.24***	7.72***
	(1.71)	(2.37)	(6.25)	(2.03)	(1.23)	(2.67)

Notes: This table presents the instrumental variable estimation of the effect of air pollution on hospitalization rates by sex. Each entry presents an individual regression of an air pollutant on an illness category. Pollution concentrations are instrumented by fitted vessel tonnage in ports, wind direction, wind speed, and their interactions. All regressions include weather controls, such as the quadratics of maximum temperature, minimum temperature, dew point temperature, and precipitation. All regressions also include county-by-year, month, day-of-week, holiday, and zip code-port pair fixed effects. An observation is a zip code-port-day. Standard errors are clustered by zip code-port pair and day. Estimates are weighted by the zip code-specific population. Significance levels are indicated by *** 1%, ** 5%, and * 10%.

Results: Different Time Windows Following Exposure

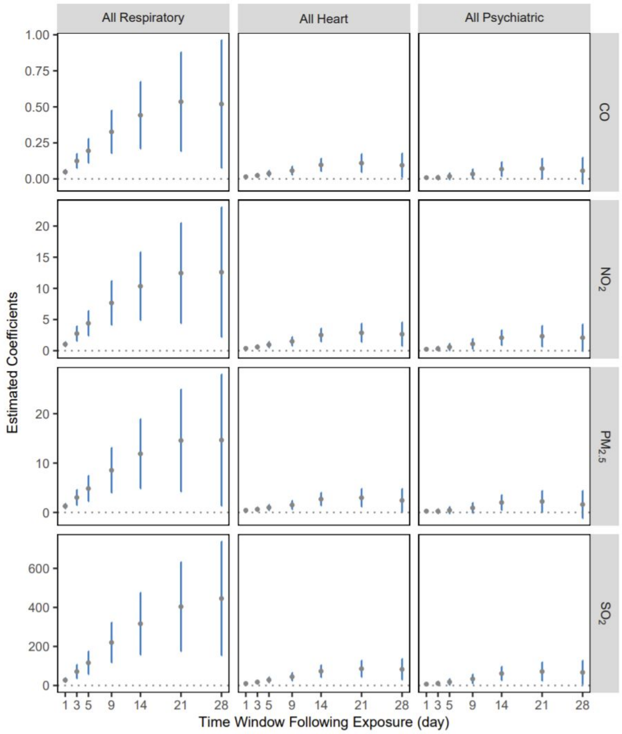

Figure B.9: Effect of air pollution on hospitalization rate for the overall population with different time windows following pollution exposure in California port areas.

Left plot is for overall sample.

Are contemporaneous effects the correct mechanism? What about longer-term outcomes.

Cumulative health effects: The estimates of the **effect of pollution on hospitalization rate increase with the length of time windows** (i.e. using a lagged P) for **respiratory illnesses.**

Next slide: The effects on heart and psychiatric diseases are flatter for blacks, and even decreasing for blacks and whites after 21 days.

Results: Time Following Exposure, Blacks (L) Whites (R)

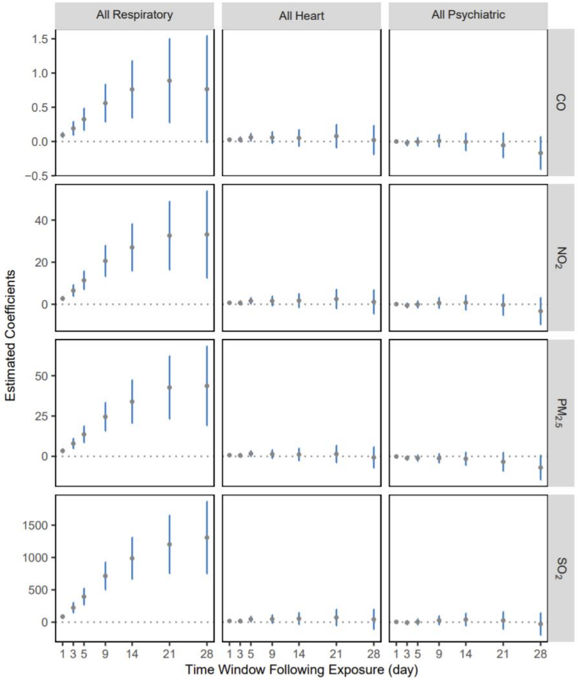

Figure B.10: Effect of air pollution on hospitalization rate for Blacks with different time windows following pollution exposure in California port areas.

