AEA Papers and Proceedings 2019, 109: 271–276
https://doi.org/10.1257/pandp.20191062

ECONOMIC INEQUALITY AND AIR POLLUTION[‡]

Does Environmental Policy Affect Income Inequality? Evidence from the Clean Air Act[†]

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This paper quantifies the impact of environmental policy on income inequality. We focus on the Clean Air Act (CAA). Prior research on the labor market effects of the CAA is inconclusive (Berman and Bui 2001; Morgenstern, Pizer, and Shih 2002; Greenstone 2002), in part, because of the multiple channels through which the CAA affects firms and workers. On the one hand, exposure to local air pollution decreases labor productivity and increases absenteeism (Office of Air and Radiation 2011). Thus, reductions in pollution due to the CAA might boost wages or employment opportunities. On the other hand, firms must take costly actions in order to comply with stricter environmental regulations, which might include firing employees or reducing wages. In this setting, there has been little prior research on the distribution of labor market impacts from environmental policy.

Our empirical analysis utilizes panel variation in the stringency of environmental regulation generated by the National Ambient Air Quality Standards (NAAQS). The NAAQS, established by the CAA, are annual county-level limits on the allowable concentrations of various air pollutants. We focus on the standards associated with fine particulate matter ($PM_{2.5}$) and tropospheric ozone (O_3) because these two species result in the largest damage among the pollutants regulated by the NAAQS (Office of Air and Radiation 2011; Muller, Mendelsohn, and Nordhaus 2011). The sample period considered for this analysis is 2005–2015. We thus focus on two specific policy changes: the 2006 $PM_{2.5}$ NAAQS (implemented in 2009) and the 2008 NAAQS for O_3 (implemented in 2012).

Annual, county-level attainment information for each of these standards allows us to quantify the impact of environmental policy on outcomes within a matched difference-in-difference (DD) framework. A county is "treated" in a given year if and only if this county is designated as out of attainment with the NAAQS standard; "non-attainment" counties face stricter environmental regulations than attainment counties. We match each county that was in non-attainment at any point in 2005–2015 to ten counties that were in attainment throughout the sample period. After matching, we see no differential trend in average outcomes between these two types of counties prior to the relevant standard coming into effect (i.e.: the "common preexisting trends" assumption holds). This facilitates a causal interpretation of our estimated effects.

We consider the annual county-level average and dispersion, as measured by the Gini coefficient, the ratio of the ninetieth percentile to the median (or 90/50 ratio), and the ratio of the ninetieth percentile to the tenth percentile (or 90/10 ratio), of three outcome variables: pollution levels, household income, and household income adjusted for the monetary damages associated with air pollution exposure (Nordhaus and Tobin 1972; Muller, Mendelsohn, and Nordhaus 2011; Muller, Matthews, and Wiltshire-Gordon 2018). Our results indicate that non-attainment with the 2006 $PM_{2.5}$ NAAQS reduced both the average and dispersion of $PM_{2.5}$. Non-attainment with

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[†]Go to https://doi.org/10.1257/pandp.20191062 to visit the article page for additional materials and author disclosure statement(s).

the 2008 O_3 NAAQS had no statistical effect on either average levels or the dispersion of O_3 levels. Despite this difference in results for $PM_{2.5}$ versus O_3, we find that non-attainment with either standard increases the dispersion of both market income and pollution-adjusted income. Though prior research has repeatedly found that there are sizable net benefits in aggregate from air quality regulations (Office of Air and Radiation 2011), our findings suggest that these benefits are disproportionately distributed to the rich. Stricter environmental regulation can exacerbate income inequality even as it benefits most individuals and society as a whole.

