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Cap-and-Trade and Environmental Justice: A Study of California's RECLAIM Program

By Aidan Acosta

Cap-and-trade has been shown by previous studies to be at least as effective as prescriptive regulation at reducing air pollution. Because cap-and-trade is more flexible for facilities than control-based regulations, it has gained important political support. However, regulators must ensure that the dispersion of emissions that is dictated by the market is environmentally just in order for cap-and-trade to be a viable solution. I investigate the changes in dispersion patterns resulting from the implementation and operation of Southern California's RECLAIM program between 1994 – 2010 using a difference-in-difference model. My results demonstrate that RECLAIM was equally effective as the counterfactual command-and-control regime. With regard to race, I find suggestive evidence that the program led to a reordering of emissions whereby Blacks benefitted, while Hispanics and other races lost out, relative to Whites. With regard to income, I find evidence that the lowest-income group benefitted, while the middle-income group lost out, relative to the highest income group.

1. Introduction

When urbanization and industrialization gripped the United States, air pollution did the same. It has been, and remains, one of the nation's greatest environmental challenges. The United States implemented its first air pollution legislation in 1955 and regulations have been evolving ever since. The creation of the Environmental Protection Agency and the approval of the Clean Air Act in 1970 (and its subsequent amendments) set the stage for stronger federal action against air pollution. For the first time, states were required to develop plans to meet the newly established National Ambient Air Quality Standards (NAAQS). In order to lower the emissions of facilities within their states, local governments have developed regulations that fall into two categories: control-based and market-based.

Control-based measures cap the amount of pollution that facilities can emit over a time period and mandate the adoption of modern technologies to meet the caps. This method is called command-and-control (CAC). The market-based method sets a regional emissions cap by issuing pollution allowances to facilities, the sum of which are equal to the cap. Facilities can sell their excess allowances to facilities that failed to reduce their emissions adequately, creating a marketplace for pollution allowances. This method is called cap-and-trade (CAT).

Cap-and-trade has been used increasingly since the introduction of the 1990 Clean Air Act Amendments to reduce different types of pollution. Nevertheless, it is often challenged on the grounds of environmental injustice because reducing the net pollution of an area can allow hotspots of pollution to emerge in specific neighborhoods. Although CO_2 does not cause localized health problems, the co-pollutants that accompany greenhouse gasses could harm disadvantaged communities if hotspots emerge. Pollution exposure can also cause greater-than-average health reduction for low-income groups, especially if markets cause pollution in their communities to increase (Marshall 2008).

My study focuses on the United States' first market-based air pollution control program, which operated from 1994-2017 in Southern California. The program was called RECLAIM, an acronym for the Regional Clean Air Incentives Market. Aptly named, the program offered a chance to 'RECLAIM' clean air, a better, healthier lifestyle, and the vistas of the Los Angeles region ("the smoggiest in the nation") which have been obscured by severe and harmful air pollution (SCAQMD.gov). RECLAIM was also the first emissions trading program to be challenged on the grounds of environmental injustice, prompting numerous researchers to study the program's impacts. My paper builds upon existing studies by assessing the overall effectiveness of RECLAIM relative to the CAC regime it replaced, and by examining the dispersion of pollution across racial and income groups.

My findings suggest that overall emissions under RECLAIM were not statistically significantly different from what they would have been under the counterfactual CAC regime, which also had a declining schedule of emissions. I find that race was not statistically significantly associated with the emissions patterns of facilities regulated by RECLAIM. However, lower-income households seem to have experienced a relative decrease in emissions under RECLAIM, while middle-income households experienced a relative increase, compared with upper-income households.

2. Program Context

RECLAIM was the first mandatory CAT program to include a broad array of industry sources and supplant a preexisting CAC regime (Fowlie, Holland, and Mansur 2012). The program operated within the South Coast Air Quality Management District (hereafter referred to as the south coast), which spans 10,473 square miles and is home to around 15 million people. The program functioned by giving facilities the option to use "add-on controls, equipment modifications, reformulated products, operational changes, shutdowns, and the purchase of excess emission reductions" to limit their discharges to a prescribed level ("Regulation XX" 2019).

RECLAIM applied to stationary sources within the south coast that reported more than four tons per year of NO_x or SO_x emissions in their annual emission reports, but excluded dry cleaners, landfill gas operations, public transit facilities, and police stations. Each polluter was given an annual allotment of RECLAIM Trading Credits (RTCs), the sum of which constituted the total level of allowable emissions within the air district. Facilities that reduced their emissions by more than the required volume could sell their excess credits to other facilities in the RTC market. Those that were unable or unwilling to reduce their emissions would have to buy enough RTCs to offset their emissions. The goal of the program was to help the south coast comply with the EPA's NAAQS at the lowest possible cost to society.

The cap-and-trade framework was appealing as it presented a more efficient alternative to a CAC regime but still promised a hard cap on nitrogen and sulfur oxides. Nevertheless, the environmental justice community was skeptical of RECLAIM. They feared that underprivileged citizens would be disadvantaged by their lack of lobbying power and that they may have greater exposure to the plants that would buy RTCs rather than reduce emissions. CAC regimes are preferred by environmental justice advocates for the same reason that they are disliked by economists: they require all plants, regardless of cost, to meet the same standards.

Evaluating the success of RECLAIM relative to the CAC regime it replaced has been a challenge since the program's inception. Facility emissions are impacted by economic fluctuations, such as volatile energy prices,[1] changes in plant or company ownership, concurrent EPA regulatory measures, and everyday management decisions. The agencies in charge of overseeing RECLAIM, as well as numerous independent academics, have used various research

[1] An energy supply crisis during the summer of 2000 incentivized California power companies restart their older power generators in the Los Angeles region to meet demand (Goulder 2013, 94).

designs to assess the program's estimated impacts. Their finding indicated that RECLAIM did not bring the south coast into compliance with the EPA's NAAQS, which ultimately led to the program's demise. On March 3, 2017, the California Air Resources Board voted 7-6 to sunset the RECLAIM program and transition back to a command-and-control system (Hiltzik 2017).

This paper seeks to evaluate the success and fairness of the program by identifying RECLAIM and non-RECLAIM facilities in the south coast and adjacent air basins, approximating the facilities' pollution dispersion zones and the demographics of those zones, and utilizing a difference in difference model to measure the impact of the program for different racial and income groups. The study spans from 1990 to 2010 and estimates the changes between baseline emissions and those of the subsequent 16 years. By evaluating the impacts of RECLAIM across demographic groups relative to the CAC counterfactual, this study will contribute to the discussion of cap-and-trade's ability to be an innovative and equitable environmental solution.

3. Literature Review

Cap-and-trade has been used increasingly since the introduction of the 1990 Clean Air Act Amendments to reduce different types of pollution. The Acid Rain Program for example, which began in 1995, has employed cap-and-trade to reduce coal fired power plant emissions of SO_2.[2] The program's final cap, set in 2010, represents a 50% reduction in emissions relative to the 1980 baseline (Chan et al. 2012). Despite its economic efficiencies, cap-and-trade is often criticized for delivering heterogeneous results. The Acid Rain Program, though successful, was found to be less beneficial to low-income groups relative to high-income ones, controlling for race. The program also benefitted minority groups more than the average population, controlling for income (Chan et al. 2012).

Environmental justice is a crucial consideration for policymakers, especially as baseline inequities caused by environmental racism and gentrification persist in many communities. Marshall (2008) illustrates the pertinence of this issue in the study area. According to Marshall, exposure to benzene, butadiene, chromium particles, and diesel particles is higher by 16-40% for

[2] Sulfur dioxide is the pollutant most directly responsible for causing acid rain (Chan et al. 2012, 421).

non-Whites compared to Whites in the south coast (2008).[3] Muller et al. (2018) cite these findings and approximate the effect of air pollution on real income. The authors calculate the fraction of mortality risk attributable to pollutants ($PM_{2.5}$ and O_3) and monetize these risks, finding that pollution acts as a regressive tax on the bottom 20% of the income distribution (Muller, Matthews, and Wiltshire-Gordon 2018). These studies and the continued Clean Air Act non-compliance in the south coast illustrate the necessity of programs that reduce net emissions and environmental inequity simultaneously (EPA 2020).

My research builds on three studies of the RECLAIM program which directly address the distribution of emissions across demographic groups. These papers use the same data sets and timeframes, but they each have different findings. The papers utilize facility level data from the California Air Resources Board and demographic data, at the block group level, from the U.S. Census. The papers all study changes in emissions for treatment facilities in the south coast versus control facilities in non-compliance counties in California between 1990-2005 and use the period 1990-1993 as the baseline. Each author finds that RECLAIM improved net emissions levels relative to the counterfactual, but they disagree on the equity of dispersion. Fowlie et al. and Mansur and Sheriff find an overall improvement in pollution levels for all considered demographics relative to the counterfactual, while Grainger and Ruangmas find that Hispanics and low-income groups benefit less under RECLAIM than under CAC (Fowlie, Holland, and Mansur 2012; Mansur and Sheriff 2019; Grainger and Ruangmas 2017). By incorporating an additional 5 years of facility level data and 10 years of demographic data I hope to modernize the scope of the aforementioned studies.

