Pollution, Test Scores and the Distribution Of Academic Achievement: Evidence From California Schools, 2002-2008

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Research Question:

- Investigate whether air pollution affect academic performance of school children in California using fixed effect least squares regression and fixed effect quantile regression.

- This issue has not be studied previously by economists; the two studies in the epidemiological literature considering it would not be considered as measuring causal effects by economists.

- Quantile regression allows us to investigate how pollution affects different parts of the achievement distribution, and has not been used previously in this literature.

Today focus on regression results.

- Our unit of analysis is at the school-grade-year level in California 2002-2008 for grades two through six. We consider four outcome variables at the grade-school level from standardized tests:
    - The mean scaled score in Mathematics (hereafter Math);
    - The percent of students at least proficient in Math;
    - The mean scaled score in English/Language Arts (hereafter English);
    - The percent of students at least proficient in English.

We consider the following pollution measures:

- **Fine Particulate Matter ($PM_{2.5}$):** Emitted directly from combustion, vehicle exhaust, construction dust, etc.
- **Coarse Particulate Matter (PM_{10}):** Emitted directly from combustion, vehicle exhaust, construction dust, etc.
- **Nitrogen dioxide (NO_2):** By-product of combustion exhaust from vehicles, boilers, or any combustion source.
- **Carbon Monoxide (CO):** From smoking cigarettes, formed through the improper burning of various fuels and exhaust of internal combustion engines (cars and trucks, generators, lawn mowers, etc.), and from improper burning of various other fuels (wood, coal, charcoal, natural gas, trash etc.).
- **Ozone (O_3):** formed in air when sunlight provides sufficient photochemical energy to drive reactions of oxygen with a number of gaseous pollutants.

Identification:

- *Crucial Identification Issue*: Poor children live in more polluted areas and have lower test scores.

- In the spirit of the previous economics literature, we use school grade fixed effects as well as time dummies and a large number of control variables in both the linear regressions and the quantile regressions to address this selection problem.

Estimating Pollution Effects Using a Fixed Effect Linear Regression Model

$$S_{gst} = \beta_1 P_{st} + \beta_2 X_{gst} + \beta_3 W_{st} + \beta_4 Z_{ct} + f_{gs} + D_t + \varepsilon_{gst},$$

- S_{gst} represents a measure of performance on a given standardized test for grade g in school s (located in county c) in year t

- P_{st} represents pollution at school s at time t;

- X_{gst} represents the racial composition in grade g at school s at time t;

- W_{st} represents school specific characteristics for school s at time t;

- Z_{ct} represents time-changing county level factors;

- f_{gs} represents school-grade FEs;

- D_t represents a full set of time dummies;

- Use date from Grades 2-6 because starting in grade 7 the math test is based on the courses taken in school by the individual students (e.g. algebra, geometry, or basic Math).

- Use only data on years 2002 through 2008 because the test format changes outside this time interval.

Pollution Data

- Pollution is measured at the school level and thus there is no variation in pollution across grades for a given school in a specific year.)

- The pollution measure used in this study is the percent of days that exceed the California Standard for that pollutant. The California standards are stricter than the federal standards for all pollutants except for $PM_{2.5}$, which is the same as the federal standard.

- We first use the longitude and latitude for each school and for each pollution monitor in California to find all monitors within a 20-mile radius of each school.

- For a given pollutant and monitor, we calculate the total number of days that exceed the standards for that pollutant and then divide by the total number of days that are tested.

- Since students usually take the California Standards Tests in April or May, we use pollution data from September through May.

- Then for a given pollutant at a given school in a given year, we take the weighted average of the percent of days exceeding the standard at each monitor, where the weighting is based on the inverse distance to the school.

- We also consider results based a number of alternative means of measuring pollution at the school levels. We present these results of this exercise below. We find that our results are robust to these changes.

Findings:

- We find that a one standard deviation reduction in ozone, fine particulate matter and especially coarse particulate matter generally increases these four performance measures in the linear and quantile regressions by a small, but statistically significant, amount.

- A one standard deviation in nitrogen dioxide has a small, but significant effect only on the Math measures scores.

- In the vast majority of cases, the carbon monoxide coefficients are insignificant.

Comparative Statics Exercises

- To put these results in perspective, we do some back-of-the-envelope calculations of the benefits of a decrease in pollution for disadvantaged neighborhoods; for ease of exposition we focus on reductions in PM_{10}.

