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Permalink

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Journal

American Journal of Epidemiology, 187(8)

ISSN

0002-9262

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Publication Date

2018-08-01

DOI

10.1093/aje/kwy110

Original Contribution

Retirements of Coal and Oil Power Plants in California: Association With Reduced Preterm Birth Among Populations Nearby

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Coal and oil power plant retirements reduce air pollution nearby, but few studies have leveraged these natural experiments for public health research. We used California Department of Public Health birth records and US Energy Information Administration data from 2001–2011 to evaluate the relationship between the retirements of 8 coal and oil power plants and nearby preterm (gestational age of <37 weeks) birth. We conducted a difference-in-differences analysis using adjusted linear mixed models that included 57,005 births—6.3% of which were preterm—to compare the probability of preterm birth before and after power plant retirement among mothers residing within 0–5 km and 5–10 km of the 8 power plants. We found that power plant retirements were associated with a decrease in the proportion of preterm birth within 5 km (−0.019, 95% CI: −0.031, −0.008) and 5–10 km (−0.015, 95% CI: −0.024, −0.007), controlling for secular trends with mothers living 10–20 km away. For the 0–5-km area, this corresponds to a reduction in preterm birth from 7.0% to 5.1%. Subgroup analyses indicated a potentially larger association among non-Hispanic black and Asian mothers than among non-Hispanic white and Hispanic mothers and no differences in educational attainment. Future coal and oil power plant retirements may reduce preterm birth among nearby populations.

birth certificates; birth outcomes; California; coal; environmental epidemiology; natural experiment; power plants; premature birth

Abbreviations: DID, difference-in-differences; LMP, last menstrual period; PM_{10}, particulate matter with an aerodynamic diameter less than or equal to 10 μm; $PM_{2.5}$, particulate matter with an aerodynamic diameter less than or equal to 2.5 μm.

Editor's note: An invited commentary on this article appears on page 1595.

Oil and coal power plants emit air pollutants including particulate matter (with an aerodynamic diameter less than or equal to 10 μm (PM_{10}) or 2.5 μm ($PM_{2.5}$)), sulfur dioxide, nitrogen oxides, benzene, lead, mercury, and other known health hazards (1). Cheap and abundant natural gas, health concerns, and legislation related to climate change have resulted in coal and oil power plant retirements across the United States in the past decade. Coal electricity accounted for 51% of US electricity generation in 2001 and 42% in 2011, with more plant retirements likely in the future (2). Residential proximity to active oil and coal power plants may harm health (1, 3, 4), particularly of pregnant women and developing fetuses (5–8). Therefore, power plant retirements may improve birth outcomes, including the proportion of preterm birth.

Preterm birth (<37 weeks of gestation) contributes significantly to infant mortality and morbidity and later-life health problems (9). While the etiology of preterm parturition is largely unknown, environmental exposures likely play a role. Numerous studies link prenatal exposure to air pollution to earlier parturition, as summarized by Sapkota et al. (10). From 2001 to 2008, Laurent et al. (11) found associations between increased $PM_{2.5}$, ozone, and nitrogen dioxide and preterm birth in California. In 2016, preterm birth rates rose in California, for the second year in a row, to 8.6% (12). Socioeconomic factors, including lower individual (13) and neighborhood (14–16) socioeconomic status and racial residential segregation (17), have also been associated with preterm birth. In California, there are racial disparities in preterm birth; non-Hispanic black women

have nearly double the prevalence of preterm birth of non-Hispanic white women (18). Despite calls in the environmental health literature (19), limited research has explored the modifying role of individual-level race/ethnicity and socioeconomic status in the relationship between air pollution and preterm birth (20–22), and none has done so in relation to point sources of pollution like power plants.

