RESEARCH SUMMARY

The Impact of Sustained Exposure to Particulate Matter on Life Expectancy: New Evidence from China's Huai River Policy

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KEY TAKEAWAYS

1. This study uses a novel analysis to determine the impact of air pollution on life expectancy in Northern China. The researchers conduct a quasi-experiment building on China's Huai River policy, which provided free coal for heating in Northern China and restricted coal in the south. The analysis compares locations just to the north and south of the Huai River.

2. The analysis was conducted with the most comprehensive data set ever compiled on health and pollution in a developing country. These conditions and data provided the researchers with the ability to measure the impact of high levels of particulate pollution over a long period of time, and isolate that impact from other factors that could affect health.

3. The researchers found that particulate pollution was 46 percent higher north of the Huai River due to the winter heating policy and resulting coal combustion. The elevated levels of air pollution reduced average lifespans by 3.1 years. The researchers discovered that this was due to increased incidences of cardiorespiratory deaths among all age groups. There was no evidence of an increase in mortality rates due to non-cardiorespiratory causes of death.

4. From the data in China, the researchers formed an important generalized metric that can apply to any country's environment: Every additional 10 micrograms per cubic meter of sustained exposure to airborne particulate matter reduces life expectancy by 0.6 years.

5. Using the metric, the researchers found that 3.7 billion life years would be saved if China met its own pollution standard (Class 1 PM10). The metric can be similarly used to discover life years saved if other countries met their own standards.

6. This metric can be used to develop estimates of the benefits of clean air regulations that can be compared with their costs.

Introduction

Air pollution is a major environmental health problem with some estimates suggesting that it is responsible for one out of every nine deaths. Indeed, an estimated 4.5 billion people are currently exposed to particulate pollution levels that are at least twice what the World Health Organization (WHO) considers safe. The air pollution challenge is especially acute in developing countries such as India and China, where particulate pollution is five to ten times higher.

While scores of studies have demonstrated that air pollution negatively impacts our health, the body of evidence has largely been unable to determine the effect of sustained exposure to pollution on a person's life expectancy, particularly at the pollution levels that currently prevail in China, India, and other parts of the world. Past studies were unable to produce this important measurement because of at least one of the following shortcomings: relied on research designs that may be unlikely to isolate the causal effects of air pollution; measured the effect of pollution exposure for a relatively short period of time (e.g., weekly or annually), failing to shed light on the effect of sustained exposure; examined settings with much lower pollution concentrations than those currently faced by billions of people in countries, including China and India, leaving questions about their applicability unanswered; and/or measured effects on mortality rates but left the full loss of life expectancy unanswered.

This study confronts these key challenges thanks to a unique social setting. In China, citizens in the north experience higher levels of pollution in part because of a government policy initiated during the planning period (i.e., 1950 to 1980) that gave those living north of the Huai River, where it is colder, free coal to power boilers for heating. While the policy's purpose was to provide warmth in the winter to those who needed it the most, it resulted in a high reliance on coal. The legacy of that policy is evident even today with very different rates of indoor heating north and south of the Huai River as the north continues to rely on the coal heating systems.

Further, a household registration system restricted mobility. Therefore, most did not leave the polluted areas for the less polluted ones. During the period of time studied, that policy had loosened. However, the researchers assessed migration patterns and discovered that migration did not appreciably alter people's lifetime exposure to air pollution. Therefore, this study can shed light on the effects of particulate pollution at a person's birthplace on their life expectancy.

The Huai River policy and household registration system have thus created a unique demarcation line where the researchers were able to study the impact of high levels of pollution over a long period of time and isolate that impact from other factors that could affect a person's health. By exploiting this setting, the researchers are able to use China as a test bed to answer:

What impacts does the continued burning of coal have on lifespans, not just in China, but in regions throughout the world? And, if countries met their own pollution standards, and those of the WHO, how many years could be saved?

Research Design

Using the unique social landscape carved out by the Huai River home heating policy and household registration system, the researchers implemented a quasi-experimental regression discontinuity design that allowed them to compare those living just to the north of the river to those living just to the south. The research design's key assumption is that while there are differences between north and south China there are not any factors affecting health that change discretely at the river, besides the policy. Importantly, the Huai River is not an administrative boundary nor is it used for determining any other policies.