I. Methods

Our analysis uses publicly available data from numerous sources. First, we exploit modeled estimates of the annual concentration levels of fine particulates ($PM_{2.5}$) and ozone (O_3) in each census block group (CACES 2018). Second, we employ annual data on the average gross adjusted income in each zip code from the Internal Revenue Service's Statistics of Income (SOI) (NBER 2018). Finally, we compute the monetary cost of the premature mortality risk due to exposure to $PM_{2.5}$ and O_3 using the approach that is standard in the literature (Muller and Mendelsohn 2009, National Research Council 2010, Office of Air and Radiation 2011):

$$(1)\quad D_{i,t} = VSL_t \times \sum_{s=1}^{2} M_{i,a,t}\left(\frac{1}{1 - \exp^{(\beta_s P_{i,t,s})}}\right),$$

where VSL_t is the value of a statistical life, expressed in year (t) dollars; $M_{i,a,t}$ is the baseline mortality rate among persons of age-cohort (a) in county (i) in year (t); $P_{i,t,s}$ is the pollution level for pollutant (s) in county (i) in year (t); and β_s is a statistically estimated parameter linking exposure to mortality risk for pollutant (s).

The Centers for Disease Control and Prevention provide data on the annual county-level mortality rate by age group (CDC 2018). We adopt the USEPA's VSL of \$7.4 million (in 2006 dollars), adjusting this VSL for inflation using the Consumer Price Index (CPI). The statistical relationship between $PM_{2.5}$ exposure and mortality risk is taken from Krewski et al. (2009). We adopt the findings from Bell et al. (2004) for O_3. Finally, monetary damage $D_{i,t}$ is subtracted from market income in order to calculate each zip code's average pollution-adjusted income for each year of sample.

Annual, county-level designations with each of the NAAQS are provided by the United States Environmental Protection Agency (USEPA 2016, 2018). Based on these designations, our matched difference-in-difference (DD) framework takes the familiar form specified in (2):

$$(2)\quad \log(Y_{i,t}) = \alpha_i + \gamma_t + \beta NA_{i,t} + \theta PREVNA_{i,t} + \varepsilon_{i,t},$$

where $Y_{i,t}$ is the outcome of interest in county (i) in year (t); α_i represents county fixed effects; and γ_t represents year fixed effects. $NA_{i,t}$ is an indicator that assumes a value of one if and only if county (i) is out of attainment with the relevant NAAQS standard in year (t); $PREVNA_{i,t}$ is an indicator that assumes a value of one if and only if county (i) is out of attainment with the *previous* NAAQS standard for the same pollutant in year (t). Finally, $\varepsilon_{i,t}$ is the error term.

As outcome variables, we consider the mean and dispersion of the following variables: household income, $PM_{2.5}$ and O_3 concentration levels, and pollution-adjusted household income. Importantly, we match each county that was ever out of attainment with the relevant standard between 2005–2015 to ten counties that were always in attainment with this standard during 2005–2015. This matching is based on the 2005 levels of each dependent variable. We provide more details on this matching estimator, based on Heckman, Ichimura, and Todd (1997) as well as Cicala (2015), in online Appendix D. For ease of exposition, we use the term "county group" for the counties consisting of the "ever-non-attainment" county and its matched "always-attainment" counties. We include county/county-group fixed effects and year fixed effects. Standard errors are clustered by county group.

II. Results

Table 1 presents our estimated coefficients and standard errors pertaining to the impact of the O_3 and $PM_{2.5}$ NAAQS on the mean and dispersion of pollution, market income, and pollution-adjusted income. The full regression results are reported in online Appendix A. Interpreting the results of this analysis as causal

Table 1—The Effect of NAAQS Non-Attainment on Pollution and Income

Dependent variable	Pollution standard	log of Gini coefficient (1)	log of mean (2)	log of 90/50 (3)	log of 90/10 (4)
Ozone	Ozone (2008)	−0.016	0.007	0.030	0.001
		(0.020)	(0.004)	(0.023)	(0.020)
$PM_{2.5}$	$PM_{2.5}$ (2006)	−0.067	−0.023	−0.129	−0.082
		(0.014)	(0.008)	(0.021)	(0.015)
Market income	Ozone (2008)	0.055	0.030	0.075	0.040
		(0.006)	(0.010)	(0.019)	(0.015)
	$PM_{2.5}$ (2006)	0.044	0.010	0.002	0.002
		(0.011)	(0.016)	(0.028)	(0.019)
Pollution-adjusted income	Ozone (2008)	0.171	0.033	0.100	0.079
		(0.010)	(0.010)	(0.021)	(0.017)
	$PM_{2.5}$ (2006)	0.192	0.067	0.084	0.080
		(0.020)	(0.019)	(0.028)	(0.021)

Note: Standard errors clustered by county group are in parentheses.

relies on the following assumption: counties that will eventually shift into non-attainment with the relevant standard have the same average trend in outcomes over time as counties that are always in attainment (the "common trends" assumption). We relegate the plots of these trends to online Appendix Section B.

