Web Material

Coal and Oil Power Plant Retirements in California Associated With Reduced Preterm Birth Among Populations Nearby

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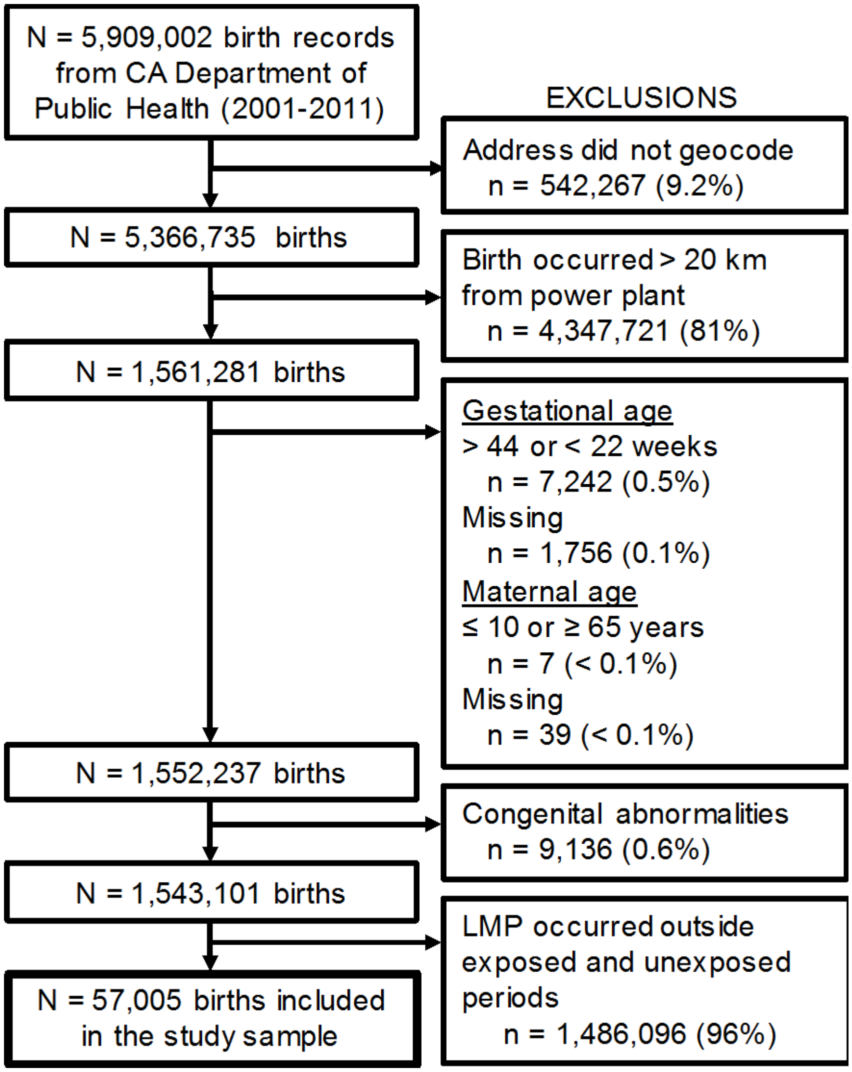
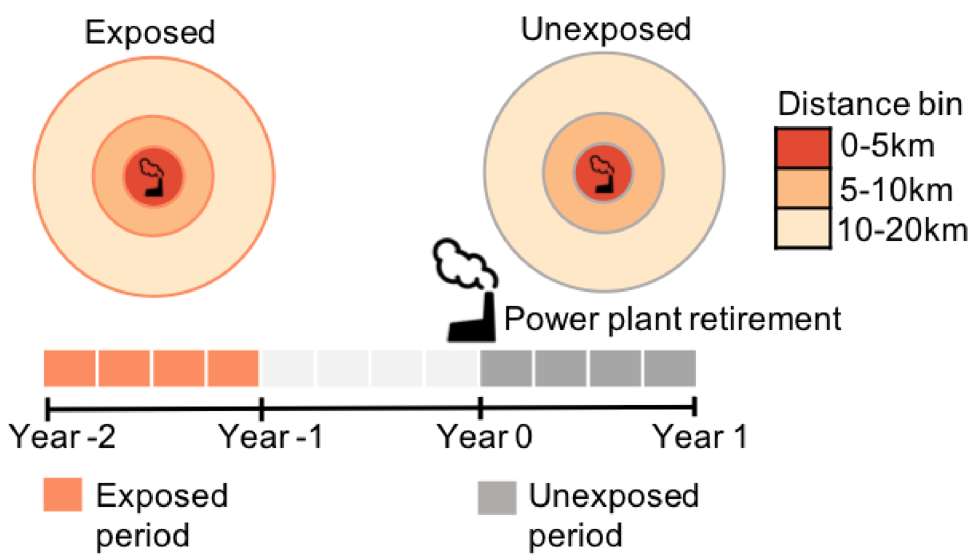
Web Figure 1: Flowchart detailing study population inclusion and exclusion.



