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Indoor air quality and academic performance

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ABSTRACT

I examine the effect of school indoor air quality (IAQ) on academic outcomes. I utilize a quasi-natural experiment, in which IAQ-renovations were completed at virtually every school in a single Texas school district at different points in time, combined with a panel of student-level data to control for many confounding factors and thereby uncover the causal effect of IAQ-renovations on academic outcomes. Results indicate that performance on standardized tests significantly improves while attendance is unresponsive to improvements in IAQ. Rough calculations suggest that IAQ-renovations may be a more cost-effective way to improve standardized test scores than class size reductions.

Introduction

Given the substantial time that children spend in schools over their lifetime and given the purpose of this activity, the school environment is an important environment to better understand. To this end, this paper evaluates the effect of indoor air quality (IAQ) in school buildings on students' standardized test scores and school attendance rates. These relationships have significant implications for both human capital accumulation and children's health and development, yet they have received no attention in the economics literature and have been analyzed elsewhere only with limited success. Combining detailed information on IAQ-related renovation projects with student-level administrative data, I find that mold remediation, ventilation improvements, and, to a lesser degree, roof repairs significantly improve test scores, but that attendance rates are generally unresponsive to renovations.

The importance of human capital accumulation to individual earnings, productivity, and economic growth is well established.[1] Furthermore, it is not just the quantity of schooling that is important for these outcomes, but also the quality of schooling.[2] Because school quality cannot be directly controlled, government policy has sought to indirectly improve quality by devoting more and more resources to a variety of school inputs. As a result, since the 1960s, real expenditures per student have more than tripled.[3] Given the importance of school quality and the sizable expenditures on school inputs, there has been significant growth in research investigating the extent to which school inputs do, in fact, affect school quality. While these studies consider a variety of inputs, including class size, teacher characteristics, family characteristics, and peer effects,

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[1] See, for example, Pierce and Welch (1996).

[2] See, for example, O'Neill (1990), Bishop (1991), Grogger and Eide (1995), Neal and Johnson (1996), and Hanushek and Kimko (2000).

[3] For example, teacher–student ratios have fallen by almost 40%, teachers with at least a master's degree have more than doubled, and the median years of teacher experience has almost doubled (Hanushek, 2003).

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there is an overwhelming lack of research concerning the physical school environment.[4] This paper suggests that the indoor environment, and in particular indoor air quality, may be an important school input to consider.

There are many reasons why indoor air pollution is an important issue in general and why improving air quality in schools might lead to improved student health and academic performance. First, according to the American Lung Association, the average American spends approximately 90% of their time indoors. Second, due to changes in building materials and household products, the U.S. Environmental Protection Agency (EPA) estimates that concentrations of some pollutants, such as volatile organic compounds (VOCs), are often 2–5 times greater indoors than outdoors and may be as much as 100 times greater. Third, since the energy crisis in the 1970s, building ventilation rates have decreased in order to conserve energy, which has tended to increase the residence time for indoor pollutants and decrease oxygen levels. This increase in exposure over time has lead the EPA to consistently rank indoor air pollution among the top five environmental health risks.[5]

While indoor air pollution poses a risk to all, the risk is greater for children since their bodies are still developing and they breathe a higher volume of air relative to their body size. After the home, the school environment is where children spend the majority of their time, suggesting that this is an environment in which exposure to harmful pollutants should be minimized. Despite this, many public schools are in disrepair. In 1995, the U.S. General Accounting Office (GAO, 1995) published a report on the condition of U.S. schools projecting that $112 billion in repairs and upgrades was needed to improve school facilities to good overall condition. These repairs and upgrades included renovations to ventilation systems and improvements to indoor air quality. More specifically, 27% of U.S. schools, with almost twelve million attending students, reported having unsatisfactory or very unsatisfactory ventilation and 19% of U.S. schools, with more than eight million attending students, reported having unsatisfactory or very unsatisfactory indoor air quality. Since many harmful indoor pollutants are not easily detectable by occupants, the number of schools with poor IAQ is likely to be much greater.

Unfortunately, studying the effects of school indoor air quality is a difficult task in practice. First, unobservable student and school characteristics that, in part, determine academic outcomes are likely correlated with school indoor air quality. For example, school districts that lack the resources to achieve good IAQ may also lack the resources to attract good students, hire good teachers, or obtain good instructional support. Without controlling for these other factors, one cannot identify a causal relationship between IAQ and academic performance. Indeed, this is a problem suffered by the vast majority of studies in this area.[6] A second and larger obstacle is that a measure of school indoor air quality is needed and such a measure is generally not well known or maintained by school districts. Furthermore, identification requires that measured IAQ vary over time *and* space if we are to control for unobserved time- and student- or school-effects.

To overcome these obstacles, I utilize a unique quasi-natural experiment. Renovation projects designed *specifically* to improve school IAQ were completed at virtually every elementary school within a single Texas school district at different points in time throughout a five-year period, providing plausibly exogenous cross-sectional and time-series variation in school indoor air quality. Coupling detailed information on these projects with a panel of student-level administrative data for the same time period, I am able to control for many of the confounding variables that may also affect academic outcomes and thereby identify the causal effect of indoor air quality-related renovation projects on academic outcomes. While these data are not without drawbacks, I argue in section "Indoor air pollution" that these are the best currently available for this purpose and that they substantially improve upon previous studies.

I find that performance on standardized tests significantly improves while attendance rates are unresponsive to indoor air quality-related renovations. Specifically, the average mold remediation project ($\$500,000$) improved math scores by 0.15 standard deviations (sds), improved reading scores by 0.14 sds, and increased the probability of passing these tests by 3–4%. The average ventilation improvement project ($\$300,000$) improved math and reading scores by 0.07 sds and 0.11 sds, respectively, and increased the probability of passing these tests by 2–3%. Larger budget mold and ventilation projects had even larger and more significant effects on test scores. The largest of the roof projects ($\$100,000+$) also marginally improved test scores and pass rates. Given the costs of renovations and the size of the effects, these results suggest that indoor air quality-related renovations are a cost-effective way to improve standardized test scores.

Air pollution, health, and academic performance

Ambient air pollution

Detrimental effects of exposure to *ambient* air pollution on infant mortality and children's health, school attendance, and test performance have been documented.[7] While this research provides evidence of a link between exposure to air pollution

[4] Jones and Zimmer (2001) and Cellini et al. (2010) examine school facilities.

[5] While indoor air pollution is a concern in developed countries, it is a much larger issue in developing countries where more than three billion people continue to use high-polluting fuels for cooking and heating. In fact, the World Health Organization estimates that indoor air pollution is responsible for 2.7% of the global burden of disease. Duflo et al. (2008) survey the current literature on indoor air pollution in developing countries. The general conclusion is that much more work needs to be done in order to understand the potentially important relationships between indoor air pollution and health, school attendance, and productivity.

[6] These studies are discussed in section "Indoor air pollution".

[7] Chay and Greenstone (2003) and Currie and Neidell (2005) study infant mortality; Neidell (2004), Beatty and Shimshack (2014), and Beatty and Shimshack (2011) examine children's respiratory health; Currie et al. (2009) focus on school attendance; and Sanders (2012) and Lavy et al. (2012) study high school test performance.