Fowlie, Holland and Mansur conducted the first study of RECLAIM (2012). The authors use four periods, 1990-1993, 1997-1998, 2001-2002, and 2004-2005 and create counterfactual emissions predictions by exploiting the fact that only a subset of the industrial facilities in California's nonattainment areas were required to participate in RECLAIM. They use historic emissions, industry classification, and county attainment as parameters to match RECLAIM facilities with a minimum of three controls (Fowlie, Holland, and Mansur 2012). The authors use the facility as the unit of analysis and estimate the demographics of their dispersion areas. They exclude power producers from a subset of their analyses because the California energy supply

[3] These pollutants increase incidences of leukemia and lung cancer, decrease red blood cell count, and harm bone marrow ("CDC | Chemical Emergencies" 2019).

crisis of 2000 caused power producers to exit the program between 2001-2007[4] (Goulder 2013). Fowlie et al. calculate the percentages of each block group's geographic area within a half, one, and two miles of each facility as a robustness check. These percentages are multiplied by the block group demographics to estimate the population makeup surrounding each facility (Fowlie, Holland, and Mansur 2012). Next, they estimate the program's impact by comparing the emissions and demographics in RECLAIM facilities' dispersion areas with those of control facilities using OLS and DID regression models (Fowlie, Holland, and Mansur 2012). Their results indicate that RECLAIM facilities' emissions fell an average of 20% relative to those of non-RECLAIM facilities and that no racial or income group experienced a statistically significant increase in emissions due to RECLAIM (Fowlie, Holland, and Mansur 2012).

Unlike Fowlie et al., Mansur and Sheriff (2019) utilize only two periods, 1990-1993 and 2004-2005, in their study. They also use individuals as the unit of analysis, rather than facilities, and model facility dispersion using three different methods. The first involves aggregating the emissions of all the facilities within 3km of each census block group centroid and calculating the cumulative NO_x emissions exposure for each individual in that block group (Mansur and Sheriff 2019). The second method follows the first, except the authors use a semicircle of 1km to the west and 4km to the east in an attempt to capture the effects of the predominantly easterly winds of the south coast region. The third method, which is utilized by Grainger and Ruangmas, is a HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory)[5] model (Mansur and Sheriff 2019). Ultimately, the authors find that the choice of dispersion model is unlikely to alter the environmental justice implications of RECLAIM (Mansur and Sheriff 2019).

Mansur and Sheriff generate a pool of control facilities by matching on historic emissions and industry classification (Mansur and Sheriff 2019). They calculate the average percent change in emissions for these matched controls between periods 1 and 2, applying this change to the period 1 emissions levels of RECLAIM facilities to predict the period 2 counterfactual (Mansur and Sheriff 2019). This method differs from Fowlie et al. by using percent changes, rather than absolute changes, to estimate counterfactual emissions. Mansur and Sheriff then use a

[4] The energy supply shortage caused power companies to restart retired generators in the LA region. This led to a significant increase in the demand for RTCs, which increased in value from an average of $400 per ton to an average of over $40,000 per ton in 2000 (Goulder 2013). In order to stabilize the RTC market, power producers were temporarily removed from the program.
[5] The HYSPLIT model is a computer model used for estimating "simple air parcel trajectories, as well as complex transport, dispersion, chemical transformation, and deposition simulations" ("HYSPLIT" 2019).

Generalized Lorenz (GL) curve to measure the total pollution and the equity of the dispersion. GL curves are estimated by plotting cumulative emissions exposure per capita as a function of population percentile, ranked in decreasing order of exposure (Mansur and Sheriff 2019). The GL curve's shape illustrates the equity of the distribution (a ray from the origin represents a totally equitable dispersion) and the total pollution level (greater average pollution levels raise the curve, all else equal) (Mansur and Sheriff 2019). The authors find that all demographics are better off under RECLAIM than under the baseline or command-and-control and find no evidence to suggest that gains accruing to one demographic group came at the expense of another (Mansur and Sheriff 2019). Nevertheless, they found that the Black demographic has the most desirable exposure distribution under all three dispersion scenarios, followed by the White distribution, followed by the Hispanic distribution. Additionally, with respect to income, the wealthiest group has the most desirable distribution under RECLAIM (Mansur and Sheriff 2019).

Grainger and Ruangmas (2017) identify control facilities using the same method as Fowlie et al. but utilize the HYSPLIT model exclusively for their dispersion estimates. The authors analyze the population weighted relative change (in tons), and the population density weighted relative change (in people × tons per square feet), that each demographic experiences under RECLAIM versus the counterfactual (Grainger and Ruangmas 2017). Ultimately, Grainger and Ruangmas find that most census blocks benefit from cap-and-trade, but higher income areas receive larger reductions in emissions under cap-and-trade, controlling for race and ethnicity (2017). Furthermore, controlling for income, Blacks receive a larger reduction, while Hispanics experience a smaller reduction, relative to whites (Grainger and Ruangmas 2017). What separates the conclusions of Grainger and Ruangmas from those of Mansur and Sheriff is the suggestion of an equity-efficiency tradeoff[6] and the finding that an increase in the poverty rate is associated with a smaller emissions reduction under cap-and-trade relative to command-and-control (Grainger and Ruangmas 2017).

It is challenging to discern which differences in the authors' methods are responsible for their heterogeneous findings, but the most plausible reason seems to be their estimation methods (Table 1). Grainger and Ruangmas use the same time periods and dispersion model as Mansur

[6] Mansur and Sheriff found no evidence that gains accruing to RECLAIM for one demographic group disadvantaged any other group, nor that average improvements within a group increased "hotspots" within the group (2019).

and Sheriff and the same counterfactual identification strategy as Fowlie et al. Additionally, all of the authors exclude power producers from their study, though Fowlie et al. include them for specific analyses. The major difference between all of the papers is that Grainger and Ruangmas use a population density weighted model, Fowlie et al. use OLS and DID models, and Mansur and Sheriff use a General Lorenz curve. It is possible that the population density weighted model led to the finding of equity-efficiency tradeoffs under cap-and-trade relative to command-and-control (2017).

Table 1. Comparison of data and methods by author

Data & Methods	**Fowlie et al.**	**Mansur and Sheriff**	**Grainger and Ruangmas**	**Acosta**
Emissions Data	CARB	CARB	CARB	CARB
Demographic Data	U.S. Census	U.S. Census	U.S. Census	U.S. Census
Time Periods	(1) 1990-1993, (2) 1997-1998, (3) 2001-2002, (4) 2004-2005	(1) 1990-1993, (2) 2004-2005	(1) 1990-1993, (2) 2004-2005	(1) 1990-1993, (2) 1999-2001, (3) 2009-2010
Control Sample Locations	All California ozone non-attainment counties	All California ozone non-attainment counties	All California ozone non-attainment counties	California air basins adjacent to the south coast
Counterfactual Identification	Historic emissions, SIC code, county attainment	Historic emissions, SIC code	Historic emissions, SIC code, county attainment	Historic emissions, RECLAIM eligibility
Exclude Power Producers?	Both	Yes	Yes	Both
Emissions Dispersion Model	.5, 1, 2-mile radii	3km radii[7], 1km west & 4km east radii, HYSPLIT	HYSPLIT	3km radii
Estimation Model	OLS, DID	General Lorenz Curve	Population weighted relative change (tons), population density weighted relative change (people × tons per square feet)	DID with industry fixed effects

Notes: Data, time periods, counterfactual identification, and power producer exclusion are relatively homogenous across authors. Emissions dispersion model, according to Mansur and Sheriff, does not have a significant impact on environmental justice implications (2019). This leaves the estimation model as the most probable cause of the authors' heterogeneous findings.

[7] Mansur and Sheriff's main results "were calculated under the assumption that the impact of NO_x emissions is evenly spread within 3 km of each facility" (2019).

4. Data

I acquired facility level data from the California Air Resources Board (CARB) for three periods: (1) 1990 and 1993[8], (2) 1999 – 2001, (3) 2009 – 2010. These periods were chosen because they align most closely with the corresponding census data and the first period predates the implementation of the RECLAIM program, allowing it to serve as a baseline. Facilities are required by California law to report their emissions to their local Air Quality Management District and CARB maintains a database of these reports (Fowlie, Holland, and Mansur 2012). Nevertheless, some facilities either fail to report their emissions or report zeros in some years. This is often the result of changes in facility ownership, voluntary exit from the program, or a facility going out of business. For this reason, I only included facilities that reported their emissions during at least one year of each period.[9] Additionally, I did not include facilities that reported NO_x and SO_x emissions below 4 tons in all the included periods because this was a criterion of joining the RECLAIM program initially. 298 facilities met all these criteria and were included in the final analysis.[10] This is comparable to Mansur and Sheriff (212 facilities), while Grainger and Ruangmas included 565 facilities and Fowlie et al. included 477. The variation is attributable to the different periods and counterfactual identification strategies applied in each study.