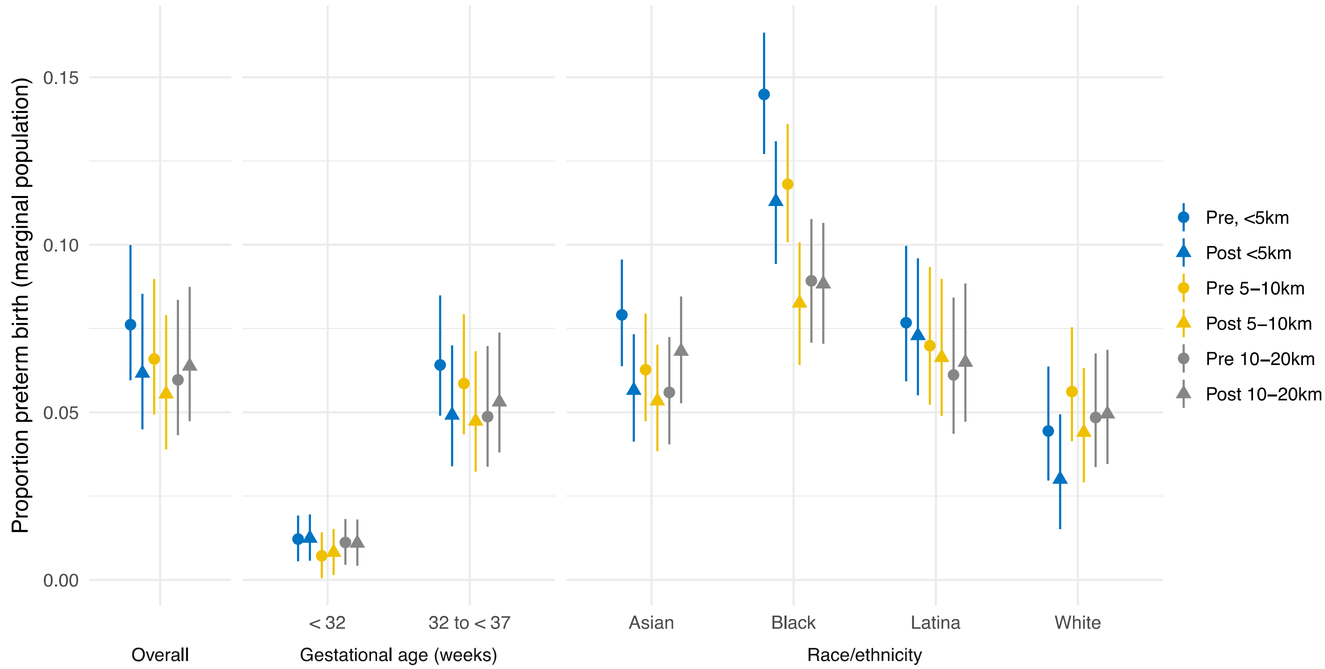
Web Figure 2: Schematic of space and time exposure definitions in relation to retiring power plants. The timeline shows date of power plant retirement (indicated by the power plant icon) and the yearlong windows used as exposed (peach rectangles) and unexposed (grey rectangles) time periods. The large circles above illustrate the distance exposure bins (i.e., 0-5km, 5-10km, and 10-20km) used in pre (exposed) and post (unexposed) retirement periods. Mothers were assigned to these same exposure bins for each power plant. We used data from the U.S. Energy Information Agency, U.S. Environmental Protection Agency (EPA), and the California EPA Air Resources Board to identify power plant locations, fuel types, and retirement dates. The California Department of Public Health provided data on mothers' home address at the time of birth and dates of birth and last menstrual period. The power plant graphic "Factory" is by Martyn Jasinski from the Noun Project.