- Using the median of free or reduced-price lunches as the threshold to determine high- and low-income schools, the percentage at least proficient in Math is 22.5 percentage points higher in high-income schools (61.8%) compared to low-income schools (39.3%). The percent of days above the standard for PM_{10} is 14.3 in low-income schools and 9.3 for high-income schools – a gap of 5.0 percentage points.

- If these low-income schools had the pollution levels of the high income schools, then the percentage at least proficient in Math would increase by 0.12, or the gap between high income and low income would fall to 22.38 percentage points, or by about 0.5%.

- In a similar vein, the difference between high income and low income schools in the percentage at least proficient in English is 28.04 percentage points. Equalizing PM_{10} exposure in terms of days above the standard between high income and low income schools would increase the percentage at least proficient in English in low income schools by 0.095, and would decrease the gap between high and low income schools to 27.945 by 0.34 %.

- Finally, consider the decrease in the average percent of days above the limit for PM_{10} between 1990 and 2008.

- We estimate that there is an 8.28 percentage point reduction in the percent of days above the standard between 1990 and 2008 for PM_{10}. The regression results suggest that this would increase the percentage at least proficient in Math and English by 0.198 and 0.157 respectively.

- To put this number in perspective, recall that the percentage at least proficient in Math is 22.5 percentage points higher in high-income schools than in low-income schools.
- Using either outcome variable, the contribution of the decrease in pollution to the improvement in the mean of the percentage at least proficient is small.

Table 3A: The Effect of Air Pollution (percent of days that exceed the standard) on Mean Scaled Scores in Mathematics – Grade-School and Year Effects

	(1)	(2)	(3)	(4)	(5)
Percent of days that exceed the standard for:					
Carbon monoxide (CO)	0.523				
	[0.419]				
Nitrogen dioxide (NO_2)		-5.139			
		[3.226]			
Ozone (O_3)			0.009		
			[0.052]		
Particulate matter$_{10}$ (PM_{10})				-0.023+	
				[0.012]	
Particulate matter$_{2.5}$ ($PM_{2.5}$)					-0.024
					[0.019]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 3B: The Effect of Air Pollution (percent of days that exceed the standard) on Percent of Students at Least Proficient in Mathematics – Grade-School and Year Effects

	(1)	(2)	(3)	(4)	(5)
Percent of days that exceed the standard for:					
Carbon monoxide (CO)	-0.123				
	[0.277]				
Nitrogen dioxide (NO_2)		-3.323+			
		[1.791]			
Ozone (O_3)			-0.089**		
			[0.032]		
Particulate matter$_{10}$ (PM_{10})				-0.024**	
				[0.0071]	
Particulate matter$_{2.5}$ ($PM_{2.5}$)					-0.012
					[0.011]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 4A: The Effect of Air Pollution (percent of days that exceed the standard) on Mean Scaled Scores in English/Language Arts – Grade-School and Year Effects

	(1)	(2)	(3)	(4)	(5)
Percent of days that exceed the standard for:					
Carbon monoxide (CO)	-0.418				
	[0.302]				
Nitrogen dioxide (NO_2)		-0.994			
		[1.915]			
Ozone (O_3)			-0.205**		
			[0.029]		
Particulate matter$_{10}$ (PM_{10})				-0.019**	
				[0.0067]	
Particulate matter$_{2.5}$ ($PM_{2.5}$)					-0.027*
					[0.011]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 4B: The Effect of Air Pollution (percent of days that exceed the standard) on Percent of Students at Least Proficient in English/Language Arts – Grade-School and Year Effects

	(1)	(2)	(3)	(4)	(5)
Percent of days that exceed the standard for:					
Carbon monoxide (CO)	0.177				
	[0.176]				
Nitrogen dioxide (NO_2)		-0.876			
		[1.380]			
Ozone (O_3)			-0.166**		
			[0.022]		
Particulate matter$_{10}$ (PM_{10})				-0.019**	
				[0.0051]	
Particulate matter$_{2.5}$ ($PM_{2.5}$)					-0.033**
					[0.0083]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 5: The Effect of Air Pollution (percent of days that exceed the standard) on Academic Performance using Monitors Functioning Throughout the Period– Grade-School and Year Effects