In order to normalize the baseline emissions levels of the treatment and control groups, and to account for the exclusion of power producers from the program between 2001 – 2007, I analyze the data in four subsamples. Separate analyses are useful as there are a larger number of facilities outside of the south coast that operate in the mining (SIC 32) and electric services (SIC 49) industries and some of these facilities emit between 500 and 2000 tons of NO_x annually.

The first subsample excludes the electric industry, the second excludes the electric and mining industries, the third excludes all facilities with reported NO_x emissions exceeding 500 tons in any period, and the fourth includes all observations (Appendix 1, 2, 3, 4). Excluding electric facilities lessens the difference between treatment and control at the baseline, but not

[8] 1991, 1992, and 1994 data are not available.
[9] Emissions for each period are equal to the average of all non-zero annual emissions quantities within that period. This is to avoid improper weighting.
[10] Hospitals, prisons, schools and universities, and ski resorts were prohibited from joining RECLAIM initially but were later allowed to enter the program if they wished. Emissions from Rule 219 equipment, rental equipment, on-site mobile sources, and ships were exempt from RECLAIM. Dry cleaners, landfill gas operations, police stations, and public transit facilities were also excluded from RECLAIM and are not included in this study.

substantially. The preferred estimates utilize all observations less than 500 tons (column 3) because this sample provides the most comparable baselines between treatment and control groups and has the largest sample size besides all observations (column 4).

Demographic data are from the 1990, 2000 and 2010 United States Censuses. My primary analyses utilize the 1990 data because it is exogenous to the implementation of RECLAIM, eliminating the possibility of populations sorting based on pollution exposure as a result of the program. The analyses using 2000 and 2010 data serve as additional robustness checks. Census data are at the block group level, where a block group contains 600-3,000 people with an optimum level of 1,500 people. The assessed block groups are within the counties comprising the south coast (Los Angeles, San Bernardino, Orange, Riverside) and the control area (Los Angeles, San Bernardino, San Luis Obispo, Kern, Santa Barbara, Ventura, San Diego, Imperial).[11] Demographic data include self-reported race and household income. Hispanic individuals are those who identify as Hispanic, regardless of race. Black and White individuals are those who identify as either Black or White, but not as Hispanic. Other individuals are those who identify as any other race, but not as Hispanic. Annual income is assessed in 2016 dollars using four classifications: (1) under $15,000, (2) $15,001 – $25,000, (3) $25,001 – $50,000, (4) over $50,000. Annual income was not available in the 2010 census.

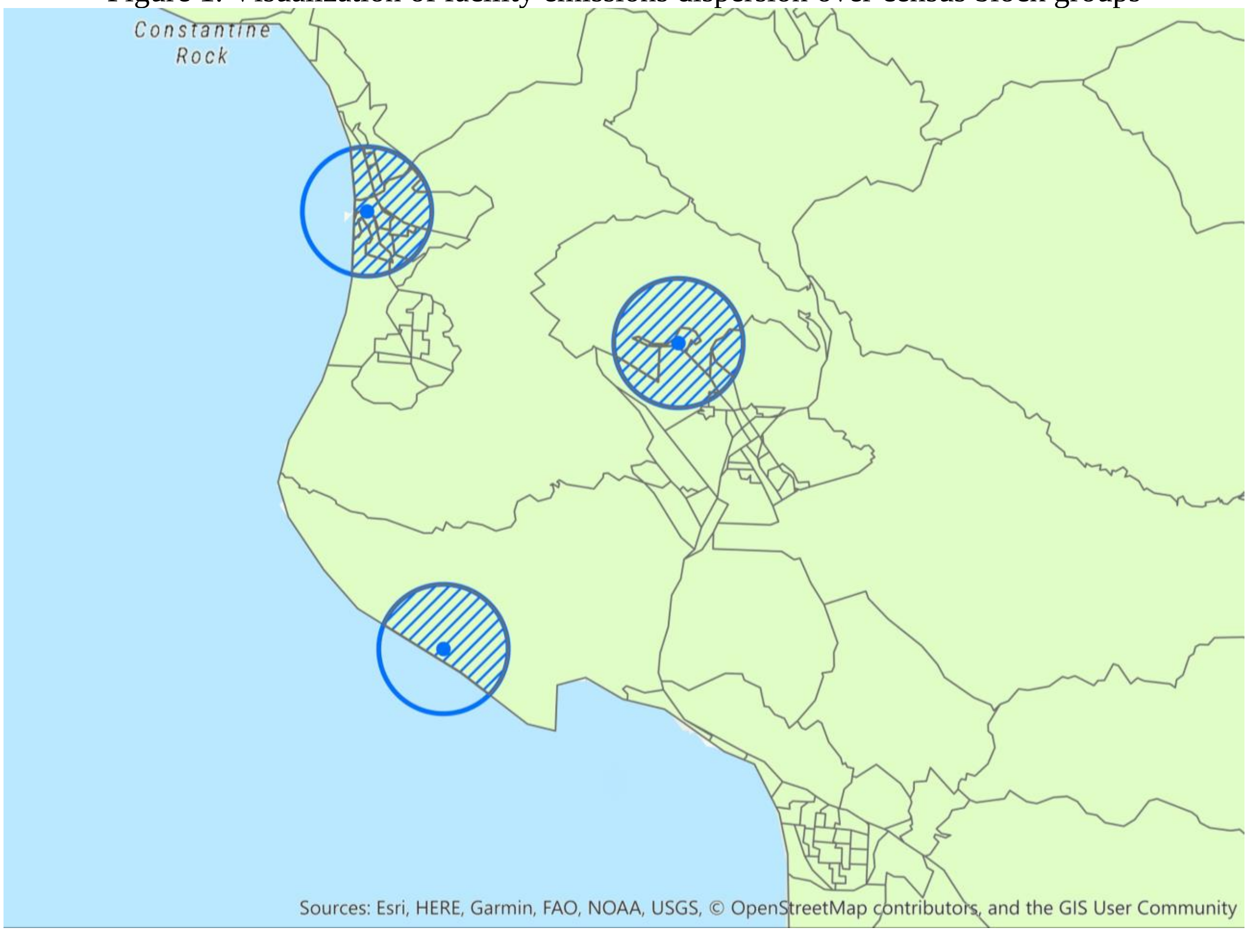
I combined facility and demographic data by running an aerial weighted reaggregation in ArcGIS Pro. This involved mapping census data onto their respective block groups and creating 3km radii around each facility to model the dispersion of emissions.[12] The buffer zones are used to approximate the ratio of each block group within the area of a facility's emissions. This ratio serves as an approximation for the proportion of the population of the block group that is impacted by the pollution of the facility (Figure 1).

The export from ArcGIS Pro provided me with three periods of facility-radius level data that includes a unique facility ID, a dummy variable for whether the facility is a RECLAIM participant, the facility SIC code, the associated levels of NO_x and SO_x, the number of people by

[11] Parts of Los Angeles and San Bernardino counties fall within multiple air basins.
[12] Mansur and Sheriff find that utilizing more advanced facility dispersion patterns, like the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) or a buffer of 4 km to the east and 1 km to the west, "are unlikely to substantially alter the environmental justice implications of RECLAIM" (2019). For this reason, I decided to use a simpler dispersion pattern of a 3km radius.

race, and the number of households by income. These data are sufficient to conduct difference-in-difference analyses.

Figure 1. Visualization of facility emissions dispersion over census block groups



Notes: Facilities are denoted by the blue dots at the center of each circle (3km radii). The circles intersect census block groups, which are outlined in light gray. The ratio of the area of a block group covered by a circle to its total area serves as an approximation for the proportion of the population of the block group that is impacted by the pollution of the facility.

5. Research Design

I employ a difference-in-difference model to estimate the treatment effect of the RECLAIM program.[13] Whereas the control facilities in previous studies are located in any non-attainment county in California, the control group in my study is limited to facilities located in the air basins adjacent to the South Coast Air Quality Management District that would have met

[13] My analysis assumes that the introduction of the RECLAIM program did not affect the level of emissions at other facilities. If the program did cause emissions to shift from facilities in the south coast to facilities exempt from the program, this would positively bias the program impacts. If the program caused emissions to shift to facilities in the south coast, this would negatively bias the program impacts.

the requirements to enroll in RECLAIM had they been located within the south coast in period 1 (Figure 2).