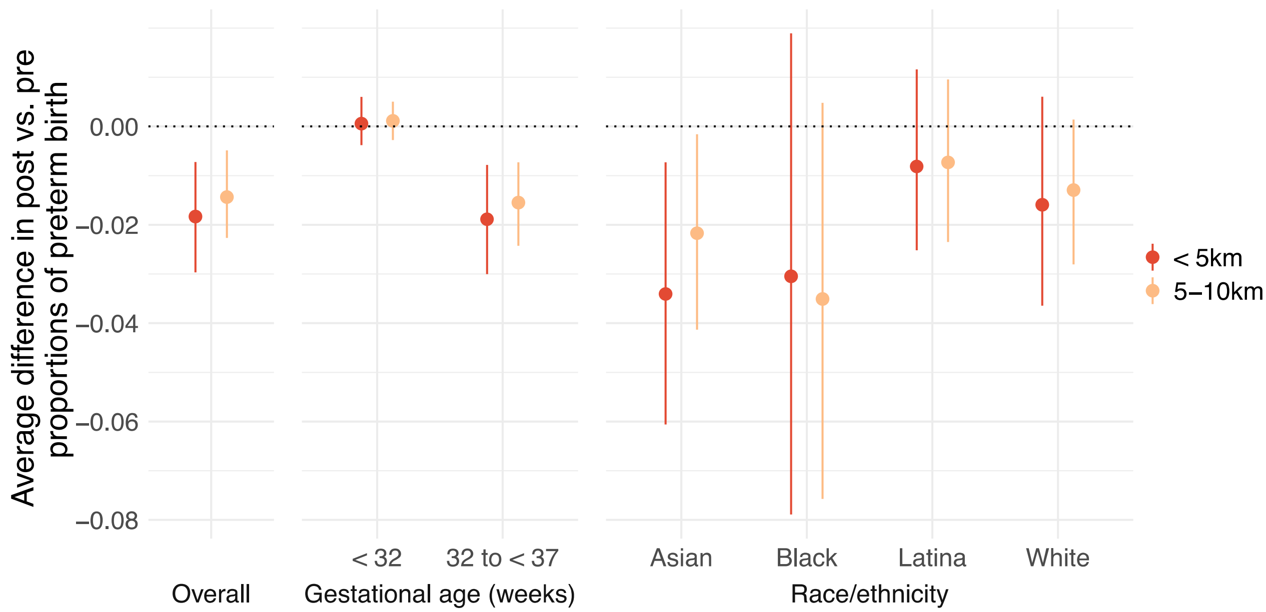
Web Table 1: Distance between maternal home address at time of birth and nearest power plant, among mothers living < 5km, by race/ethnicity

	Distance in kilometers	
	Mean (SD)	Median (IQR)
Overall	2.9 (1.3)	3.1 (2.0, 4.0)
Maternal race/ethnicity		
Non-Hispanic		
Asian	3.1 (1.3)	3.1 (2.1, 4.2)
Black	2.1 (1.4)	1.9 (0.8, 3.3)
White	3.4 (1.0)	3.5 (2.7, 4.2)
Hispanic	2.8 (1.3)	2.9 (1.8, 2.9)

Web Figure 3: Predicted probabilities of preterm birth by pre- and post-retirement exposure status and distance bin. Predicted probabilities from unadjusted a difference-in-differences linear mixed models with random intercept for power plant. Circles represent the predicted probability of preterm birth in the pre- power plant retirement period retirement and triangles represent the predicted probability after power plant retirement Blue circles and lines represent predicted probability and 95% CI of preterm birth within 5km of retiring power plants yellow points and lines represent the difference-in-difference coefficient and 95% CI for births between 5-10km (compared to births 10-20km away).



Web Figure 4: Average difference in proportions of preterm birth pre vs. post plant retirement by distance bin. Results from an unadjusted difference-in-differences linear mixed models with random intercept for power plant. Red points and lines represent the difference-in-difference coefficient and 95% CI for births within 5km of retiring power plants (compared to births 10-20km away) and orange points and lines represent the difference-in-difference coefficient and 95% CI for births between 5-10km (compared to births 10-20km away).