The socioeconomically patterned distribution of air pollution complicates the study of the relationship between race/ethnicity, socioeconomic factors, and preterm birth. Compared with non-Hispanic white persons, persons of all other races/ethnicities tend to experience higher levels of air pollution and other environmental hazards prenatally (23–25) and might also differ systematically by other attributes (e.g., health behaviors, psychosocial stress) correlated with preterm birth (26). This confounding could lead to spurious associations between air pollution and preterm birth. To avoid confounding by socioeconomic characteristics, we leveraged a natural experiment provided by power plant retirements. Power plant retirements should affect all nearby residents equally. That is, their retirement provides exogenous variation in exposure that we can exploit to assess associations with health (27, 28). Researchers have used other natural experiments to evaluate the association of extreme weather (29), earthquakes (30), and air pollution (7, 31–35) with birth outcomes. Few studies have used these designs, however, to explore the potential benefits of reduced air pollution for preterm birth (31, 33–35). We analyzed data in California during 2001–2011, when 8 coal and oil power plants retired, to assess the association between power plant retirements and preterm birth while considering the modifying roles of race/ethnicity and socioeconomic status.

METHODS

Study population

The California Department of Public Health provided data from its Birth Statistical Master Files on all births ($n = 5,909,002$) between January 1, 2001, and December 31, 2011. We geocoded mothers' home addresses to a latitude/longitude and census block group using ArcGIS (Esri, Redlands, California). We restricted the study cohort to geocoded singleton births within 20 km of power plants (Web Figure 1, available at https://academic.oup.com/aje). We made further exclusions based on maternal age, gestational age, congenital abnormalities, and timing of conception, arriving at a final sample size of 57,005 births. The study was approved by the University of California, Berkeley (#2013-10-5693), and the California Health and Human Services Agency committees for the protection of human subjects.

Exposure assessment

We defined exposure to coal and oil power plants along 2 dimensions, space and time (Web Figure 2), using data from the US Energy Information Agency (EIA) (36), the US Environmental Protection Agency Air Markets Program (37), and the California Environmental Protection Agency Air Resources Board (38). Based on home address, we assigned mothers to one of 3 area bins within the larger 20-km circular area: 0–5 km; 5–10 km; and 10–20 km. While coal and oil power plants produce

secondary air pollutants that can travel over 100 km, we restricted this study to an area within 20 km of power plants to maximize change in exposure related to retirement (39). We considered the 0–5-km bin the most exposed, followed by the 5–10-km bin, with the 10–20-km bin as a temporal control group, because its exposure was likely minimal. Based on date of mothers' last menstrual period (LMP), we further classified exposure to a coal or oil power plant according to time. Exposed mothers had an LMP in the year-long period 2 years prior to power plant retirement and unexposed mothers had an LMP in the year after power plant retirement. We selected these relatively short time windows before and after plant retirement to improve comparability of study populations and to eliminate the potential for fixed-cohort bias (40).

Outcome assessment

Gestational age was estimated based on LMP prior to 2007 and on best clinical estimate (combination of LMP and ultrasound) from 2007 to 2011. LMP-based methods may overestimate preterm birth (41, 42). In our population, however, gestational age estimated by LMP only and by best obstetrical estimate had a Spearman correlation of 0.98 from 2007 to 2011. Furthermore, our study design only compared differences in the proportion of preterm birth between women in different bins measured during the same time periods and therefore (except for births around 2 power plants that retired during 2006 and 2008) used the same measure of gestational age. We defined preterm birth as delivery before 37 gestational weeks. Early preterm birth was defined as <32 gestational weeks and late preterm birth as ≥32 and <37 gestational weeks.

Covariates

We constructed covariates based on data in the Birth Files, the 2000 US Census, and the 2005–2009 American Community Survey, which we downloaded from the National Historical Geographic Information System website (43). A priori, we identified individual-level variables that could potentially affect the association between power plant retirements and preterm birth: maternal age in years, maternal race/ethnicity (Hispanics of any race and non-Hispanic Asian, black, white, and other), maternal educational attainment (did not complete high school, high-school diploma or equivalent, some college/Associate's Degree, college degree, and graduate school), number of prenatal visits, infant sex, and month of birth. We also identified census-block–level proportion of residents living below the federal poverty threshold and proportion with less than a high-school diploma, based on residential address and year of birth.