Equation 1 estimates the effects of the RECLAIM program on overall emissions levels:

$$NO_{x,i} = \beta_0 + \beta_1\, Post_t + \beta_2\, RECLAIM_i + \beta_3\, DID_i + \lambda_{SIC} + U_{it},$$

where $Post_t$ is a binary term indicating the later period of the difference-in-difference, $RECLAIM_i$ is a binary term indicating treatment, DID_i is the interaction term equal to $Post_t \times RECLAIM_i$, and λ_{SIC} is a vector representing the controls for industry fixed effects. The coefficient on DID_i represents the incremental difference between average NO_x emissions under RECLAIM relative to the counterfactual between the specified periods.

I estimate treatment effects on racial groups and income groups separately because individual-level data on both race and income was not available.[14] Performing analyses with household-level income controls and individual-level race controls simultaneously would lead to multicollinearity, as race and income are highly correlated (Table 7).

Equation 2 estimates the impact of RECLAIM on Blacks, Hispanics, and other races:

$$NO_{x,i} = \beta_0 + \beta_1\, Post_t + \beta_2\, RECLAIM_i + \beta_3\, DID_i + \beta_4\, Black_i + \beta_5\, Hispanic_i + \beta_6\, Other_i + \beta_7\, Post_t \times Black_i + \beta_8\, Post_t \times Hispanic_i + \beta_9\, Post_t \times Other_i + \beta_{10}\, Black_i \times DID_i + \beta_{11}\, Hispanic_i \times DID_i + \beta_{12}\, Other_i \times DID_i + \lambda_{SIC} + U_{it},$$

where the coefficient on $Black_i \times DID_i$ represents the incremental difference between average NO_x emissions for Blacks relative to Whites under RECLAIM versus the counterfactual between the specified periods, controlling for Hispanics, other races and industry fixed effects. The coefficients on $Hispanic_i \times DID_i$ and $Other_i \times DID_i$ are interpreted in the same way.

[14] i.e. the data contains the number of households by income range and the number of individuals by race, but not the number of individuals of a given race who are within a given income range.

Equation 3 estimates the impact of RECLAIM on households with annual incomes below \$25K and between \$25K – \$50K:

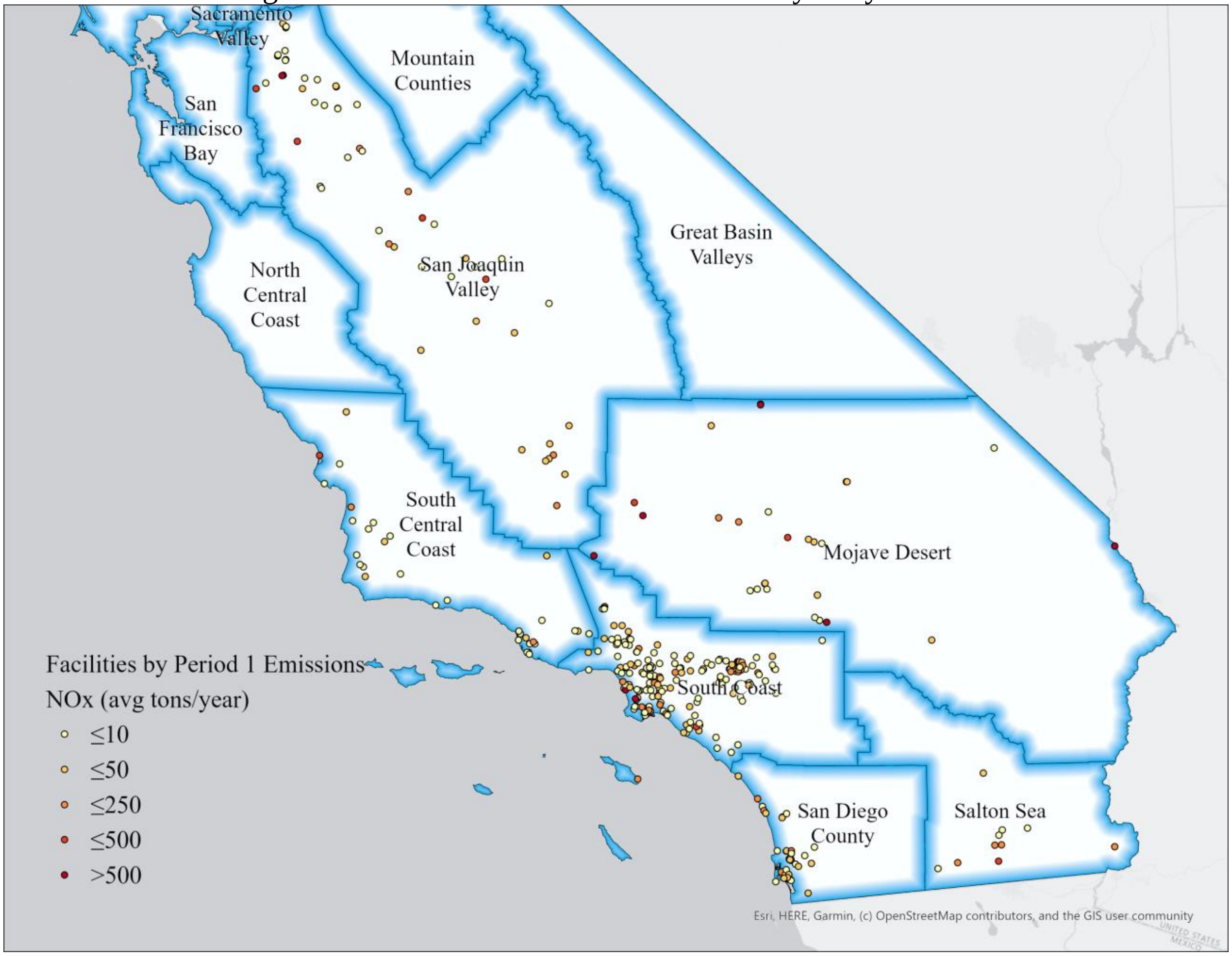
$$NO_{x,i} = \beta_0 + \beta_1\, Post_t + \beta_2\, RECLAIM_i + \beta_3\, DID_i + \beta_4 <\$25K_i + \beta_5\, \$25 - \$50K_i + \beta_6\, Post_t \; x <\$25K_i + \beta_7\, Post_t \; x \; \$25 - \$50K_i + \beta_8 <\$25K_i \; x \; DID_i + \beta_9\, \$25 - \$50K_i \; x \; DID_i + \lambda_{SIC} + U_{it},$$

where the coefficient on $<\$25K_i \; x \; DID_i$ represents the incremental difference between average NO_x emissions for households with incomes below \$25K relative to households with incomes over \$50K under RECLAIM versus the counterfactual between the specified periods, controlling for households with incomes between \$25K – \$50K and industry fixed effects. The coefficient on $\$25 - \$50K_i \; x \; DID_i$ is interpreted in the same way.

6. Results

In this section I will present the effects of the RECLAIM program on pollution levels, both overall and for specific groups. The outcome of interest is the change in facility-radius-level annual NO_x emissions. Whether the change in emissions levels induced by RECLAIM, in comparison to CAC, is correlated with demographics is of primary interest. Although my primary results utilize 1990 demographic data, the analyses that utilize 2000 and 2010 data yield similar results (Appendix 5, 6, 7).

Figure 2. Facilities included in the final analysis by air basin



Notes: Facilities and their period 1 emissions levels are denoted by colored circles. RECLAIM facilities are located in the South Coast. Control facilities are in the air basins adjacent to the South Coast and would have met the requirements to enroll in RECLAIM in period 1.

The first results of note are the baseline NO_x emissions across treatment and control facilities. When including all observations, baseline emissions in the control group are 2.59 times greater than those of the treatment group (Table 2). One reason for this is the large number of power producers (SIC 49) and mining (SIC 32) facilities in the control group. 75% of the facilities that exceeded 500 tons of NO_x emissions in period 1 operate in these industries, while 66% of the facilities that exceeded 500 tons of NO_x emissions in all periods operate in these industries (Appendix 3, 4). When including only observations where NO_x does not exceed 500 tons, the baselines are similar (Table 3). Tables for the other subsamples can be found in the appendix (Appendix 1, 2).

Table 2. Mean NO_x emissions by treatment and control (all observations)

Mean NO_x Emissions (tons)	*Period*			
	1	**2**	**3**	**Total**
Non-RECLAIM	250.76	187.88	123.08	187.41
	645.04	592.73	381.14	552.94
	125	125	124	374
RECLAIM	96.81	82.89	49.32	76.34
	351.19	367.62	276.54	334.09
	173	173	173	519
Total	161.39	126.93	80.12	122.86
	500.93	477.12	325.78	442.35
	298	298	297	893

Note: Results in the table represent, from top to bottom, mean, standard deviation, and sample size.

Table 3. Mean NO_x emissions by treatment and control ($NO_x < 500$)

Mean NO_x Emissions (tons)	*Period*			
	1	**2**	**3**	**Total**
Non-RECLAIM	40.58	37.89	24.70	34.42
	62.71	65.81	54.87	61.52
	109	109	108	326
RECLAIM	38.17	31.68	20.64	30.16
	60.53	71.19	58.38	63.90
	166	166	166	498
Total	39.12	34.14	22.24	31.85
	61.30	69.05	56.96	62.97
	275	275	274	824

Note: Results in the table represent, from top to bottom, mean, standard deviation, and sample size.