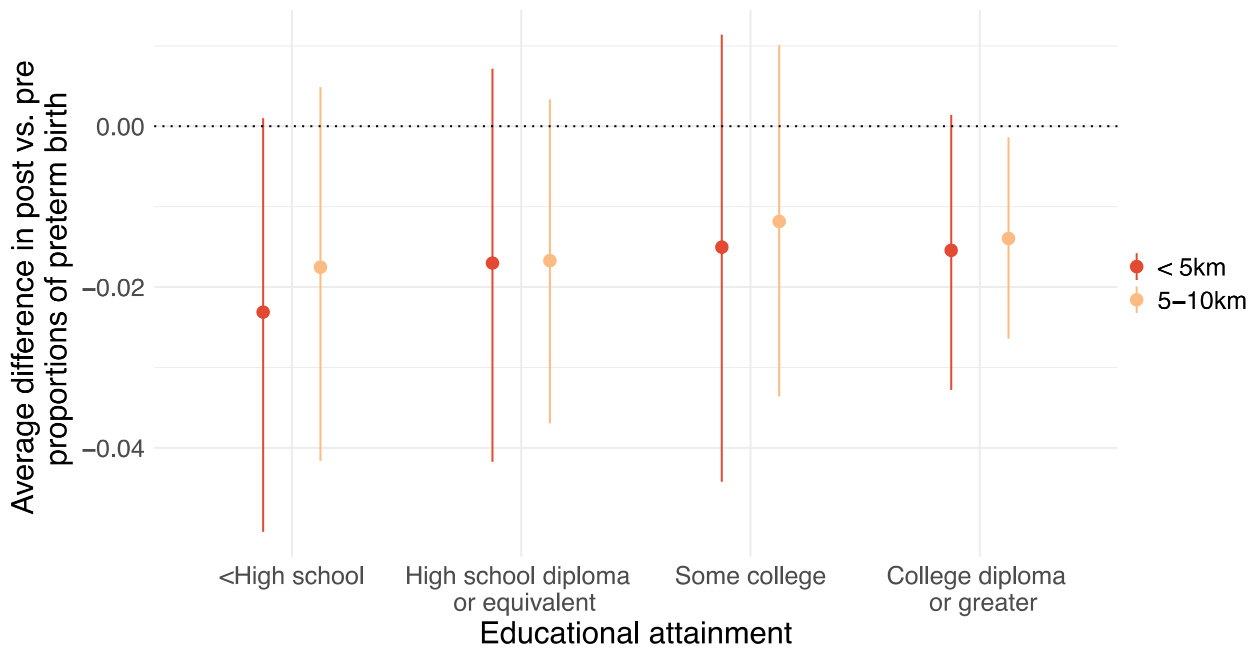


Web Table 2: Difference-in-difference estimates for preterm birth from unadjusted and adjusted linear mixed models

	Unadjusted DiD estimate				Adjusted DiD estimate[a]			
	<5km		5-10km		<5km		5-10km	
	DiD estimate	95% CI	DiD estimate	95% CI	DiD estimate	95% CI	DiD estimate	95% CI
Preterm birth (proportion)	-0.018	-0.030, -0.008	-0.014	-0.023, -0.006	-0.019	-0.031, -0.008	-0.015	-0.024, -0.007
Early preterm birth (< 32 weeks)	0.001	-0.004, 0.006	0.001	-0.002, 0.005	0	-0.005, 0.005	0.001	-0.003, 0.004
Moderate to late (32 to < 37 weeks)	-0.019	-0.029, -0.009	-0.015	-0.024, -0.006	-0.020	-0.031, -0.009	-0.016	-0.025, -0.008
Maternal race/ethnicity								
Non-Hispanic								
Asian	-0.034	-0.059, -0.011	-0.022	-0.038, -0.001	-0.033	-0.058, -0.008	-0.024	-0.041, -0.005
Black	-0.030	-0.079, -0.019	-0.035	-0.076, 0.009	-0.037	-0.086, 0.009	-0.026	-0.069, 0.015
White	-0.016	-0.037, 0.004	-0.013	-0.027, 0.002	-0.015	-0.037, 0	-0.014	-0.028, 0
Hispanic	-0.008	-0.027, 0.009	-0.007	-0.023, 0.010	-0.012	-0.031, 0.007	-0.009	-0.026, 0.007
Maternal educational attainment								
< High school diploma	-0.021	-0.047, 0.004	-0.014	-0.034, 0.010	-0.023	-0.047, 0.006	-0.018	-0.038, -0.005
High school diploma or equivalent	-0.011	-0.037, 0.012	-0.016	-0.037, 0.003	-0.017	-0.044, 0.008	-0.017	-0.038, 0.001
Some college	-0.014	-0.042, 0.013	-0.014	-0.035, 0.008	-0.015	-0.044, 0.013	-0.012	-0.035, 0.010
College degree or greater	-0.016	-0.035, 0.002	-0.013	-0.026, -0.001	-0.015	-0.034, 0.003	-0.014	-0.029, 0