The first row in Table 1 indicates that non-attainment with the 2008 O_3 NAAQS had no statistical impact on the dispersion of O_3, measured either using the Gini coefficient, 90/50 ratio, or 90/10 ratio. However, noncompliance slightly increases average O_3 levels ($p < 0.10$). While this may seem counterintuitive, O_3 is formed through complex nonlinear processes. Thus, efforts to reduce the number of hours with high O_3 levels can increase annual average O_3 levels (Seinfeld and Pandis 1998). Further, average O_3 levels have remained roughly constant for decades (Muller and Ruud 2016).

However, non-attainment with the 2006 $PM_{2.5}$ NAAQS unambiguously reduced average $PM_{2.5}$ levels. In non-attainment counties, the mean $PM_{2.5}$ level is 2.3 percent lower than in attainment counties ($p < 0.01$). Further, noncompliance with the 2006 NAAQS reduced the within-county dispersion of $PM_{2.5}$. On average, non-attainment results in roughly a 7 percent decrease in the Gini coefficient, a 13 percent decrease in the 90/50 ratio, and an 8 percent decrease in the 90/10 ratio ($p < 0.01$ in all cases).

Summarizing, Table 1 suggests that the 2008 O_3 NAAQS did not appreciably affect the distribution of O_3 levels. Due to this, any effect on income inequality is likely through firms' compliance behavior rather than improvements in workers' health and labor productivity. In contrast, the 2006 $PM_{2.5}$ NAAQS clearly impacted both the level and dispersion of $PM_{2.5}$. This standard thus potentially affects income inequality both through improvements in worker welfare and changes in firm behavior.

The third row in Table 1 quantifies the effect of NAAQS compliance status on market income. Non-attainment with the 2008 O_3 NAAQS exacerbates inequality in market income. Specifically, the Gini coefficient is 5 percent larger in non-attainment counties on average ($p < 0.01$). Both the 90/10 and the 90/50 ratios also increase as a result of non-attainment ($p < 0.01$). Finally, Table 1 indicates that noncompliance with the 2008 O_3 NAAQS induced a 3 percent increase in relative mean income ($p < 0.01$). Importantly, the specifications reported in Table 1 also control for attainment status with the prior standard for ozone announced in 1997. The results for this prior standard cannot be interpreted causally because it was already in place by 2005 when our sample period begins. Hence, we cannot assess preexisting trends. Nevertheless, Table A.3 in the online Appendix reports largely similar estimates for the prior O_3 standard, with the important exception that we find no statistical impact of the 1997 standard on the Gini coefficient.

Table 1 also reports the effect of the 2006 $PM_{2.5}$ NAAQS on the distribution of market income. As with O_3, we find that noncompliance with the 2006 $PM_{2.5}$ standard exacerbates income inequality. Non-attainment increases the Gini coefficient by about 4 percent $(p < 0.01)$ and the 90/50 and 90/10 ratios by less than 1 percent, though these coefficients are not statistically significant at conventional levels. In contrast to the O_3 standard, we find no statistical evidence that non-attainment with the $PM_{2.5}$ standard affects mean household income. Finally, Table A.4 in the online Appendix reports that attainment status with the 1997 $PM_{2.5}$ NAAQS reduces the market-income Gini coefficient by 10 percent $(p < 0.10)$. As with the 2006 $PM_{2.5}$ NAAQS, the prior standard has no effect on mean income levels or the 90/50 and 90/10 ratios.

Summarizing, we find that non-attainment with either 2008 O_3 NAAQS or 2006 $PM_{2.5}$ NAAQS results in substantial increases in income inequality. Given that pollution exposure disproportionately impacts lower income individuals, our results suggest that these two standards primarily affect the distribution of income through costly actions taken by firms. In particular, compliance with binding standards requires that polluting firms allocate additional resources to abatement. In doing so, they likely either decrease wages or reduce their number of employees. In turn, these actions are likely to disproportionately impact low-productivity, low-wage earners.