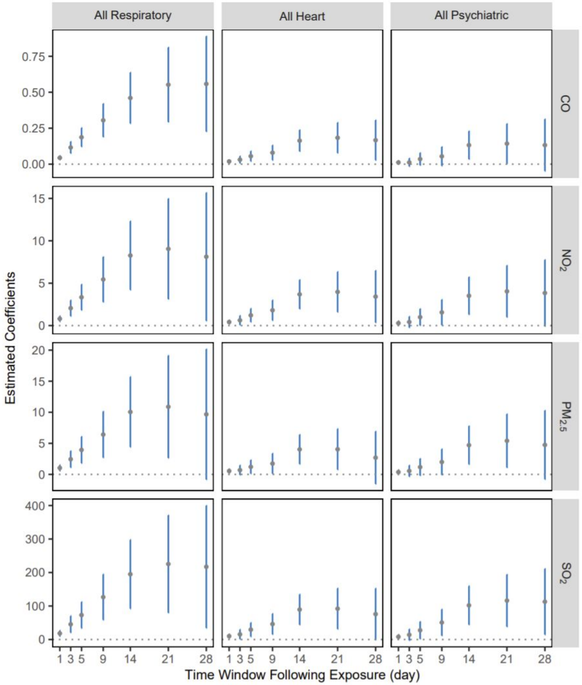

Figure B.11: Effect of air pollution on hospitalization rate for whites with different time windows following pollution exposure in California port areas.

Results: Quantifying the Economic Impacts

Table 3: Effect of one additional vessel in a port over an entire year on hospitalizations and medical costs in California

	All Respiratory (1)	All Heart (2)	All Psychiatric (3)
Panel A: Hospital visits per million residents			
Black	2,400	510	130
White	520	280	230
Overall Population	780	280	200
Panel B: Medical costs per capita (2017 USD)			
Black	21	5	1
White	5	3	2
Overall Population	7	3	2

Notes: Panel A presents the back-of-the-envelope calculations of the effect of one additional vessel in port on annual hospitalizations, based on the instrumental variable estimates in Tables 1 and 2. Panel B presents the medical costs associated with the hospitalizations in Panel A based on the payment data from the Centers for Medicare and Medicaid Services. The average medical costs are $8,917 for psychiatric illnesses, $8,715 for respiratory illnesses, and $9,679 for heart-related illnesses. Based on the U.S. 2010 Decennial Census, the total population residing in the zip codes within 25 miles of California's major ports is 15.08 million, where 1.12 million are Black, and 5.07 million are white. All numbers are rounded to two significant figures.

One additional vessel results in **more hospitalizations for respiratory + heart diseases for blacks**, but **more psychiatric visits for whites**.

Amounts to: 3.0 additional visits per thousand black residents in a year versus 1.0 per thousand white residents.

Cost data: 2017 inpatient discharge data from CMS; amounts to $27 medical cost per capita for black and $9 for white residents.

A Question

- Why are the hospitalization effects on black people relatively more skewed towards physical conditions (heart + respiratory diseases) rather than psychiatric?
    - Is there a culture among black people that de-emphasizes taking care of mental health?
    - Even more differential access to mental health care than physical health care?
        - McGuire and Miranda (2008), “Racial and Ethnic Disparities in Mental Health Care: Evidence and Policy Implications”
    - <u>Related to the mechanism of impact</u>: Are black residents around the ports experiencing the pollutants more directly due to having jobs on site, versus white residents who only feel stressed out by the noise?
        - Maybe these black patients who are already seeing doctors for physical conditions do not have the time/resources to see more doctors for mental conditions.