[a] Linear mixed model adjusted for maternal age (linear and quadratic terms); maternal race/ethnicity; maternal educational attainment; and number of prenatal visits; infant sex and month of birth; and neighborhood-level poverty and educational attainment

Web Figure 5: Average difference in proportions of preterm birth pre vs. post plant retirement by distance bin and maternal education attainment. Results from a difference-in-differences linear mixed model with random intercepts for power plant model that controlled for maternal age, race/ethnicity, educational attainment, number of prenatal visits, month of birth, neonate sex, and neighborhood-level educational attainment and poverty. Red points and lines represent the difference-in-difference coefficient and 95% CI for births within 5km of retiring power plants (compared to births 10-20km away) and orange points and lines represent the difference-in-difference coefficient and 95% CI for births between 5-10km (compared to births 10-20km away).

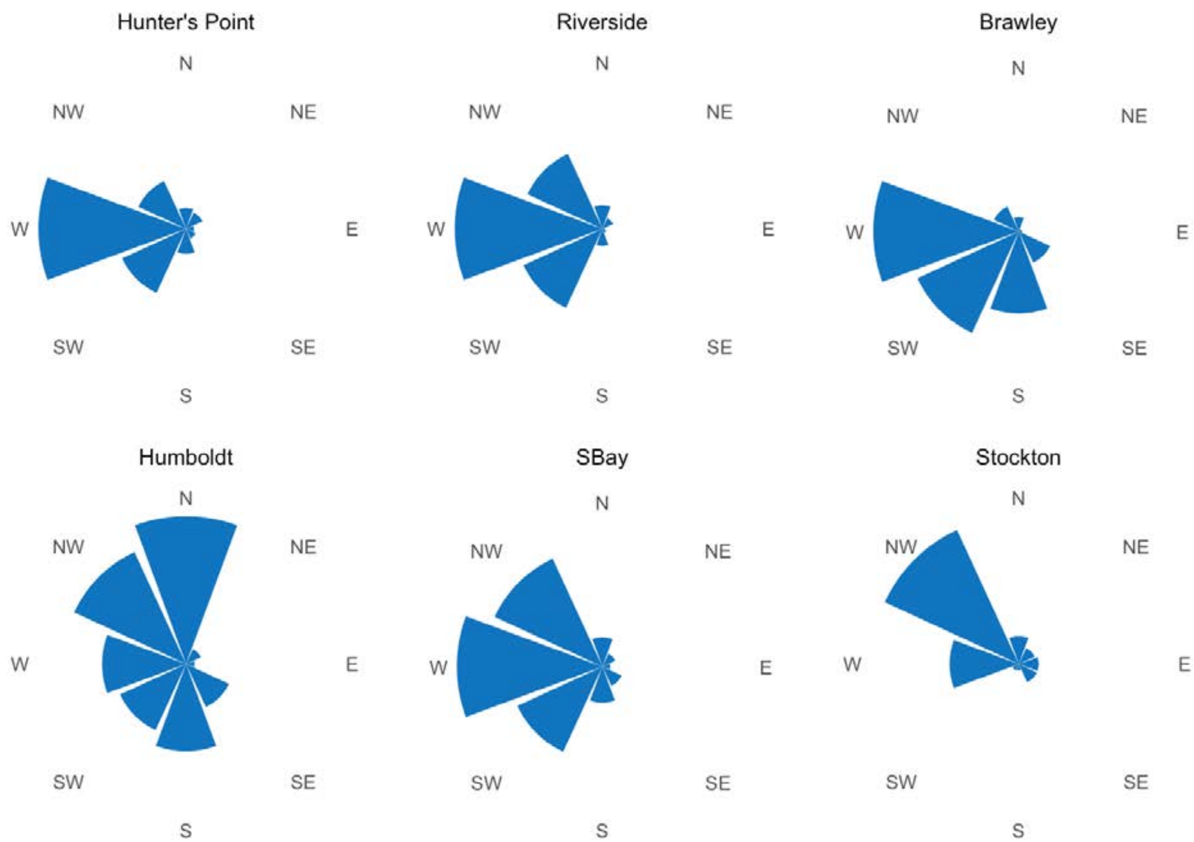


Web Appendix 1: Wind sensitivity analysis

Wind exposure assignment

Living downwind of coal and oil power plants may increase exposure to associated air pollution. Therefore, we calculated the number and proportion of days of pregnancy that mothers lived downwind. To do so, we purchased hourly wind data captured from weather stations located < 5km from the six power plants that retired between 2007-2011 from Weather Source (https://weathersource.com/). Weather Source provided wind direction as a continuous variable in degrees ranging from 0 to 360, where 0 and 360 degrees indicate wind blowing from due north and wind speed as m/s. We estimated daily average wind direction from the closest weather station to each power plant. To determine the number