Table 4 illustrates the difference in emissions levels under RECLAIM relative to the counterfactual CAC regime. The coefficient on $Post_i$ represents the incremental difference in average NO_x emissions between the specified periods in each panel. The coefficient on $RECLAIM_i$ represents the incremental difference between average NO_x emissions for RECLAIM versus non-RECLAIM facilities in the first period in each panel. The coefficient on DID_i represents the incremental difference between average NO_x emissions for RECLAIM versus non-RECLAIM facilities between the specified periods in each panel. The coefficients on DID_i

are not statistically significant in any table or column, suggesting that the program was not responsible for any meaningful changes in emissions levels. This finding stands in contrast to that of Fowlie et al., who found that emissions from RECLAIM fell an average of 20% relative to those of non-RECLAIM facilities over the first 10 years of the program (Fowlie, Holland, and Mansur 2012).

Table 4. Changes in NO_x emissions under RECLAIM relative to CAC

	(1) Non-Electric	(2) Non-Mining, Non-Electric	(3) NOx < 500	(4) All Observations
Panel A. Change in NOx emissions between periods 1 and 2				
Post 2	-2.298	-19.34	-7.011	-62.88
	(19.06)	(12.14)	(7.395)	(46.90)
RECLAIM	-164.5	-26.42	-6.041	-186.8*
	(159.6)	(97.45)	(10.37)	(101.6)
DID 2 (Post 2 x RECLAIM)	-5.660	12.81	0.526	48.96
	(23.37)	(18.48)	(8.807)	(45.27)
Constant	236.5**	103.8*	44.98***	269.8***
	(93.02)	(57.46)	(6.665)	(58.03)
R-squared	0.018	0.001	0.004	0.023
Observations	450	416	554	596
Panel B. Change in NOx emissions between periods 1 and 3				
Post 3	-73.06	-14.46	-15.54**	-128.8**
	(60.69)	(26.31)	(7.331)	(58.25)
RECLAIM	-153.0	-17.85	1.925	-182.4*
	(153.1)	(89.74)	(9.987)	(100.5)
DID 3 (Post 3 x RECLAIM)	36.67	-18.46	-4.272	81.29
	(60.87)	(27.35)	(11.42)	(54.89)
Constant	229.7**	98.43*	39.47***	267.5***
	(100.7)	(50.91)	(5.638)	(66.15)
R-squared	0.021	0.003	0.024	0.033
Observations	449	415	551	595
Panel C. Change in NOx emissions between periods 2 and 3, excluding period 1				
Post 3	-71.49	4.198	-17.56***	-66.08
	(75.40)	(25.74)	(4.509)	(52.53)
RECLAIM	-175.8	-21.79	-10.40**	-139.9

	(162.5)	(79.11)	(4.727)	(107.6)
DID C (Post 3 x RECLAIM)	43.07	-30.59	2.888	32.51
	(74.30)	(25.68)	(6.038)	(52.31)
Constant	238.1**	89.79*	45.48***	208.5***
	(111.9)	(48.41)	(3.153)	(71.63)
R-squared	0.022	0.003	0.017	0.021
Observations	449	415	551	595
Number of SIC codes	44	43	45	45

Table 5 illustrates the difference in emissions levels by regulatory regime for different racial groups. Although the results are not statistically significant, the signs on the coefficients suggest that Blacks benefitted while Hispanics and other races lost out relative to Whites under RECLAIM compared with the CAC regime. The coefficients on the DID terms, representing the changes in emissions for Whites under RECLAIM, are inconsistent and insignificant. The coefficient on $Other_i \times DID_i$ in panel C was automatically omitted due to collinearity.

Considering observations in column 3, Blacks see a small decrease while Hispanics and other races see a small increase in emissions relative to Whites under RECLAIM. This trend is consistent across panels A, B, and C, though only the coefficient on $Hispanic_i \times DID_i$ in panel B is significant at even the 10% level.

In column 1, the magnitude of the coefficients on the interaction terms is much greater, particularly for Black populations. The coefficient on $Black_i \times DID_i$ is significant at the 10% level in panels B and C. The increased magnitude is likely attributable to electric facilities outside the RECLAIM area and in close proximity to Black populations reducing their emissions more significantly than non-RECLAIM facilities. Notably, Appendix 1 demonstrates that non-electric RECLAIM facilities reduced emissions to 60% of baseline levels in period 3, whereas non-electric, non-RECLAIM facilities reduced emissions to 65% of baseline levels in the same period. Thus, changes in non-electric emissions for Blacks are not aligned with changes in total non-electric emissions.

Despite suggestive evidence of a reordering of emissions dispersions under RECLAIM, the lack of statistical significance makes it impossible to make any definitive claims about the program’s effects. The suggestive evidence is consistent with the findings of Grainger and Ruangmas and Mansur and Sheriff, while the lack of statistical significance is consistent with the findings of Fowlie et al.

Table 5. Changes in NO_x emissions by race under RECLAIM relative to CAC

	(1) Non-Electric	(2) Non-Mining, Non-Electric	(3) NOx < 500	(4) All Observations
Panel A. Change in NOx emissions between periods 1 and 2				
Post 2	-93.02	-38.23	0.983	-103.2*
	(79.78)	(76.96)	(12.46)	(54.40)
RECLAIM	-114.4	-0.849	-4.131	-125.8
	(144.7)	(100.9)	(10.86)	(91.08)
DID 2 (Post 2 x RECLAIM)	105.4	49.85	-11.19	57.09
	(105.9)	(105.4)	(19.17)	(73.75)
Black	-217.4	-252.2	-22.47	-574.7
	(216.5)	(238.6)	(73.07)	(343.2)
Hispanic	-405.1**	-259.6*	7.758	-295.5**
	(174.4)	(136.2)	(15.03)	(138.5)
Other	233.8	91.13	-95.71*	-295.5
	(487.9)	(427.7)	(55.81)	(523.3)
Black x Post 2	2,274	71.41	0.272	1,515
	(2,289)	(544.1)	(86.93)	(1,728)
Hispanic x Post 2	-125.4	99.80	-31.85	-58.31
	(302.6)	(136.9)	(24.28)	(177.2)
Other x Post 2	202.8	-209.2	-3.232	-383.7*
	(561.9)	(256.7)	(76.69)	(201.0)
Black x DID 2	-2,568	-117.2	-75.05	-1,501
	(2,459)	(596.4)	(66.79)	(2,011)
Hispanic x DID 2	174.6	-105.3	50.40	97.35
	(365.7)	(166.5)	(37.39)	(218.8)
Other x DID 2	-376.3	68.42	31.29	570.1
	(695.8)	(422.5)	(106.0)	(401.5)
Constant	339.8***	186.0**	49.82***	390.1***
	(111.1)	(74.88)	(7.738)	(77.42)
R-squared	0.061	0.023	0.017	0.050
Observations	449	415	561	595
Panel B. Change in NOx emissions between periods 1 and 3				
Post 3	-141.1*	-84.31	-12.31	-180.8**
	(80.35)	(73.24)	(11.65)	(68.06)
RECLAIM	-99.44	6.646	6.830	-119.1
	(134.0)	(93.03)	(10.65)	(87.79)
DID 3 (Post 3 x RECLAIM)	54.16	19.65	-21.82	21.96
	(74.12)	(75.70)	(22.78)	(58.75)
Black	-245.2	-257.6	-103.5*	-575.5*
	(209.3)	(256.1)	(55.78)	(329.3)
Hispanic	-389.0**	-249.5*	15.82	-285.5**
	(166.9)	(129.5)	(12.62)	(135.7)
Other	50.70	75.00	-156.4***	-405.0
	(445.3)	(408.9)	(57.47)	(473.8)
Black x Post 3	2,126*	1,802	97.36	1,542

	(1,062)	(1,113)	(98.84)	(1,044)
Hispanic x Post 3	-4.873	-4.327	-35.60**	38.34
	(188.1)	(179.8)	(16.24)	(120.9)
Other x Post 3	-665.0	-381.4	15.90	-612.8
	(547.1)	(425.6)	(65.89)	(409.2)
Black x DID 3	-2,196*	-1,707	-66.51	-1,281
	(1,164)	(1,206)	(120.6)	(1,256)
Hispanic x DID 3	143.9	86.46	43.76*	98.55
	(192.9)	(165.4)	(23.10)	(117.8)
Other x DID 3	690.6	299.5	85.21	1,059***
	(624.0)	(505.0)	(87.25)	(382.1)
Constant	340.7**	179.5**	49.65***	391.2***
	(126.7)	(72.59)	(6.814)	(88.41)
R-squared	0.064	0.035	0.049	0.059
Observations	449	415	551	595

