

The effects of air pollution on educational outcomes: A natural experiment from the GDR

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Extended Abstract

Air pollution is one of the most pervasive environmental determinants of health and human capital. A large literature shows that pollution harms respiratory and cardiovascular health, reduces productivity, and impairs cognitive performance in the short run. Yet we know much less about whether sustained pollution exposure during late adolescence—a period in which students face high-stakes examinations and make decisive educational choices—produces persistent losses in human capital formation. This paper addresses that question by studying the effects of a sudden and sustained increase in air pollution in the German Democratic Republic (GDR) after the 1982 Soviet oil supply shock.

The core empirical challenge in this literature is endogenous sorting: families may relocate away from polluted areas, and better-off households may be more able to mitigate exposure. The GDR provides a rare institutional setting in which these concerns are sharply attenuated. Residential mobility, school assignment, and access to private mitigation technologies were heavily constrained under the socialist regime. Students were assigned to schools based on residence, and the education system was highly centralized, with standardized curricula and grading rules. As a result, the location of schooling—and thus local pollution exposure—was much less subject to parental choice than in market economies. This setting therefore offers an unusually credible environment for identifying the causal effects of pollution on educational outcomes.

The paper exploits a natural experiment generated by the 1982 cut in Soviet oil deliveries to East Germany. Because the GDR was highly dependent on Soviet energy imports and had few domestic alternatives, the regime responded by rapidly expanding the use of domestic lignite (brown coal) in power generation, industrial heating, and household heating. Lignite is a particularly dirty fuel, with high sulfur content and high emissions of sulfur dioxide (SO₂) and particulates. Since lignite is costly to transport over long distances, combustion and related industrial activity were spatially concentrated near mining and power-generation regions. This created a sharp and geographically uneven increase in air pollution after 1982, with counties near lignite areas experiencing a substantially larger deterioration in air quality than more distant counties.

The analysis proceeds in three parts. First, I establish the environmental first stage: the oil shock led to a large and persistent increase in local SO₂ pollution in counties close to lignite mining areas. Second, I examine short-run educational effects using individual-level administrative data on university applicants' transcripts and study preferences from the GDR's centralized admissions system. Third, I investigate whether these educational disruptions translated into differences in early labor-market and tertiary-track outcomes using administrative employment records from the GDR's centralized labor register.

Environmental first stage: documenting the pollution shock

To measure local pollution, I use newly digitized and validated historical air-quality monitoring data from the former GDR, focusing on SO₂ because it has the broadest spatial and temporal coverage in the

historical monitor network. I assign county-level pollution exposure using station readings and geocoded county locations. Treatment status is defined by geographic proximity to active lignite mining areas: in the baseline specification, a county is classified as treated if its centroid lies within 60 kilometers of an active lignite mine during the post-shock period.

I estimate a county-level difference-in-differences model comparing treated and control counties before and after 1982, with county and year fixed effects. The results show a clear and economically large first stage. Counties near lignite mining areas experienced an increase in annual mean SO_2 concentrations of about $28.8 \mu\text{g}/\text{m}^3$ after 1982 relative to more distant counties. This corresponds to roughly a 20 percent increase relative to pre-shock levels. Event-study estimates show no evidence of differential pre-trends before 1982 and a persistent post-shock divergence thereafter, consistent with the GDR's continued reliance on lignite throughout the 1980s.

Educational outcomes: transcript grades and study orientation

The second part of the paper examines whether this pollution shock affected academic performance during the final years of secondary education, especially among students on the academic track leading to the Abitur (the university-qualifying school-leaving certificate). For this analysis, I use administrative records from the GDR's Central Office for University Admissions, which centralized applications to higher education. These records include rich information on applicants' background characteristics, school transcript grades, certificate timing, and intended field of study.

The key advantage of these data is that they provide individual-level educational outcomes in a centralized and standardized institutional environment. Because school transfers were rare and admission to the upper-secondary academic track was centrally regulated, local exposure to pollution during schooling is plausibly exogenous to individual ability and family sorting in a way that is difficult to achieve in most contemporary settings.

I link each application to the student's school location (proxied through administrative residence information) and assign treatment based on proximity to lignite regions. Since applications could be submitted with delay, treatment timing is anchored to the year the school transcript was issued rather than the application year. The main outcome is the transcript grade, where higher numerical values indicate worse performance. I estimate difference-in-differences specifications with fixed effects for cohorts and schools, and include controls for gender, month of birth, social background, party and youth-organization membership, and schooling track characteristics.