of days during pregnancy that mothers lived downwind of power plants, we calculated the angle between each power plant and mothers' residences at delivery and defined a downwind day as residence within 22.5º of the daily mean wind direction. We then divided mothers into three groups: those that never lived downwind during pregnancy (n = 10545 [18.5%]), those that lived downwind 1-90 days (n = 38,645, [67.8%]), and those that lived downwind ≥ 90 days during pregnancy (n = 7815, [13.7%]).

Web Figure 6: Wind rose plots of daily average wind direction at each of the six plants from 2007-2011. Data for wind rose plots and wind analyses were obtained from Weather Source (in May 2017) and were estimated to within a 5km grid of each power plant. Each plot corresponds to one of the six locations closest to the power plants in this analysis and depicts the daily average wind direction from 2007 to 2011.



Web Table 3: Difference-in-difference estimates for preterm birth from adjusted[a] linear mixed models stratified by days downwind during pregnancy

	< 5km		5-10km	
	DiD estimate	95% CI	DiD estimate	95% CI
Overall	-0.019	-0.031, -0.008	-0.015	-0.024, -0.007
Downwind days during pregnancy				
0	-0.015	-0.029, -0.002	-0.010	-0.021, 0.001
1-90	-0.039	-0.082, 0.007	-0.001	-0.044, 0.041
≥90	-0.026	-0.059, 0.011	-0.005	-0.048, 0.040

[a] Linear difference-in-differences mixed model adjusted for maternal age (linear and quadratic terms); maternal race/ethnicity; maternal educational attainment; and number of prenatal visits; infant sex and month of birth; and neighborhood-level poverty, and educational attainment

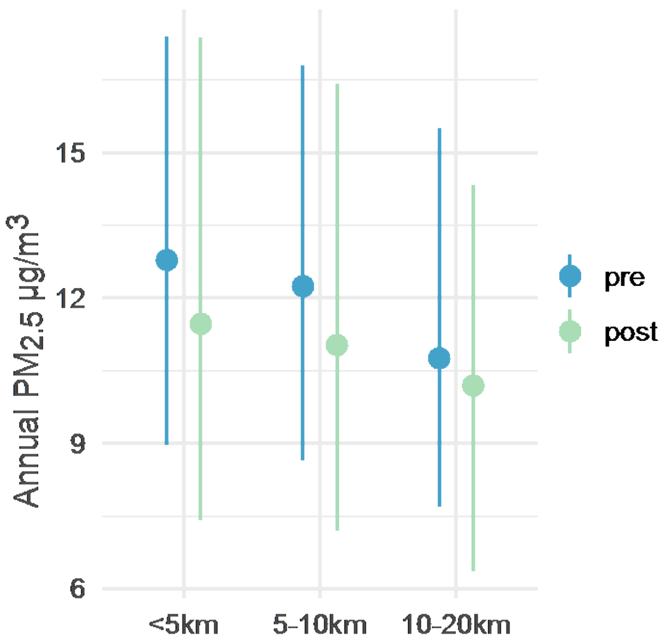
Web Table 4: Difference-in-difference estimates for preterm birth from adjusted[a] linear mixed models that included neighborhood foreclosures