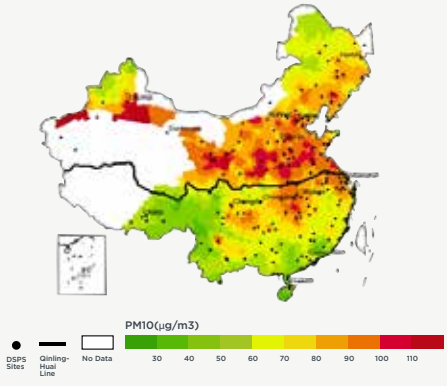
To perform the study, the researchers used the most comprehensive data set ever compiled on health and pollution in a developing country. They first collected air pollution data for six main pollutants in 154 cities in the north and south from 1981 to 2012, with the main subject being particulate matter pollution smaller than 10 microns (PM10)—widely believed to be the deadliest and most prevalent form of air pollution.

The researchers then linked the particulate pollution data to mortality data from 2004 to 2012. For this, they used the Chinese Center for Disease Control and Prevention's (CDC) Disease Surveillance Points (DSP) survey, a remarkably high-quality nationally representative survey that captures the variation in wealth, urbanism and geographic distribution through a coverage population of more than 73 million people at 161 locations. All fatalities were assigned a cause of death based on an autopsy; the researchers grouped the reported causes into cardiorespiratory deaths (i.e., heart, stroke, lung cancers, and respiratory illnesses) that are plausibly related to air pollution exposure and non-cardiorespiratory deaths (i.e., cancers other than lung and all other causes). They also analyzed a wide range of other factors—including smoking prevalence, dietary patterns, surface water pollution, and education level—to isolate the effect of pollution from other reasons that could affect mortality.

Findings

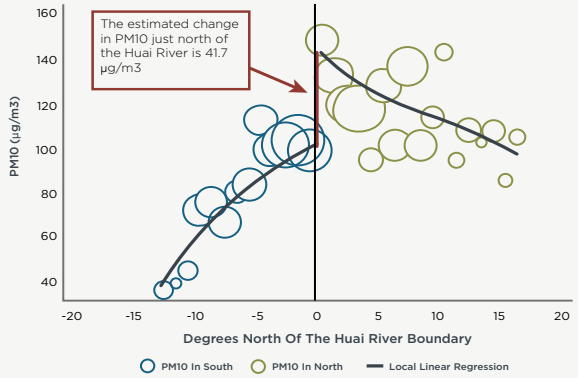
1. Particulate air pollution was 46 percent higher north of the Huai River due to the winter heating policy that led to heavy burning of coal. While the researchers observed a stark difference in PM10 levels just to the north of the river, they did not see similar differences in nitrogen dioxide and sulfur dioxide pollution. A potential explanation is that both sulfur dioxide and nitrogen dioxide are gaseous air pollutants that are lighter and travel further

Figure 1 ·
Pollution In China And The Huai River/Qinling Mountain Range



Note: The cities shown are the locations of the Disease Surveillance Points (DSP). The figure coloring shows a high resolution grid of pollution throughout China. Areas left in white are not within an acceptable range of any pollution monitoring station, and so contain no pollution data.

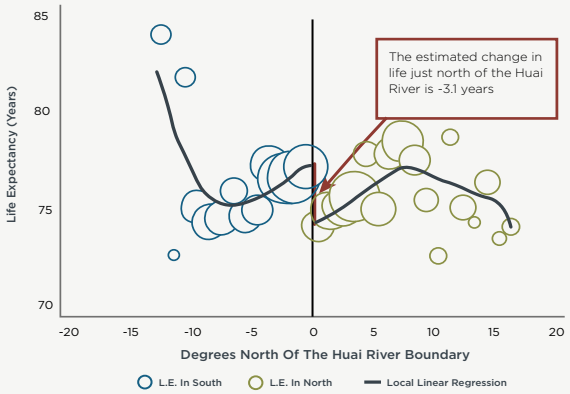
Particulate Matter Levels (PM10) South And North Of The Huai River Boundary



Note: Circles represent the average PM10 concentration across locations within 1-latitude distance from the Huai River, with the size of the circle proportional to the population at the DSP locations within the relevant bin. The vertical line represents the Huai River.

than PM10, so even though emissions are likely higher in the north there isn't a discrete difference in ambient concentrations. Therefore, PM10 exposure can be isolated from other air pollutants as a potential health risk due to living north of the Huai River.

Figure 2 · Life Expectancy South And North Of The Huai River Boundary



Note: Circles represent the average life expectancy across locations within 1-latitude distance from the Huai River, with the size of the circle proportional to the population at the DSP locations within the relevant bin. The vertical line represents the Huai River.