Statistical analysis

We summarized the raw proportion of preterm births (overall, early, and late) according to before/after power plant retirement and distance (in 1-km bins). We compared characteristics of the 10–20-km bin before and after power plant retirements using Wilcoxon tests for continuous variables and χ^2 tests for categorical variables to assess whether shifting population characteristics could explain temporal differences.

We used a difference-in-differences (DID) approach (44) to estimate the association between power plant retirements and the probability of preterm birth nearby. We separately examined preterm birth overall, early preterm birth, and late preterm birth. In each case, term birth was the reference outcome. The DID estimator subtracted the change in preterm birth from before to after retirement among those mothers living 10–20 km from power plants (changes that result, presumably, only from secular trends) from the change in preterm birth among those mothers living 0–5 km and 5–10 km from power plants (changes that result from power plant retirement and secular trends in preterm birth). Under the assumption that secular trends are parallel in both groups and that the model (1) is correctly specified, the resulting DID estimator corresponds to the difference in preterm birth rates attributable to power plant retirements. We used a linear mixed model with random intercepts for power plants to account for the nonindependence of births that took place around the same power plant:

$$\text{Pr}(\text{Preterm birth for mother } i \text{ near power plant } j)$$
$$= \beta_0 + \beta_1 \times 5km\_bin_{ij} + \beta_2 \times 10km\_bin_{ij}$$
$$+ \beta_3 \times retired_{ij} + \beta_4 \times 5km\_bin_{ij} \times retired_{ij}$$
$$+ \beta_5 \times 10km\_bin_{ij} \times retired_{ij} + b_j + \varepsilon_{ij} \qquad (1)$$

Where *5km_bin* and *10km_bin* are binary indicators for residence within 5 km or 5–10 km of power plant *j* at birth; *retired* is a binary indicator of power plant *j* status; β_4 and β_5 represent our DID coefficients of interest, and b_j is a power plant-level random intercept ($b_j \sim N[0, \sigma^2]$). We subsequently added covariates to model (1): maternal age (linear and quadratic terms), race/ethnicity, educational attainment, and number of prenatal visits; infant sex and birth month; and neighborhood-level poverty and educational attainment. We hypothesized that certain subpopulations might benefit more from plant retirement, and we therefore ran analyses stratified by maternal race/ethnicity (Hispanic and non-Hispanic Asian, black, and white; other was excluded due to small numbers) and educational attainment. Exposure variables were generated with QGIS (QGIS Development Team (2018), Open Source Geospatial Foundation Project, qgis.osgeo.org), and analyses were conducted with R, version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

Sensitivity analyses

We conducted several sensitivity analyses (Web Appendix 1). We repeated our main analysis separately for mothers who lived downwind of their power plant for 0, 1–90, and ≥90 days during pregnancy. We anticipated that mothers living downwind would experience higher levels of air pollution in the period before retirement and therefore a greater reduction in exposure afterward (3, 8). To control for changes in socioeconomic context during the California housing crisis (45), we linked CoreLogic (http://www.corelogic.com/) data on the number of foreclosures—defined as the final transfer of a foreclosed property deed to a new owner—at the block-group level in the year of birth between 2005–2011. To assess changes in air quality near retiring power plants, we linked daily $PM_{2.5}$ estimates from the US Environmental Protection Agency Community Multiscale Air Quality Modeling System. Finally, we implemented a negative exposure

control (46) by randomly selecting 8 new oil and coal power plants in California that had not retired during our study period, assigning them the retirement dates of the original 8 retired power plants, and repeating our main analyses (Web Appendix 2). A null relationship between residential proximity to these new power plants (which did not actually retire) with the original retirement dates would provide evidence that our main results were not due to time trends in premature birth rates.