	<5km		**5-10km**	
	DiD estimate	95% CI	DiD estimate	95% CI
Preterm birth (proportion)	-0.019	-0.031, -0.008	-0.015	-0.024, - 0.005

[a] Linear mixed model adjusted for maternal age (linear and quadratic terms); maternal race/ethnicity; maternal educational attainment; and number of prenatal visits; infant sex and month of birth; and neighborhood-level poverty, educational attainment, and number of foreclosures during the year of birth

We also wanted to evaluate whether changes in socioeconomic context, especially during the housing crisis that occurred in California (39) beginning in 2007 might explain observed associations. In the analysis, presented in Web Table 3, we further adjusted our final model for the number of foreclosures in the year of birth in each mother's block group.

Web Figure 7: Change in median and interquartile range $PM_{2.5}$ concentrations by distance bins. This plot is based on daily census tract level $PM_{2.5}$ estimates from the U.S. Environmental Protection Agency Community Multiscale Air Quality Model (CMAQ), available at https://www.epa.gov/hesc/rsig-related-downloadable-data-files. These data were available for the years 2002-2012. The blue points and lines represent the median and interquartile range of annual $PM_{2.5}$ concentration in census tracts located within 5km, 5-10km, and 10-20km of power plants in the yearlong exposed period before retirement. The green points and lines represent the median and interquartile range of annual $PM_{2.5}$ concentration in the yearlong unexposed period after power plants retired. Because we did not have access to data in the pre-period for the two power plants that retired in 2002, this plot only features the 6 power plants that retired between 2006-2011.



Web Appendix 2: Negative control power plant sensitivity analysis

Negative control power plant methods

In order to assess whether secular trends among populations living very near power plants accounted for the association between plant retirement and birth outcomes, we implemented a negative exposure control. We took the following steps:

1) Identified all oil and coal power plants in California that either retired before or after our study period (2001-2011).
2) Randomly selected 8 of these power plants and noted their location (i.e., latitude and longitude).
3) Randomly assigned to these newly selected power plants the retirement dates of power plants included in the main analysis.
4) Used the latitude and longitude of the 8 new power plants to identify births in three surrounding area bins: <5km, 5-10km, 10-20km.
5) Restricted the set of new births to those whose mothers had last mensural periods in the same two yearlong exposure periods used in the main analysis.
6) Repeated the original analysis with unadjusted and adjusted difference-in-differences linear mixed models with random intercepts for power plants.

Negative control power plant results

In step (2) we selected 5 oil and 3 coal power plants. Proceeding through step (5) resulted in the inclusion of 85,520 births, 5,380 (6.3%) of which were preterm. We found no relationship between preterm birth and residential proximity to these new 8 power plants when we assumed they retired on the same dates as the original 8 power plants (**Web Table 6**). This result provides evidence against the hypothesis that the findings from the main study were due to time trends among populations living near power plant facilities in the state. Although the possibility remains that the retired plants experienced secular trends that were not experienced by the negative control plants, this seems unlikely.

Web Table 5: Difference-in-difference estimates for preterm birth from adjusted[a] linear mixed models from the negative control analysis

	Unadjusted DiD estimate				Adjusted DiD estimate[a]			
	<5km		5-10km		<5km		5-10km	
	DiD estimate	95% CI	DiD estimate	95% CI	DiD estimate	95% CI	DiD estimate	95% CI
Preterm birth (proportion)	0.006	-0.004, 0.016	0	-0.011, 0.011	0.006	-0.004, 0.015	-0.001	-0.012, 0.010

[a] Linear mixed model adjusted for maternal age (linear and quadratic terms); maternal race/ethnicity; maternal educational attainment; and number of prenatal visits; infant sex and month of birth; and neighborhood-level poverty and educational attainment