The bottom two rows of Table 1 reports the effects of NAAQS non-attainment on adjusted gross income net of the per-capita monetary damages from pollution. This table reveals that, for both pollutants, the effects for pollution-adjusted income have the same sign as for market income. The evident difference is that the effects of non-attainment on pollution-adjusted income are considerably larger. Noncompliance with the 2008 O_3 standard increases mean market income and mean pollution-adjusted income by very similar magnitudes, about 3 percent. However, non-attainment has a much larger effect on dispersion in pollution-adjusted income. For example, non-attainment with the 2008 O_3 NAAQS results in a 17 percent increase in the Gini coefficient for pollution-adjusted income $(p < 0.01)$. The corresponding effect for market income is about 5 percent. The effect of non-attainment on the 90/50 ratio in market income is 7.5 percent, whereas the corresponding effect for pollution-adjusted income is 10 percent. And, non-attainment with the 2008 O_3 NAAQS increases the 90/10 ratio by 8 percent compared to 4 percent for market income. Table A.5 in the online Appendix reports similar effects on pollution-adjusted income for non-attainment with the prior O_3 standard, the one exception being that non-attainment with the 1997 O_3 standard is not significantly associated with the Gini coefficient.

Similarly, non-attainment with the 2006 $PM_{2.5}$ NAAQS induces a 7 percent increase in the average of pollution-adjusted income. Recall that we found no estimated impact of non-attainment on average market income. The effects of non-attainment with the 2006 $PM_{2.5}$ NAAQS on dispersion are also far larger for pollution-adjusted income relative to market income. For example, non-attainment results in a 19 percent increase in the pollution-adjusted income Gini $(p < 0.01)$ and a 4 percent increase in the market-income Gini $(p < 0.01)$. And, while there is no significant effect of $PM_{2.5}$ non-attainment on either the 90/50 or 90/10 ratios for market income, these ratios, when calculated for pollution-adjusted income, increase by about 8 percent $(p < 0.01)$ in response to non-attainment. Finally, Table A.6 in the online Appendix indicates that non-attainment with the 1997 $PM_{2.5}$ is associated with a 5 percent decrease in average pollution-adjusted income $(p < 0.05)$. In addition, non-attainment with this prior standard reduced the pollution-adjusted income Gini coefficient by about 19 percent $(p < 0.01)$, which is roughly the same magnitude as the increase from the 2006 NAAQS.

When interpreting these findings, it is important to note that pollution-adjusted income is distributed much less equally than market income because low-income households tend to be in high-pollution areas and have higher baseline mortality risks (Muller, Matthews, and Wiltshire-Gordon 2018). To the extent that environmental policy reduces pollution exposure and the damages from pollution, these benefits accrue disproportionately to cities, which tend to have higher income on average than rural areas. Thus, environmental policy potentially exacerbates pollution-adjusted income inequality because low-income households bear the brunt of adverse labor market effects without concomitant damage reductions.

This is especially likely for the 2008 O_3 NAAQS since Table C.1 in the online Appendix reports that this standard did not reduce the distribution of the monetary damages from pollution. In contrast, non-attainment with the 2006 $PM_{2.5}$ standard reduced mean pollution damage ($p < 0.01$), as well as both the 90/50 and 90/10 ratios ($p < 0.01$). The worsening of pollution-adjusted income from the 2006 $PM_{2.5}$ NAAQS suggests that the adverse impact of this policy on market income inequality overwhelms the slight reduction and equalization in damage. Finally, while the 2008 O_3 NAAQS and the 2006 $PM_{2.5}$ NAAQS appear to have increased inequality in both market and pollution-adjusted income, the 1997 NAAQS for $PM_{2.5}$ had the opposite effect. This suggests that the effect of stricter environmental policy on income inequality depends crucially on the stringency of existing regulations.

We conclude by noting that further research is required to fully document how large-scale environmental policies affect the distribution of income. Our results offer a provocative glimpse of the intersection between the Clean Air Act, labor markets, and human health effects. While pollution standards can reduce pollution levels and thus result in significant environmental benefits in aggregate, our findings suggest that these standards appear to distort the distribution of economic resources in complex, and at times unfortunate, ways.

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