	Mathematics		English/Language Arts	
	Mean scaled score	Percent at least proficient	Mean scaled score	Percent at least proficient
	(1)	(2)	(3)	(4)
Percent of days that exceed the standard for:				
Carbon monoxide (CO)	0.745	-0.192	-0.533	0.249
	[0.600]	[0.402]	[0.423]	[0.261]
Nitrogen dioxide (NO_2)	-4.845+	-2.821+	0.068	-0.202
	[2.946]	[1.638]	[1.709]	[1.246]
Ozone (OZ)	0.007	-0.091**	-0.209**	-0.175**
	[0.052]	[0.032]	[0.029]	[0.022]
Particulate matter$_{10}$ (PM_{10})	-0.027*	-0.026**	-0.023**	-0.024**
	[0.011]	[0.007]	[0.006]	[0.005]
Particulate matter$_{2.5}$ ($PM_{2.5}$)	-0.015	-0.006	-0.025*	-0.031**
	[0.019]	[0.011]	[0.011]	[0.008]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 6: The Effect of Air Pollution (percent of days that exceed the standard) on Academic Performance using Monitors within a 10 mile Radius – Grade-School and Year Effects

	Mathematics		English/Language Arts	
	Mean scaled score (1)	Percent at least proficient (2)	Mean scaled score (3)	Percent at least proficient (4)
Percent of days that exceed the standard for:				
Carbon monoxide (CO)	0.354	-0.114	-0.570+	0.231
	[0.429]	[0.287]	[0.319]	[0.173]
Nitrogen dioxide (NO_2)	-4.192+	-1.349	-0.695	-0.149
	[2.352]	[1.354]	[1.378]	[0.992]
Ozone (O_3)	0.011	-0.068*	-0.149**	-0.120**
	[0.049]	[0.031]	[0.028]	[0.021]
Particulate matter$_{10}$ (PM_{10})	-0.002	-0.013+	-0.015*	-0.015**
	[0.012]	[0.007]	[0.007]	[0.005]
Particulate matter$_{2.5}$ ($PM_{2.5}$)	-0.004	-0.009	-0.024*	-0.030**
	[0.020]	[0.012]	[0.012]	[0.009]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 7: The Effect of Air Pollution (percent of days that exceed the standard) on Academic Performance using Observations where all Pollutants and Test Scores are Available – Grade-

	Mean scaled score (1)	Percent at least proficient (2)	Mean scaled score (3)	Percent at least proficient (4)
Percent of days that exceed the standard for:				
Carbon monoxide (CO)	0.735+	-0.034	-0.264	0.259
	[0.429]	[0.277]	[0.305]	[0.174]
Nitrogen dioxide (NO_2)	-5.584	-2.730	0.142	-0.423
	[3.692]	[2.018]	[2.064]	[1.534]
Ozone (O_3)	0.017	-0.096**	-0.213**	-0.167**
	[0.057]	[0.035]	[0.032]	[0.024]
Particulate matter$_{10}$ (PM_{10})	-0.016	-0.023**	-0.018**	-0.020**
	[0.012]	[0.007]	[0.007]	[0.005]
Particulate matter$_{2.5}$ ($PM_{2.5}$)	-0.015	-0.010	-0.022*	-0.030**
	[0.019]	[0.011]	[0.011]	[0.008]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 8: Quantile Regressions Results for Mathematics and English/Language Arts

Quantile	10%	20%	40%	50%	60%	80%	90%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Mathematics Mean Scaled Score							
Carbon monoxide (CO)	0.496	0.087	0.022	0.52	0.266	0.412	0.536
	[0.478]	[0.498]	[0.555]	[0.411]	[0.401]	[0.766]	[0.438]
Nitrogen dioxide (NO_2)	-5.615	-3.786	-7.393**	-5.151*	-4.437*	-3.245	-5.056*
	[4.288]	[3.228]	[2.778]	[2.327]	[2.101]	[2.374]	[2.579]
Ozone (O_3)	0.005	0.012	0.019	0.016	0.005	-0.034	-0.051+
	[0.030]	[0.024]	[0.021]	[0.018]	[0.020]	[0.024]	[0.028]
Particulate matter$_{10}$ (PM_{10})	-0.024**	-0.027**	-0.022**	-0.017**	-0.022**	-0.025**	-0.020**
	[0.0056]	[0.0044]	[0.0043]	[0.0038]	[0.0039]	[0.0050]	[0.0060]
Particulate matter$_{2.5}$ ($PM_{2.5}$)	0.0007	-0.021*	-0.025**	-0.030**	-0.029**	-0.046**	-0.048**
	[0.012]	[0.0010]	[0.0090]	[0.010]	[0.012]	[0.0086]	[0.012]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 8: Quantile Regressions Results for Mathematics and English/Language Arts