Panel C. Change in NOx emissions between periods 2 and 3, excluding period 1

Post 3	-154.8*	-72.95	-22.52***	-137.8**
	(80.42)	(44.35)	(6.151)	(62.11)
RECLAIM	-132.0	4.042	-6.229	-90.34
	(147.1)	(78.57)	(5.931)	(96.05)
DID 3 (Post 3 x RECLAIM)	108.2	16.40	0.275	59.54
	(97.87)	(55.72)	(10.27)	(83.61)
Black	-82.45	-280.3	-114.2***	-298.2
	(244.6)	(167.3)	(36.08)	(250.1)
Hispanic	-371.0**	-199.5**	23.66	-275.1**
	(166.2)	(89.96)	(17.27)	(132.7)
Other	108.5	-78.48	-143.2**	-217.6
	(405.8)	(299.6)	(55.12)	(357.7)
Black x Post 3	1,916*	1,751	76.94	1,185
	(1,113)	(1,173)	(98.76)	(1,095)
Hispanic x Post 3	-10.23	-42.70	-7.233	46.20
	(159.5)	(151.2)	(26.31)	(101.4)
Other x Post 3	-135.0	-2.746	55.01	41.65
	(240.8)	(123.2)	(36.15)	(209.4)
Black x DID 3	-2,134*	-1,624	-34.63	-1,234
	(1,210)	(1,233)	(112.7)	(1,242)
Hispanic x DID 3	133.2	95.87	6.035	69.93
	(177.1)	(154.1)	(28.85)	(100.6)
Other x DID 3	-	-	-	-
Constant	333.4**	166.1**	53.15***	304.9***
	(129.4)	(71.74)	(6.516)	(82.22)
R-squared	0.054	0.027	0.039	0.042
Observations	449	415	561	595
Number of SIC codes	44	43	45	45

Notes: The Black, Hispanic, and Other controls represent the fraction of the population that identifies as that race. The full magnitude of the coefficients represents a full fractional increase in the associated demographic category.

Table 6 illustrates the difference in emissions levels by regulatory regime for different income groups. The signs on the coefficients on the interaction terms are inconsistent across the panels and columns. Notably, their signs are opposite across all panels of columns 2 and 3. I continue to emphasize the results in column 3 due to the similar control and treatment baselines.

Across all panels of column 3, those households with incomes below $25K seem to have benefitted relative to households with incomes over $50K under RECLAIM. This finding is significant at the 5% level in panels B and C and at the 10% in panel A. Households with incomes between $25K and $50K seem to have lost out relative to households with incomes over $50K under RECLAIM. This finding is significant at the 1% level in panel C and at the 5% level in panels A and B. Households with incomes over $50K seem to have benefitted under RECLAIM. This finding is significant at the 1% level in panel C and at the 5% level in panels A and B.

Because of the inconsistency of findings from different data subsamples, it is unclear whether the effects of RECLAIM differed by 1990 income distributions. Nevertheless, the most statistically significant findings suggest that RECLAIM did affect these income groups differently. The evidence of the lowest-income group benefitting relative to the highest-income group contradicts the findings of Grainger and Ruangmas and Mansur and Sheriff, who found that low-income households lost relative to upper-income ones under cap-and-trade.

Table 6. Changes in NO_x emissions by income under RECLAIM relative to CAC

	(1) Non-Electric	(2) Non-Mining, Non-Electric	(3) NOx < 500	(4) All Observations
Panel A. Change in NOx emissions between periods 1 and 2				
Post 2	-187.1	-81.97	32.64*	-196.8**
	(128.2)	(104.5)	(17.91)	(85.42)
RECLAIM	-169.3	-31.81	-1.887	-187.5*
	(159.6)	(94.80)	(10.43)	(97.49)
DID 2 (Post 2 x RECLAIM)	318.8*	170.0	-51.82**	267.3**
	(174.8)	(157.3)	(24.07)	(122.7)
< $25K	-339.4	29.32	-30.83	-81.53
	(334.0)	(195.8)	(64.07)	(314.8)
$25 - $50K	268.0	-570.0	182.1	154.4
	(788.9)	(647.7)	(162.4)	(463.8)
< $25K x Post 2	-138.5	82.97	27.15	-93.80
	(245.8)	(69.86)	(41.13)	(156.8)

$25 - $50K x Post 2	1,046	172.4	-219.0*	747.4
	(896.6)	(424.2)	(124.6)	(623.6)
< $25K x DID 2	225.1	24.79	-128.2*	-103.3
	(254.7)	(139.7)	(64.41)	(311.5)
$25 - $50K x DID 2	-1,873	-802.8	427.4**	-911.4
	(1,157)	(892.2)	(186.4)	(1,051)
Constant	282.3***	215.5**	14.31	261.8***
	(75.60)	(95.64)	(16.64)	(57.97)
R-squared	0.037	0.012	0.027	0.030
Observations	450	416	554	596

Panel B. Change in NOx emissions between periods 1 and 3

Post 3	-172.5	-224.5*	7.722	-213.4**
	(112.8)	(113.7)	(11.94)	(80.35)
RECLAIM	-157.3	-26.89	3.808	-184.0*
	(149.8)	(88.07)	(11.25)	(95.99)
DID 3 (Post 3 x RECLAIM)	187.1*	199.6*	-47.30**	206.3***
	(98.05)	(116.5)	(19.18)	(70.33)
< $25K	-233.3	6.327	2.523	-13.30
	(247.9)	(194.4)	(34.85)	(258.2)
$25 - $50K	14.75	-548.6	88.19	10.13
	(636.0)	(629.1)	(61.14)	(387.7)
< $25K x Post 3	45.47	-183.4	17.83	41.10
	(254.3)	(119.3)	(22.99)	(189.8)
$25 - $50K x Post 3	393.9	1,216**	-133.5**	336.2
	(943.4)	(526.7)	(64.12)	(650.2)
< $25K x DID 3	31.61	274.3	-143.2**	-167.2
	(273.2)	(208.3)	(63.98)	(246.1)
$25 - $50K x DID 3	-759.4	-1,383*	412.3**	-370.4
	(886.8)	(805.5)	(154.7)	(620.1)
Constant	296.7***	214.6**	19.94	270.1***
	(86.62)	(100.2)	(13.46)	(64.73)
R-squared	0.029	0.015	0.041	0.035
Observations	449	415	551	595

Panel C. Change in NOx emissions between periods 2 and 3, excluding period 1

Post 3	-107.5	-203.5**	-13.14*	-122.1
	(122.0)	(84.57)	(7.510)	(78.25)
RECLAIM	-177.3	-31.09	-9.917*	-137.0
	(159.2)	(78.75)	(5.561)	(101.0)
DID 3 (Post 3 x RECLAIM)	166.8*	162.5	-39.90***	153.9**

	(84.85)	(105.2)	(13.89)	(58.10)
< $25K	-489.0	37.48	-8.987	-290.4
	(480.1)	(166.5)	(41.97)	(368.4)
$25 - $50K	692.6	-613.6	27.33	468.6
	(1,177)	(448.7)	(80.57)	(753.4)
< $25K x Post 3	238.3	-237.5	32.88	247.3
	(477.9)	(157.8)	(23.52)	(330.9)
$25 - $50K x Post 3	-170.5	1,279**	-66.11	-76.12
	(1,516)	(548.0)	(59.28)	(1,001)
< $25K x DID 3	-2.918	289.9	-159.6**	-145.1
	(310.5)	(204.7)	(71.85)	(239.7)
$25 - $50K x DID 3	-602.7	-1,278	444.3***	-408.5
	(935.8)	(789.7)	(155.5)	(598.7)
Constant	238.0***	210.6**	42.23***	193.2***
	(69.32)	(79.75)	(13.06)	(52.69)
R-squared	0.035	0.015	0.029	0.028
Observations	449	415	551	595
Number of SIC codes	44	43	45	45

Notes: The < $25K and $25 - $50K controls represent the fraction of households within those income brackets. The full magnitude of the coefficients represents a full fractional increase in the associated income category.

The correlations between racial and income groups provide additional insights about the effects of the RECLAIM program (Table 7). Being Hispanic is most strongly correlated with being in the lowest income group, yet the lowest income group benefitted most relative to the highest income group. Nevertheless, Hispanics lost out relative to Whites. Being Hispanic is almost as strongly correlated with being in the middle-income group, which is more consistent with the coefficients on income. Being Black is most highly correlated with being in the middle-income group, yet the middle-income group lost out relative to the highest income one while Blacks benefitted relative to Whites.

These correlations, in combination with the aforementioned results, allow for speculation about how the RECLAIM program impacted specific groups. Blacks are the smallest population group and a large portion of the population is concentrated in a small number of facility dispersion areas. This could explain why the coefficients on Black and middle-income are not aligned. It is likely that the small number of facilities in these areas succeeded in lowering their emissions relatively more than average, increasing the magnitude of the coefficient on $Black_i$ *x* DID_i, while facilities near middle-income Hispanic and other race areas purchased more credits.