2. Heavy particulate air pollution cuts lifespans north of the Huai River short by 3.1 years. After linking the pollution data to the mortality data, the researchers found those residing just to the north of the river lived 3.1 fewer years than those just to the south. The shorter lifespans were almost entirely due to an increase in cardiorespiratory deaths linked to poor air quality. Elevated mortality was evident throughout the entire life cycle. The researchers did not see a higher mortality rate caused by other illnesses. They also saw no differences in health behaviors such as smoking regularly, drinking heavily, and not exercising enough—all factors that can spur cardiorespiratory illnesses.

3. Every 10 micrograms per cubic meter of air pollution released into the atmosphere cuts life expectancy by 0.6 years. From the data in China, the researchers were able to form an important generalized metric that can be applied to any country's environment: Every additional 10 micrograms per cubic meter of sustained exposure to PM10 reduces life expectancy by 0.6 years.

> "The results greatly strengthen the case that long-term exposure to particulates air pollution causes substantial reductions in life expectancy. They indicate that particulates are the greatest current environmental risk to human health, with the impact on life expectancy in many parts of the world similar to the effects of every man, woman and child smoking cigarettes for several decades. The histories of the United States, parts of Europe, Japan and a handful of other countries teach us that air pollution can be reduced, but it requires robust policy and enforcement."
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> **MICHAEL GREENSTONE**
> **DIRECTOR, ENERGY POLICY INSTITUTE AT THE UNIVERSITY OF CHICAGO**

4. An accumulated 3.7 billion life years could be saved if China met its own pollution standards. Using the metric, the researchers are able to calculate life years saved if the country met its own pollution standard. They find that an accumulated 3.7 billion life years would be saved if China met its own standard.

Policy Implications

Using the Results to Develop a New Air Quality Index

A significant take-away from this study is the production of a metric from which the impact of pollution on lifespans can be assessed at a country and even county level. This metric allows for the calculation of life years lost that could be gained from policies that cause a country to meet its own air pollution standards or any other standard, including the WHO's standard.

To make this information accessible, the Energy Policy Institute at the University of Chicago has developed the Air Quality-Life Index (AQLI), which translates particulate pollution concentrations into their impact on lifespans using the metric produced from this study. As such, the AQLI provides a reliable measure of the potential gain in life expectancy communities could experience from policies that reduce air pollution. The AQLI serves as an important complement to the frequently used Air Quality Index (AQI) that is a complicated function of air pollution concentrations and does not map directly to health.

Mounting Evidence

This study follows on a 2013 PNAS study, "Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy," conducted by some of the same researchers and employing a similar research design. Both studies discover remarkably similar results, reinforcing the accuracy of the findings.

In the months following its 2013 release, China widened its air-quality monitoring rules and created an air quality action plan that set specific pollution reduction targets. The government pledged in August 2017 to cut northern air pollution by 15 percent year-on-year in the winter months in order to meet key targets laid out in the action plan. As part of its efforts, China is switching its primary source of heating from coal-fired boilers to gas-fired or electric units, and has shut down many polluting plants. The consequence is that, particulate air pollution in some of China's most polluted cities, including Beijing, has improved significantly.

Building off the earlier study, this new study is able to provide direct evidence on the smaller pollution particles that are more often the subject of environmental regulations (PM10), thanks to the availability of new data sources. The researchers also use data from a more recent time period (i.e., 2004-2012, instead of the 1990s), which covers a population eight times larger than analyzed in their previous study. Further, due to the dramatic implications for human health, the new study provides an important opportunity to validate the earlier study's findings.

Strikingly, the two studies find the same basic relationship between pollution and life expectancy—a relationship now observed over two different time periods. The two studies also produced a metric that can be used to determine the impact of pollution on life expectancy in any region. When the earlier metric—which relied on the broader pollution measure of total suspended particulates (because PM10 data was unavailable in this period)—is converted to PM10, it indicates that a reduction of 10 micrograms per cubic meter of PM10 increases life expectancy by 0.66 years. That is well within the margin of error of the 0.64 years this paper discovered.

Finally, the earlier study found that those in the north lived 5.5 fewer years than those in the south, versus the 3.1 years discovered in this study. The smaller difference in life expectancy on different sides of the river reflects a greater decline in air pollution just north of the Huai River compared to just south of the river since the 1990s.

The Energy Policy Institute at the University of Chicago (EPIC) is confronting the global energy challenge by working to ensure that energy markets provide access to reliable, affordable energy, while limiting environmental and social damages. We do this using a unique interdisciplinary approach that translates robust, data-driven research into real-world impacts through strategic outreach and training for the next generation of global energy leaders.

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