RESULTS

Our study population included 57,005 births that took place within 20 km of one of 8 retiring coal ($n = 2$) or oil ($n = 6$) power plants in California during 2001–2011 (Figure 1). Before retirement, the 8 power plants emitted, on average, 177 tons of nitrogen oxides annually; this fell to just 4 tons per year after retirement (37, 38). Overall, 6.3% of births were preterm. The distribution of maternal and neonatal characteristics and neighborhood-level factors according to before/after-retirement status and distance bin appears in Table 1. Within 5 km, non-Hispanic black mothers lived an average of 2.1 (standard deviation, 1.4) km from power plants, compared with 3.4 (standard deviation, 1.0) km for non-Hispanic white mothers and 2.8 (standard deviation, 1.3 km) km for Hispanic mothers (Web Table 1).
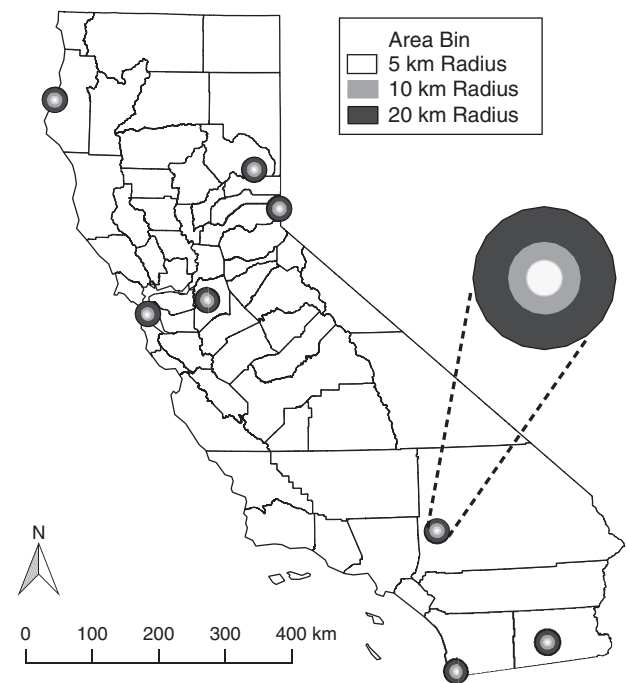

Figure 1. Map illustrating locations of 2 coal and 6 oil power plants that retired during 2001–2011 in California, serving as a basis for an analysis of preterm birth before versus after coal and oil power plant retirement . Solid black borders indicate county boundaries. Concentric circles represent the area bins used in the study. The innermost light grey circle is the 0–5-km bin, the next darker grey area is the 5–10-km bin, and the darkest grey area is the 10–20-km bin.

Table 1. Maternal and Neonatal Characteristics of Births Before and After Power Plant Retirement According Distance From the Power Plant, California, 2001–2011