Table 7. Correlations between racial and income groups

	Black	Hispanic	Other	White
< $25K	0.152	0.384	-0.164	-0.357
	0.000	0.000	0.000	0.000
$25K - $50K	0.220	0.362	-0.140	-0.362
	0.000	0.000	0.000	0.000
> $50K	-0.201	-0.424	0.175	0.405
	0.000	0.000	0.000	0.000

Notes: Results in the table represent correlation (first row) and statistical significance (second row).

7. Conclusion

Cap-and-trade presents an opportunity to achieve environmental goals at the minimum cost to society. Nevertheless, environmental justice communities fear that market-based pollution control leads to heterogeneous outcomes for different demographic groups and especially harms low-income and minority communities. As market-based controls emerge as a popular option for policy makers, it is imperative to study the impacts and designs of past programs. RECLAIM, being the first cap-and-trade program in the country to be challenged on the grounds of environmental justice, provides especially valuable insights. I hope to add clarity and evidence to the discussion of the program's performance.

Similar to Fowlie et al., I did not find statistically significant evidence of race being a determinant of changes in emissions distributions. Nevertheless, the signs on the coefficients on the interaction terms were largely consistent across subsamples and provide suggestive evidence that Blacks benefitted from RECLAIM while Hispanics and other races lost out relative to Whites. This reordering of emissions dispersions, though not statistically significant, is consistent with the findings of Grainger and Ruangmas.

In terms of income, I find some statistically significant evidence that households with incomes below $25K and above $50K benefitted from RECLAIM, while households with incomes between $25K – $50K lost out. This finding is inconsistent with those of Grainger and Ruangmas and Mansur and Sheriff, who both found that the highest-income group benefitted most under the program.

My results indicate that RECLAIM did not lead to environmental injustice in the form of significantly disparate emissions distributions for different populations. RECLAIM almost certainly led to a reordering of emissions, but the distribution under RECLAIM is not clearly superior, or inferior, to that of the CAC counterfactual. This research also reveals that the emissions caps could likely have been more aggressive to achieve greater emissions reductions for all demographic groups. Nevertheless, if a cap-and-trade regime is less expensive to operate than a CAC one and still delivers similar results, then more programs like RECLAIM could save society significant resources.

One method for future cap-and-trade programs to operate even more efficiently would be through the standardization of allowances and private-sector, voluntary emissions offsets. If allowances and credits could be traded interchangeably, a cap could be maintained in the SCAQMD, or any region, while prices would be set by the free market. This would also supplement the ongoing efforts of the Taskforce on Scaling Voluntary Carbon Markets to create the first voluntary market for emissions offsets. As equity is a chief concern of the stakeholders in this effort, partnerships between compliance and voluntary markets could be an excellent opportunity to address pollution disparities and increase economic efficiency simultaneously. Partnerships would also decrease the barriers to entry for new cap-and-trade programs, as they would not need to create allowance markets of their own. This is a subject that requires more research, especially as voluntary markets for carbon are still in development.

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9. Appendix

Appendix 1. Mean NO_x emissions by treatment and control (non-electric)

Mean NO_x Emissions (tons)	*Period*			
	1	**2**	**3**	**Total**
Non-RECLAIM	205.68	203.38	133.89	181.17
	587.48	684.29	408.45	570.91
	87	87	86	260
RECLAIM	91.40	83.44	55.01	76.62
	378.86	406.26	309.17	366.49
	138	138	138	414
Total	135.59	129.82	85.30	116.95
	472.66	533.05	351.84	458.75
	225	225	224	674

Note: Results in the table represent, from top to bottom, mean, standard deviation, and sample size.

Appendix 2. Mean NO_x emissions by treatment and control (non-mining, non-electric)

Mean NO_x Emissions (tons)	*Period*			
	1	**2**	**3**	**Total**
Non-RECLAIM	81.87	62.53	67.48	70.64
	261.78	238.68	265.74	254.65
	77	77	76	230
RECLAIM	90.23	83.70	57.30	77.08
	386.01	416.07	317.18	374.69
	131	131	131	393
Total	87.13	75.86	61.04	74.70
	344.60	360.19	298.70	335.20
	208	208	207	623

Note: Results in the table represent, from top to bottom, mean, standard deviation, and sample size.

Appendix 3. Observations of NO_x > 500 tons by facility ID and SIC code (period 1)

	SIC Code					
	28	**29**	**32**	**45**	**49**	**Total**
Observations > 500	1	3	6	1	9	20

Appendix 4. Observations of NO_x > 500 tons by facility ID and SIC code (all periods)

	SIC Code							
	10	**28**	**29**	**32**	**45**	**49**	**97**	**Total**
Observations > 500	1	3	7	15	3	16	2	47

Appendix 5. Changes in NOx emissions by race under RECLAIM relative to CAC (2000)

	(1) Non-Electric	(2) Non-Mining, Non-Electric	(3) NOx < 500	(4) All Observations
Panel A. Change in NOx emissions between periods 2 and 3				
Post 3	-107.9	-50.53	-18.81**	-96.37
	(85.68)	(76.38)	(8.688)	(57.69)
RECLAIM	-103.0	12.62	-6.525	-72.38
	(134.7)	(80.49)	(6.402)	(88.14)
DID 3 (Post 3 x RECLAIM)	-19.17	-42.29	-15.38	-72.05
	(103.4)	(114.0)	(15.31)	(70.33)
Black	-287.8	-130.6	-131.1***	-463.8*
	(213.3)	(226.8)	(38.40)	(236.4)
Hispanic	-356.9**	-238.6**	16.07	-292.4***
	(132.5)	(105.4)	(20.01)	(98.82)
Other	-334.3	-235.6	-94.69**	-465.1*
	(311.9)	(279.9)	(37.79)	(237.0)
Black x Post 3	392.7	914.9	123.9	311.1
	(832.8)	(944.9)	(77.24)	(681.7)
Hispanic x Post 3	8.439	16.67	-10.19	45.10
	(135.2)	(140.4)	(21.23)	(89.30)
Other x Post 3	150.9	11.33	-22.81	4.425
	(279.3)	(283.7)	(65.75)	(151.1)
Black x DID 3	-265.8	-740.9	-75.06	-73.76
	(823.6)	(983.1)	(87.91)	(667.1)
Hispanic x DID 3	105.4	59.39	21.17	91.84
	(173.5)	(174.7)	(23.76)	(102.4)
Other X DID 3	131.1	126.2	109.4	432.7*
	(402.1)	(439.6)	(71.16)	(235.0)
Constant	394.9**	200.7**	55.81***	365.4***
	(156.1)	(85.29)	(9.503)	(103.4)
R-squared	0.042	0.020	0.038	0.042
Observations	449	415	561	595
Number of SIC codes	44	43	45	45

Notes: Results using 2000 census baseline. The Black, Hispanic, and Other controls represent the fraction of the population that identifies as that race. The full magnitude of the coefficients represents a full fractional increase in the associated demographic category.

Appendix 6. Changes in NOx emissions by income under RECLAIM relative to CAC (2000)

	(1) Non-Electric	(2) Non-Mining, Non-Electric	(3) NOx < 500	(4) All Observations
Panel A. Change in NOx emissions between periods 2 and 3				
Post 3	-378.2*	-194.8*	-12.53	-298.8**
	(202.9)	(114.4)	(11.47)	(139.2)
RECLAIM	-177.8	-24.69	-11.50**	-141.4
	(159.7)	(78.51)	(4.997)	(106.2)

DID 3 (Post 3 x RECLAIM)	395.6	159.6	-9.651	330.1*
	(244.2)	(116.5)	(18.62)	(176.2)
< $25K	328.9	-53.23	-44.56	205.2
	(342.6)	(140.2)	(44.74)	(196.8)
$25 - $50K	-444.4	-131.4	164.1	-98.27
	(401.7)	(318.5)	(99.15)	(327.7)
< $25K x Post 3	-529.5	-418.2	59.35*	-58.65
	(367.6)	(395.1)	(31.63)	(347.4)
$25 - $50K x Post 3	1,865*	1,247	-77.29	1,149
	(964.8)	(836.1)	(72.04)	(763.2)
< $25K x DID 3	386.0	542.3	-115.2*	-51.55
	(368.2)	(430.9)	(62.13)	(336.9)
$25 - $50K x DID 3	-1,955*	-1,314	162.0	-1,368*
	(1,025)	(917.2)	(119.2)	(798.0)
Constant	272.6***	129.6***	20.16	192.2**
	(93.76)	(40.30)	(15.17)	(78.94)
R-squared	0.035	0.015	0.034	0.032
Observations	449	415	561	595
Number of SIC codes	44	43	45	45

Notes: Results using 2000 census baseline. The < $25K and $25 - $50K controls represent the fraction of households within those income brackets. The full magnitude of the coefficients represents a full fractional increase in the associated income category.