Mechanism of Racial Disparities: Exposure vs Vulnerability

Question: Are these disparities due to Blacks living in more polluted areas (**exposure**) or Blacks having greater **vulnerability** to air pollution exposure?

- **Differential exposure** is part of the story: the Black population tends to live closer to ports; Black patients are from zip codes that face high exposure.
- **Vulnerability**: do blacks have higher *marginal* damage in response to similar pollutant exposures than whites?

Exploring Vulnerability as a Mechanism

- Identify zip codes that have similar distance (11-21 miles) to ports and similar pollution levels, but with different racial composition.
- Two groups: “Predominantly black” and “predominantly white” zip codes.
- Same IV regression as before of health outcome on pollutant concentration for each zip code group, including temporal and zip code-port fixed effects.
- Results: Holding exposure constant, **blacks seem to face higher marginal damage than whites.**

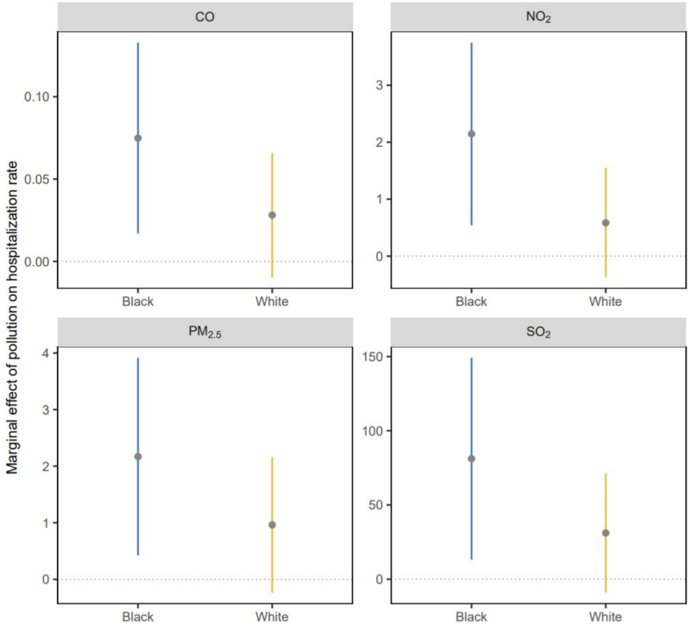

Figure 5: Marginal effects of pollution on hospitalization rates by race in zip codes with a similar distance to ports and pollution exposures.

What are the possible mechanisms?

- Differences in baseline health, income, avoidance behavior, defensive investments (e.g. air filters at home), or other socioeconomic factors.
- <u>Caveat</u>: The two zip code groups are matched by distance to ports and pollution levels, but not by their demographics
  - E.g. if the predominant black zip code group also has a greater elderly population, or a higher percentage of people who work directly at the ports, then we should expect their marginal damage to be higher for reasons that might not have to do (directly) with race
- Note that if black people generally harder to access health care than white people, then these estimated disparities are actually underestimates of the true differential effects of pollution on health outcomes of blacks versus whites

Placebo Tests (Optional)

- Rules out the possibility that lagged distant tropical cyclones might affect air pollution through channels other than port traffic that still have effects days later
  - Looked at areas similarly distant from the cyclones but far away from ports, and found no effect of instrument on pollution levels.
- Rules out the possibility that some other factor related to port traffic may be influencing hospital admissions besides air pollution
  - Looked at hospitalizations for illnesses unrelated to pollution exposure such as external neck wounds, appendicitis, etc. and found statistically insignificant relationship with port traffic

Extensions + Robustness Checks (Optional)

- Main findings are robust to choice of weather controls, radius from ports, definition of lagged distant cyclone instrument (distance threshold, different lags, multiple lags, count of cyclones), definition of hospitalizations (principal or secondary diagnoses).
- Finds **no statistically significant relationship between instrument and road traffic**, which might have affected health outcomes in channels separate from air pollution.
- Joint estimation of co-emitted and co-transported pollutants (i.e. including CO, NO2, SO2 in the same regression) reveals more complex patterns
    - SO2 is the driver of health outcomes for blacks as they live closer to ports and are likely to be exposed to emissions from fossil fuels with high sulfur content

Policy Implications

Policy question: What is the effect on racial disparities in health outcomes of policies aimed to regulate emissions from marine ships?