Characteristic	Distance From the Power Plant											
	0–5 km				5–10 km				10–20 km			
	Before (n = 4,207)		After (n = 4,494)		Before (n = 7,811)		After (n = 8,120)		Before (n = 16,065)		After (n = 16,308)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Maternal age, years[a]	29 (24–34)		31 (26–35)		29 (24–34)		30 (24–34)		31 (26–35)		29 (24–34)	
Maternal race/ethnicity												
Non-Hispanic												
Asian	825	19.6	988	22	2,233	28.6	2,397	29.5	2,850	17.7	3,103	19
Black	326	7.8	354	7.9	472	6.0	507	6.2	2,022	12.6	2,106	12.9
White	972	23.1	1,063	23.7	2,721	34.8	2,784	34.3	4,902	30.5	4,773	29.3
Hispanic	2,058	48.9	2,075	46.2	2,331	29.8	2,385	29.4	6,067	37.8	6,018	36.9
Other	4	0.1	2	0.04	5	0.1	8	0.1	6	0.04	11	0.1
Missing	22	0.5	12	0.3	49	0.6	39	0.5	218	1.4	297	1.8
Maternal educational attainment												
Did not complete high school	1,141	27.1	1,087	24.2	1,397	17.9	1,246	15.3	3,659	22.8	3,504	21.5
High-school diploma or equivalent	1,000	23.8	1,093	24.3	1,543	19.8	1,692	20.8	3,932	24.5	3,823	23.4
Some college	758	18.0	809	18.0	1,405	18.0	1,495	18.4	3,203	19.9	3,489	21.4
College degree	712	16.9	870	19.4	1,909	24.4	2,186	26.9	2,690	16.7	3,022	18.5
Graduate school	550	13.1	590	13.1	1,474	18.9	1,400	17.2	2,191	13.6	1,957	12.0
Missing	46	1.1	45	1.0	83	1.1	101	1.2	390	2.4	513	3.2
Prenatal visits[a]	12 (10–14)		12 (10–14)		12 (10–15)		12 (10–15)		12 (10–14)		12 (10–15)	
Neonate sex												
Female	2,075	49.3	2,153	49.0	3,827	49.0	3,916	48.2	7,860	48.9	7,897	48.4
Male	2,132	50.7	2,341	52.1	3,984	51.0	4,204	51.8	8,205	51.1	8,411	51.6
Gestational age, weeks[a]	40 (38–41)		40 (39–41)		39 (39–40)		40 (39–40)		39 (39–40)		39 (39–40)	
Preterm (<37 weeks)	316	7.5	272	6.1	516	6.6	450	5.5	994	6.2	1,068	6.5
Late preterm (≥32 and <37 weeks)	265	6.3	216	4.8	460	5.9	384	4.7	815	5.1	889	5.5
Early preterm (<32 weeks)	51	1.2	56	1.2	56	0.7	66	0.8	179	1.1	179	1.0
Neighborhood characteristics[b]												
Living below federal poverty threshold, %[a]	15.6 (7.8–26.7)		15.8 (7.1–26.7)		15.4 (7.8–27.1)		15 (7.4–26.7)		9.7 (4.9–19.3)		9.4 (4.7–18.8)	
Less than high-school diploma or equivalent, %[a]	10.9 (6.2–18.7)		10.7 (5.8–18.5)		13.6 (7.3–22.2)		12.9 (6.6–21.8)		10.7 (4.8–18.3)		10.0 (4.3–18.0)	
Annual foreclosures[a]	0 (0–2)		3 (1–7)		0 (0–1)		3 (1–8)		0 (0–2)		5 (2–12)	

[a] Data expressed as median (interquartile range).

[b] Neighborhood characteristics assigned based on mother's block group of residence at time of birth; poverty and educational attainment obtained from the 2000 US Census and the 2005–2009 American Community Survey (43); California foreclosure data obtained from CoreLogic (http://www.corelogic.com/).

We assessed the appropriateness of the comparison group (10–20-km) by comparing maternal and neonatal characteristics across exposure bins in the period before retirement. The 0–5-km bin included a higher proportion of Hispanic mothers (49%) and a lower proportion of non-Hispanic black and white mothers (8% and 23%, respectively) compared with the 5–10-km (30% Hispanic, 6% black, 35% white) and 10–20-km (38% Hispanic, 13% black, 31% white) bins (Table 1).

We evaluated the presence of secular trends according to distance bin before and after power plant retirements (Table 1). Across bins, we observed increased maternal education, proportion of non-Hispanic Asian births, and reduced neighborhood poverty. In the 10–20-km bin we noted a reduction after retirement in the proportion of non-Hispanic white births; in the 0–5-km bin we saw a decreased proportion of Hispanic births and an increased proportion of non-Hispanic Asian births.

Estimated association of power plant retirement and preterm birth

On average, the prevalence of preterm birth decreased near power plants after retirement (Figure 2), with larger reductions closer to power plants (Web Figure 3). As anticipated in a DID design, unadjusted and adjusted analyses yielded similar estimates (Figure 3, Web Figure 4, Web Table 2). In adjusted analyses, we found that power plant retirements resulted in a decrease in the proportion of preterm births at a distance of 0–5 km (−0.019, 95% CI: −0.031, −0.008) and between 5–10 km (−0.015, 95% CI: −0.024, −0.007) (Figure 3A). For the 0–5-km area, this corresponds to a reduction in preterm birth from 7.0% to 5.1%. In analyses stratified by timing of birth, we found significant associations only for moderate to late preterm birth (Figure 3B: for 0–5 km, $\beta = -0.020$, 95% CI: −0.031, −0.009; for 5–10 km $\beta = -0.016$, 95% CI: −0.025, −0.008).