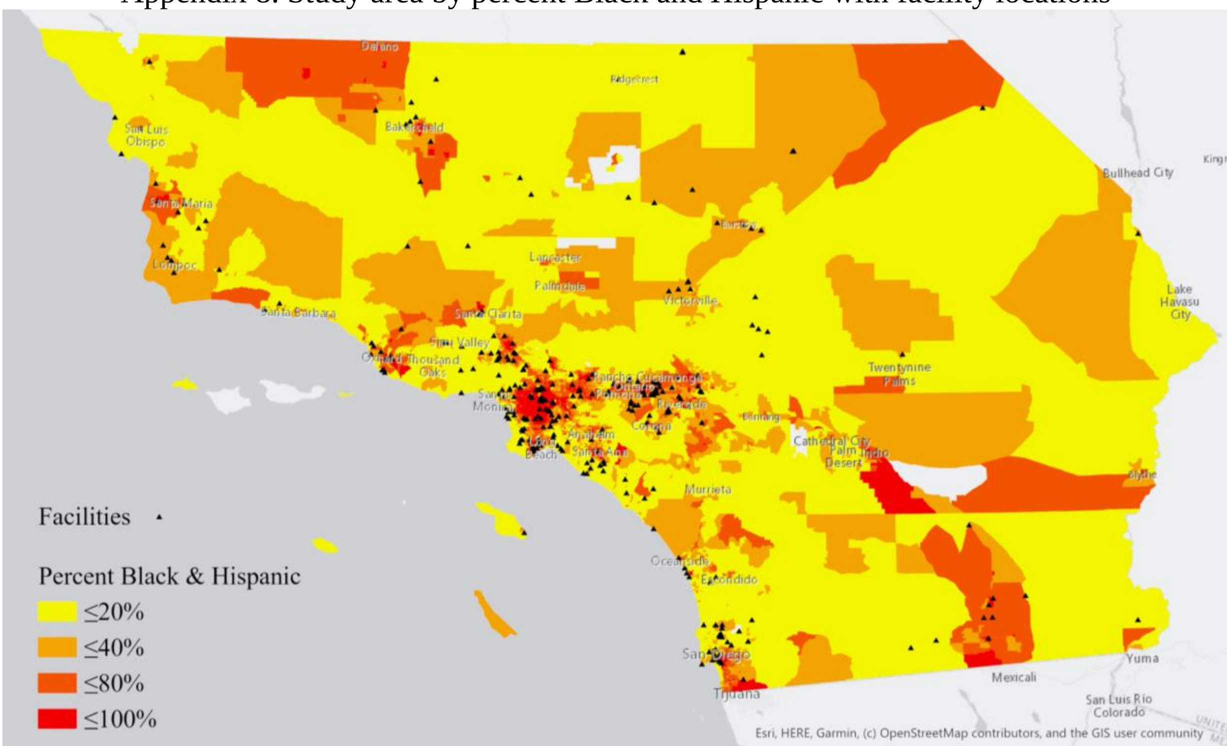
Appendix 7. Changes in NOx emissions by race under RECLAIM relative to CAC (2010)

	(1) Non-Electric	(2) Non-Mining, Non-Electric	(3) NOx < 500	(4) All Observations
Panel A. Change in NOx emissions between periods 2 and 3				
Post 3	-73.08	-41.05	-19.65**	-77.84
	(84.40)	(86.73)	(7.781)	(55.58)
RECLAIM	-113.6	30.43	-7.331	-76.65
	(154.8)	(80.30)	(6.458)	(98.54)
DID 3 (Post 3 x RECLAIM)	33.02	-52.27	-13.69	-43.33
	(145.8)	(133.8)	(16.19)	(110.5)
Black	450.1	-247.0	-106.6***	163.2
	(594.5)	(182.3)	(39.42)	(523.6)
Hispanic	-414.9**	-307.9**	8.712	-355.2***
	(159.4)	(145.6)	(21.73)	(112.2)
Other	-393.6	-367.1	-93.11**	-514.8**
	(293.4)	(307.1)	(34.68)	(219.4)
Black x Post 3	-348.4	553.6	96.31	-259.1
	(765.0)	(561.0)	(64.98)	(574.1)
Hispanic x Post 3	23.00	38.52	-7.009	64.22
	(151.9)	(156.3)	(19.33)	(96.12)
Other x Post 3	118.1	31.15	-3.857	24.19
	(247.0)	(249.3)	(49.41)	(141.7)
Black x DID 3	-355.6	-419.3	-74.99	-212.9
	(384.1)	(564.6)	(70.09)	(304.1)
Hispanic x DID A	68.54	39.91	19.63	80.58
	(205.2)	(212.6)	(21.00)	(127.2)

Other X DID A	-2.308	90.11	80.07	301.2
	(406.4)	(414.7)	(61.41)	(285.1)
Constant	407.2***	259.5**	57.92***	382.8***
	(139.6)	(111.9)	(10.71)	(88.42)
R-squared	0.048	0.025	0.035	0.045
Observations	449	415	561	595
Number of SIC codes	44	43	45	45

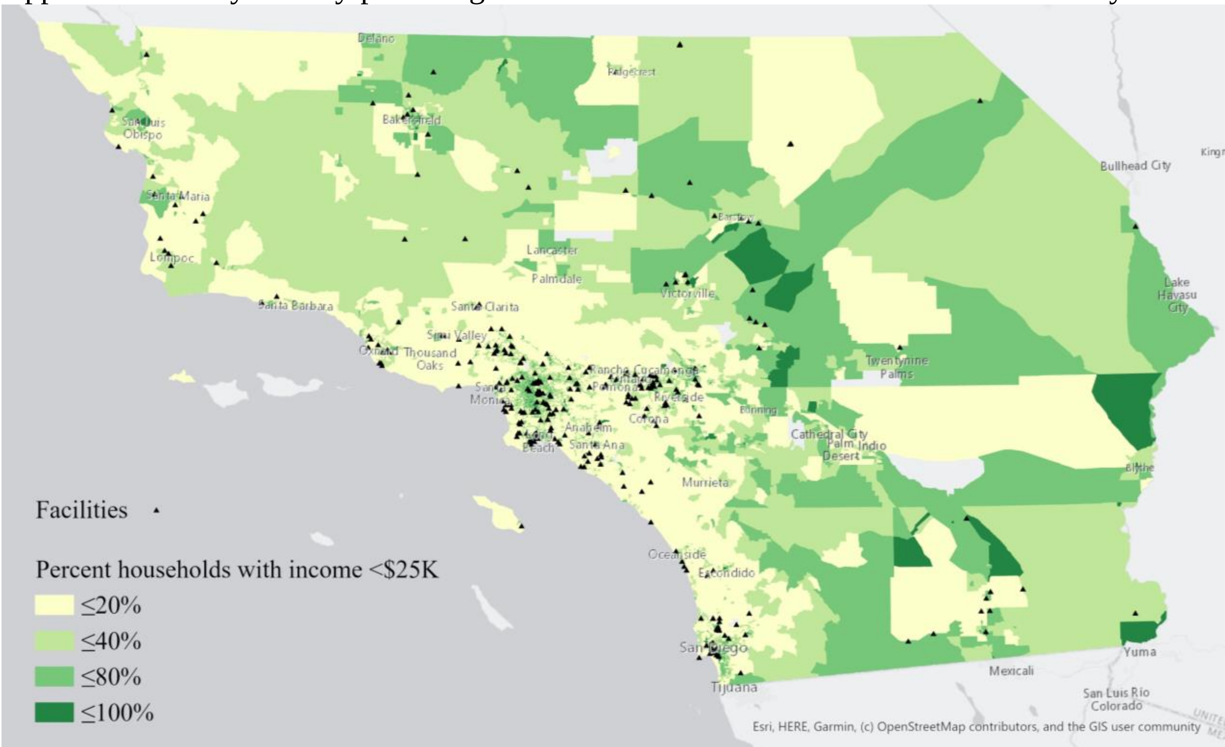
Notes: Results using 2010 census baseline. The Black, Hispanic, and Other controls represent the fraction of the population that identifies as that race. The full magnitude of the coefficients represents a full fractional increase in the associated demographic category.

Appendix 8. Study area by percent Black and Hispanic with facility locations



Notes: In order of increasing darkness, the sum of Hispanic and Black individuals (P) makes up $P \leq 20\%$, $20\% < P \leq 40\%$, $40\% < P \leq 80\%$, and $P \leq 100\%$ of the block group population, respectively. Facility locations are marked with black triangles.

Appendix 9. Study area by percentage of households with income <$25K with facility locations



Notes: In order of increasing darkness, the sum of households with incomes below $25K ($P$) makes up $P \leq 20\%$, $20\% < P \leq 40\%$, $40\% < P \leq 80\%$, and $P \leq 100\%$ of the block group population, respectively. Facility locations are marked with black triangles.