Setting: First Phase of California's "Ocean-Going Vessel at Berth Regulation", beginning on January 1, 2010.

The Policy

- Aimed to limit air pollutant emissions from container ships, passenger ships, and refrigerated cargo ships at the six major California ports
- By (1) using onshore electricity when docked or (2) find an equivalent emission reduction through alternative fuels or emission control equipment
- <u>First phase</u>: Beginning on January 1, 2010, vessel operators were required to reduce at-berth permission of NOx and Particular Matter (PM) by 10%.
- **Question**: What is the effect of this policy on air pollutant concentrations?

Empirical Strategy

- Regression Discontinuity Design
- Relies on the sharp discontinuity in how port activities were fueled on January 1, 2010
  - No incentive for port/ship operators to comply before this date because onshore electricity and cleaner fossil fuels are more expensive than conventional fuels
  - Infrastructure might have been installed prior to, but likely not being used
- Estimate the following equation using an augmented local linear approach:

$$P_{ipt} = \rho Policy_t + \eta_1 Date_t + \eta_2 Policy_t \times Date_t + \beta V_{pt} + \mathbf{W}_{it}\theta + \delta_t + \mu_{ip} + e_{ipt}.$$

Policy = dummy for whether the policy is in effect at date t
Date = “running variable”, normalized to be zero on the first date of the policy

Results

- **First step:** Use full data sample to regress log pollution measures on the exogenous variables (weather controls, instrumented vessel tonnage, FEs) and obtain the residuals.
- **Second step:** Regress the residuals obtained from the first step on the RDD terms within a narrow bandwidth of dates
  - Primary specification uses a bandwidth of 65 dates on each side of the policy threshold

Results: Second Step

Table 5: Effect of California Ocean-Going Vessel At-Berth Regulation on air pollution, RDD estimation

	Dependent variable: residual of log pollution concentration			
	CO	NO_2	$PM_{2.5}$	SO_2
	(1)	(2)	(3)	(4)
CA Regulation	−0.12*	−0.20**	0.17	−0.17
	(0.07)	(0.09)	(0.10)	(0.21)
Date	0.005***	0.004**	0.002	0.01**
	(0.002)	(0.002)	(0.002)	(0.004)
CA Regulation × Date	−0.01***	−0.004*	−0.01***	−0.01
	(0.003)	(0.002)	(0.003)	(0.01)
Pre-policy Mean	608.01	18.36	14.54	1.83
Observations	4,710	5,288	2,928	3,171

Notes: This table presents the second-stage augmented local linear RDD estimation of the effect of the California at-berth regulation on air pollutant concentrations. The second-stage RDD dependent variable is taken from the residuals by regressing log pollution concentrations on weather controls (i.e., the quadratics of maximum, minimum, and dew point temperature, precipitation, wind speed, and relative wind direction between a monitor-port pair), fixed effects (i.e., county-by-year, month, day-of-week, holiday, and port-monitor pair), and log vessel tonnage (instrumented by seven-day lagged and 500-mile distant cyclones from ports). The local linear bandwidth is specified as 65 days on both sides of the policy threshold. An observation is a monitor-port-day. Standard errors are clustered by monitor-port pair and normalized day. Significance levels are indicated by *** 1%, ** 5%, and * 10%.

The regulation leads to a decrease in average pollution concentrations by 20% for NO2.