The results show a statistically significant deterioration in educational performance among students in more polluted regions after 1982. In the preferred specification, transcript grades worsen by about 0.03 grade points, which corresponds to roughly 0.05 standard deviations of the grade distribution. While the magnitude may appear modest in absolute terms, it is meaningful in the GDR's centralized and selective higher-education system, where even small grade differences could affect admission probabilities and study placement at the margin. Dynamic event-study estimates reinforce the causal interpretation. Pre-treatment coefficients are close to zero and statistically insignificant, supporting the parallel-trends assumption. After 1982, the adverse effect emerges gradually and becomes more pronounced over subsequent years, a pattern consistent with cumulative exposure rather than a one-time shock. This gradual build-up also aligns with a mechanism in which sustained pollution affects learning, attendance, and cognitive endurance over time, rather than only exam-day performance.

A key insight of the analysis is that effects are not uniform across subjects. Subject-level estimates show larger and more precisely estimated deteriorations in cognitively demanding and cumulative-learning subjects, especially mathematics, physics, chemistry, and biology. By contrast, effects in artistic subjects such as music and art are close to zero and statistically insignificant. This pattern is difficult to reconcile with a simple change in grading standards and instead points toward a genuine decline in learning and performance under sustained pollution exposure. Additional heterogeneity results suggest somewhat larger adverse effects for male students than for female students, although the estimated impacts are negative for both groups.

Early labor-market and tertiary-track outcomes

The third part of the paper examines whether the pollution shock is associated with differences in early post-school trajectories. For this purpose, I use administrative employment records from the GDR's centralized labor register, the *Datenspeicher Gesellschaftliches Arbeitsvermögen* (GAV). The surviving archival version provides a comprehensive cross-section of employment and labor-market status in 1989, with detailed information on education, labor-market entry channels, occupation, and place of residence.

I construct a cohort-based difference-in-differences design using expected Abitur graduation year (derived from birth month and year using the GDR school-entry rule) and county of residence. The main analysis focuses on individuals with a regular Abitur and on cohorts for whom outcomes can be meaningfully observed by 1989. This design does not follow individuals over time, but it exploits variation across cohorts and regions in exposure to the post-1982 lignite pollution shock during late secondary schooling.

The labor-market outcomes are designed to capture tertiary progression and academic sorting at labor-market entry. I consider three different outcomes in this stage of the analysis: (i) an indicator for tertiary-track entry (based on administrative entry-channel codes), (ii) an indicator for completed tertiary education at labor-market entry, and (iii) an occupation-based proxy for academic qualification. I estimate linear probability models with county and cohort fixed effects, controlling for gender, month of birth, and available family-background proxies.

The results indicate that pollution exposure during the school years reduced early tertiary-related outcomes. Exposed Abitur cohorts are about 2.6 percentage points less likely to enter the labor market via a tertiary track and about 2.7 percentage points less likely to be observed entering with completed tertiary education. They are also about 1 percentage point less likely to enter occupations associated with academic qualifications. These effects remain visible under stricter cohort restrictions designed to mitigate right-censoring (for example, by focusing on earlier cohorts more likely to have completed tertiary education by 1989), suggesting that the findings are not solely an artifact of delayed graduation.

Taken together, the grade and labor-market evidence is consistent with a human-capital channel: the pollution shock worsened school performance during a critical educational phase and reduced subsequent progression into tertiary and academic pathways. The estimates for labor-market outcomes should be interpreted as early-career effects in the pre-reunification observation window, but they already indicate meaningful shifts in human-capital accumulation and occupational sorting.

Contribution and broader significance

This paper contributes to three strands of literature. First, it adds to research on the causal effects of air pollution by studying a sharp and sustained industrial pollution shock in a setting with unusually limited scope for avoidance and sorting. Second, it contributes to the literature on pollution and education by focusing on late adolescence and upper-secondary performance, a stage that remains underexplored relative to early childhood or same-day exam effects. Third, it speaks to the literature on long-run human-capital formation by showing how environmental shocks can shape educational and early occupational trajectories at a critical juncture of the life cycle.

The GDR setting is especially informative because it reveals the potential magnitude of pollution harms when households cannot easily respond. In market settings, measured effects may understate the full welfare cost of pollution if families relocate, change behavior, or invest in mitigation. In contrast, the institutional rigidity of the GDR allows the analysis to capture a less attenuated effect of exposure on students' realized schooling environments and outcomes. More broadly, the findings underline that the costs of air pollution extend beyond health and contemporaneous productivity. Environmental shocks can alter educational performance, tertiary progression, and occupational sorting, thereby affecting human-capital formation and economic opportunity. These effects are likely to be particularly consequential when pollution exposure occurs during periods of high-stakes educational selection. In that sense, the paper highlights an important but often overlooked dimension of environmental policy: clean air is not only a health policy, but also an education and equality-of-opportunity policy.