Quantile	10%	20%	40%	50%	60%	80%	90%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel B: Percent at Least Proficient in Mathematics							
Carbon monoxide (CO)	-0.641	-0.340	-0.256	-0.338+	-0.364+	-0.274	-0.332
	[0.409]	[0.414]	[0.388]	[0.200]	[0.199]	[0.378]	[0.457]
Nitrogen dioxide (NO_2)	-3.042	-1.878	-3.340**	-4.066**	-4.685**	-4.462**	-4.347+
	[2.228]	[1.759]	[1.229]	[1.395]	[1.257]	[1.729]	[2.308]
Ozone (O_3)	-0.040*	-0.066**	-0.095**	-0.105**	-0.116**	-0.143**	-0.151**
	[0.016]	[0.014]	[0.013]	[0.014]	[0.013]	[0.016]	[0.021]
Particulate matter$_{10}$ (PM_{10})	-0.017**	-0.020**	-0.025**	-0.026**	-0.030**	-0.030**	-0.032**
	[0.0040]	[0.0029]	[0.0030]	[0.0031]	[0.0033]	[0.0038]	[0.0047]
Particulate matter$_{2.5}$ ($PM_{2.5}$)	0.012	0.0054	-0.0063	-0.011*	-0.022**	-0.028**	-0.032**
	[0.0077]	[0.0060]	[0.0051]	[0.0050]	[0.0055]	[0.0063]	[0.0066]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 8: Quantile Regressions Results for Mathematics and English/Language Arts

Quantile	10%	20%	40%	50%	60%	80%	90%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel C: English/Language Arts Mean Scaled Score							
Carbon monoxide (CO)	-0.998*	-0.744*	-0.502+	-0.339	-0.540**	-0.574+	-0.609*
	[0.469]	[0.332]	[0.264]	[0.235]	[0.185]	[0.348]	[0.290]
Nitrogen dioxide (NO_2)	0.422	-1.072	-1.777	-0.967	-0.501	-0.639	0.258
	[2.658]	[1.494]	[1.440]	[1.676]	[1.137]	[1.703]	[2.914]
Ozone (O_3)	-0.191**	-0.205**	-0.196**	-0.211**	-0.222**	-0.224**	-0.262**
	[0.015]	[0.012]	[0.012]	[0.012]	[0.013]	[0.012]	[0.020]
Particulate matter$_{10}$ (PM_{10})	-0.014**	-0.015**	-0.019**	-0.021**	-0.021**	-0.022**	-0.025**
	[0.0047]	[0.0038]	[0.0026]	[0.0026]	[0.0023]	[0.0030]	[0.0039]
Particulate matter$_{2.5}$ ($PM_{2.5}$)	-0.022**	-0.026**	-0.028**	-0.029**	-0.029**	-0.024**	-0.027**
	[0.0063]	[0.0051]	[0.0047]	[0.0044]	[0.0047]	[0.0064]	[0.0069]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.

Table 8: Quantile Regressions Results for Mathematics and English/Language Arts

Quantile	10%	20%	40%	50%	60%	80%	90%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel D: Percent at Least Proficient in English/Language Arts							
Carbon monoxide (CO)	0.320+	0.168	0.153	0.074	-0.032	-0.021	-0.186
	[0.194]	[0.140]	[0.230]	[0.171]	[0.107]	[0.214]	[0.247]
Nitrogen dioxide (NO_2)	-2.148	-1.826	-2.069+	-1.164	-0.576	-0.258	0.687
	[1.448]	[1.368]	[1.164]	[1.220]	[1.482]	[1.523]	[1.266]
Ozone (O_3)	-0.142**	-0.149**	-0.163**	-0.178**	-0.182**	-0.204**	-0.252**
	[0.013]	[0.010]	[0.008]	[0.010]	[0.011]	[0.013]	[0.016]
Particulate matter$_{10}$ (PM_{10})	-0.019**	-0.017**	-0.019**	-0.020**	-0.020**	-0.022**	-0.023**
	[0.0027]	[0.0022]	[0.0022]	[0.0025]	[0.0023]	[0.0027]	[0.0035]
Particulate matter$_{2.5}$ ($PM_{2.5}$)	-0.024**	-0.023**	-0.029**	-0.036**	-0.036**	-0.033**	-0.036**
	[0.0050]	[0.0046]	[0.0033]	[0.0032]	[0.0032]	[0.0047]	[0.0060]

+ significant at the 10% level, * significant at the 5% level, ** significant at the 1% level.