Race/ethnicity and educational-attainment subgroups

Subgroup analyses indicated a stronger association between power plant retirement and preterm birth among non-Hispanic black and Asian mothers compared with non-Hispanic white and Hispanic mothers (Figure 3C). We did not observe differential associations with maternal educational attainment (Web Figure 5).

Sensitivity analyses

We observed variability in wind direction by power plant over the study period (Web Figure 6). Among mothers living 0–5 km from power plants and downwind 1–90 days and ≥90 days during pregnancy, we found that retirements were followed by a decreased proportion of preterm birth: −0.039, 95% CI: −0.082, 0.007, and −0.026, 95% CI: −0.059, 0.011, respectively. We did not observe, however, a reduction preterm birth among downwind mothers living 5–10 km from power plants (Web Table 3). We also specified a model including the number of block-group–level foreclosures in the year of birth

and found no change to the results (Web Table 4). Data from the Environmental Protection Agency Community Multiscale Air Quality model suggested a reduction in annual average $PM_{2.5}$ concentrations across distance bins, with a larger median change in the 0–5-km (−1.3 $\mu g/m^3$) and 5–10-km (−1.2 $\mu g/m^3$) bins compared with the 10–20-km bin (−0.6 $\mu g/m^3$) (Web Figure 7). As a negative control analysis, we repeated analyses with plants that did not retire during the study period. As expected, we observed no association between the negative control plants and change in the proportion of preterm birth (Web Table 5).

DISCUSSION

We used a natural experiment in California when 8 oil and coal power plant retired to quantify the relationship with preterm birth. After retirements, we found reductions in the probability of preterm birth within 5 km and 5–10 km, using pregnant women living 10–20 km away to control for secular trends. These improvements were limited to moderate and late preterm birth, larger in magnitude among non-Hispanic Asian and black women, and they did not differ by maternal educational attainment. A negative control analysis, in which we refitted our models to consider plants that did not retire during the study period, was null, suggesting that our results are not likely due to secular trends. In light of present disparities in environmental exposures and birth outcomes (18, 21, 25), our findings may have relevance to future policy decisions regarding power plant retirement priorities and transitions to renewable and cleaner energy.

We hypothesized that reduced air pollution after power plant retirement accounted for the majority of the reduced probability of preterm birth nearby. Air pollution may increase risk of preterm birth by altering normally progressing gestation through activation of proinflammatory cytokines (47), preeclampsia (48), growth restriction (49), or increased maternal susceptibility to infection (22). While we were unable to track individual-level changes in air pollution exposure, data from the US Environmental Protection Agency Community Multiscale Air
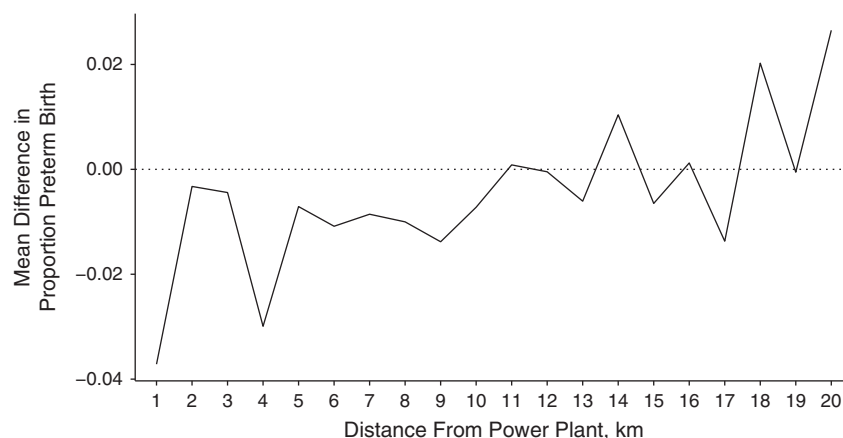