Results: Second Step

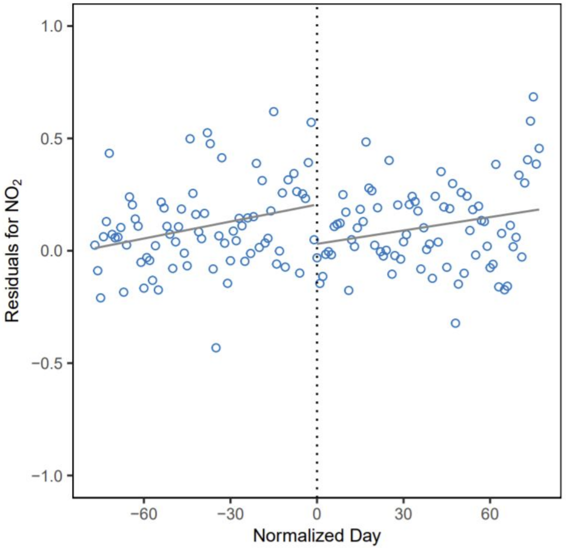

Figure 6: Residuals of NO_2 concentrations for the RDD analysis.

Notes: This figure plots daily average residuals across all monitor-port pairs for NO_2. The grey solid lines are linear fitted lines of the residuals. The policy date is normalized to be zero, indicated by the vertical dotted lines. A few extreme values are not shown in the figure.

Downward breaks of linear trends in residuals around the policy date.

Results: Effect on Hospitalizations and Medical Costs

Regulation led to **9.9 avoided hospital visits per thousand Black residents per year** ($88 avoided costs), and **3.4 avoided visits per thousand White residents** ($31 avoided costs)**.**

Authors calculated that these benefits outweighed the costs of policy, with **savings of $558 million in medical costs per year.**

Results **robust to choice of bandwidth**, and **placebo tests** show pollution was not driven by seasonal effects or anything else that might have been happening in CA on January 1, 2010.

Table 6: Effect of California Ocean-Going Vessel At-Berth Regulation on annual hospitalizations and medical costs

	All Respiratory (1)	All Heart (2)	All Psychiatric (3)
Panel A: Hospital visits per million residents			
Black	-7,900	-1,600	-420
White	-1,700	-920	-740
Overall Population	-2,500	-920	-640
Panel B: Medical costs per capita (2017 USD)			
Black	-69	-15	-4
White	-15	-9	-7
Overall Population	-22	-9	-6

Notes: Panel A presents the back-of-the-envelope calculations of the effect of the California at-berth regulation on annual hospitalizations based on the estimates in Tables 2 and 5. Panel B presents the medical costs associated with the hospital visits in Panel A based on the payment data from Centers for Medicare and Medicaid Services. The average medical costs are $8,917 for psychiatric illnesses, $8,715 for respiratory illnesses, and $9,679 for heart-related illnesses. Based on the US 2010 Decennial Census, total population residing in the zip codes within 25 miles of the major ports in California is 15.08 million, in which 1.12 million are Black and 5.07 million are white. All numbers are rounded to two significant figures.

Dynamic Simulations

Concern: If the regulations reduced fossil fuel use in ports but increased its usage from electricity generation, then pollution might have been shifted from one place to another.

Solution: Authors simulate a scenario on the National Energy Modeling System, a general equilibrium model that includes all major energy markets, energy supply sectors, demand sectors, conversion sectors, etc. This provides **a detailed simulation linking energy consumption in ports and electricity generation.**

Result: They find that **reduction in emissions from marine vessels is substantial**, while the **increase in emissions from electricity generation is extremely small**. This is because the power sector uses much cleaner energy sources on average (e.g. natural gas and renewables).

Conclusions

This paper:

- Uses a quasi-experiment, where port traffic is influenced by lagged distant tropical cyclones, to investigate the effect of port traffic on local air pollution and hospitalizations, and the racial disparities therein
- Finds that increasing vessel tonnage increases air pollution concentrations in areas surrounding the ports
- Finds that this leads to increased hospitalizations for respiratory, heart and psychiatric ailments that disproportionately affect Black residents
- Suggests that the disparities arise from differential exposure as well as differential response functions given exposure level