Figure 2. Mean difference (after retirement minus before retirement) in proportion preterm birth (gestational age of <37 weeks) according to distance in kilometers from power plant ($n = 57,005$ total births; 3,616 preterm births), California, 2001–2011.
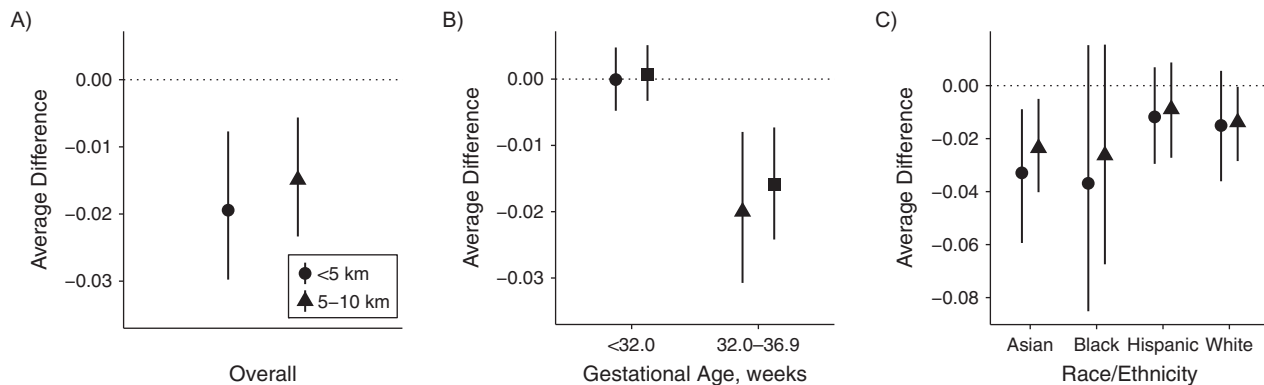
Figure 3. Average difference in proportions of preterm birth before versus after coal and oil power plant retirement according to distance bin, California, 2001–2011. A) Overall; B) according to gestational age; C) according to race/ethnicity. Results from difference-in-differences linear mixed models with random intercept for power plant; adjusted for maternal age, race/ethnicity, educational attainment, number of prenatal visits, month of birth, neonate sex, and neighborhood-level educational attainment and poverty. Black circles and lines represent the difference-in-differences coefficient and 95% confidence interval for births within 5 km of retiring power plants (compared with births 10–20 km away) and black triangles and lines represent the difference-in-differences coefficient and 95% confidence interval for births 5–10 km away (compared with births 10–20 km away).

Quality model indicated reductions in $PM_{2.5}$ near retiring power plants and reductions in emissions of nitrogen oxides from the power plants of 98% in the year after retirement (50).

Many prior preterm birth studies have focused on traffic-related air pollution or nonspecific particulate matter exposures (21, 22, 51–56), although some have evaluated source-specific emissions (11, 22, 54). Four studies estimated the relationship between living near power plants and adverse birth outcomes (5–8). Among 400,000 births in Florida, Ha et al. (6) reported a 2.2% increase in odds of preterm delivery for each 5 km closer to any power plant. When stratifying by fuel type, they did not find a significant association between coal plants and preterm birth but did observe an association with oil plants. Due to sample size considerations, we did not stratify by oil and coal fuel type.

Studies that have evaluated differential associations between air pollution and preterm birth according to race/ethnicity or socioeconomic status have generally found stronger relationships among racial/ethnic minorities and those of lower socioeconomic status (21, 52, 54, 56). Pereira et al. (22) used a within-woman design, to account for genetic and social determinants of preterm birth, and reported a significant association between $PM_{2.5}$ and preterm birth only among black and Hispanic mothers. Other work has reported stronger associations between air pollution and preterm birth among mothers of higher socioeconomic status (57). Such paradoxical associations may arise, for example, when socioeconomically advantaged black mothers experience race-related stressors (18, 58) that may amplify associations between air pollutants and adverse birth outcomes. We identified larger associations among non-Hispanic Asian and black mothers. The larger associations for non-Hispanic black mothers might have arisen because these women lived closer on average to the power plants within a given bin and therefore likely had higher exposure levels, and higher preterm birth rates at baseline, implying the potential for greater absolute difference.

Studies drawing on natural experiments to evaluate the role of air pollution in preterm birth have yielded heterogeneous results. In Utah, married, non-Hispanic white mothers in their first or second trimester of pregnancy when a steel mill closed in 1986–1987 were less likely to give birth prematurely than those who became pregnant before plant closure (31). No association was found between reduced PM_{10} or nitrogen dioxide levels during the 2008 Beijing Olympics and preterm birth (35). During 2006–2010, Beijing had mean PM_{10} levels of 135 μg/m³, far exceeding California's annual average PM_{10} standard of 20 μg/m³. In Uruguay, when volcanic eruption led to an increase in average PM_{10} levels from 21.2 μg/m³ to 46 μg/m³, Balsa et al. (33) observed a 10% increase in odds of preterm birth for a 10-μg/m³ increase in third-trimester PM_{10} levels. Currie and Walker (34) found reduced prematurity (defined as <38 weeks of gestation) among mothers living within 2 km of major roads, compared with mothers living 2–10 km away, when the introduction of the E-ZPass in Pennsylvania and New Jersey reduced air pollution. We used a similar DID design with mothers living 10–20 km from power plants to control for secular trends.

Air pollution may be differentially associated with spontaneous and medically indicated preterm birth (51, 59). Our birth records did not include that information, thereby preventing analyses stratified by type of labor onset, which might be preferable because hospital-specific practices (i.e., medically induced labor driven by hospital, physician, and patient practices/beliefs) can lead to spatial confounding (51). However, our DID study design likely limited confounding related to hospital practices and other potential community-level confounding variables.

Natural experiments have other strengths. Ethically, one cannot randomize exposure to participants, but with natural experiments, one can approximate experimental designs while effectively enrolling whole populations (27, 28). Despite these strengths, there are limitations related to DID model assumptions.

We assumed that power plant retirements were the only reason for the larger reduction in prevalence of preterm birth in the 0–5-km and 5–10-km bins compared with the 10–20-km bin during the study period. The assumption of parallel trends, that the rate of change of preterm birth in the treatment and comparison groups would have been the same in the absence of power plant retirements, is untestable in our study because we have just one before and after period. A time-varying imbalance between the treatment and comparison groups that we did not adjust for in our analysis could have biased our results (44). Last, power plants do not emit pollution uniformly but rather ramp up production during times of high demand. The DID design did not permit us to estimate an exposure-response, but rather to test for an association of preterm birth with active versus inactive power plants.

We were unable to geocode the residential addresses of 9.2% of the original 5.4 million singleton births. These nongeocoded births did not differ markedly from geocoded births on variables such as age and educational attainment (data not shown), but this omission may have introduced selection bias (60). Of the 57,005 births examined, data were also missing for race/ethnicity ($n = 637$), educational attainment ($n = 1,178$), and number of prenatal visits ($n = 292$). We used missing indicators and saw little difference in unadjusted and adjusted results; in DID analyses, covariates primarily improve precision of estimates rather than providing control for confounding. A further limitation includes potential exposure misclassification because we based estimates on residential distance from power plants at the time of birth. We were unable to consider residential mobility or time spent away from home.

In conclusion, our study showed that coal and oil power plant retirements in California were associated with reductions in preterm birth, providing evidence of the potential health benefits of policies that favor the replacement of oil and coal with other fuel types for electricity generation. Moreover, given that effect estimates were stronger among non-Hispanic black women, such cleaner energy policies could potentially not only improve birth outcomes overall but also reduce racial disparities in preterm birth.

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