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The effect of air pollution on mortality in China: Evidence from the 2008 Beijing Olympic Games ☆

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ABSTRACT

By exploiting exogenous variations in air quality during the 2008 Beijing Olympic Games, we estimate the effect of air pollution on mortality in China. We find that a 10 percent decrease in PM_{10} concentrations reduces the monthly standardized all-cause mortality rate by 8 percent. Men and women are equally susceptible to air pollution risks. The age groups for which the air pollution effects are greatest are children under 10 years old and the elderly.

Introduction

Air pollution imposes significant health risks on humans in developing countries where the levels of pollution are often several orders of magnitude higher than those in developed countries (Chen et al., 2013a; Ebenstein et al., 2015; Greenstone and Hanna, 2014). Accurately estimating the health effects of air pollution is critical for the environmental regulation debate and optimal environmental policy design. Overstating the effects will lead to over-regulation and hinder economic growth, while underestimating the effects will leave a large number of people unprotected and create significant and unnecessary welfare losses.

This study uses a natural experiment to estimate the causal effects of air pollution on mortality in China. To ensure that the air for the 2008 Beijing Olympic Games (BOG08) was relatively clean, the Chinese government enforced a series of stringent air pollution regulations in Beijing and its neighboring cities from late-2007 through late-2008. These regulations resulted in a sudden and significant improvement in air quality in the regulated cities. By comparing the mortality rates in

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the regulated cities with those in the unregulated cities before, during, and after the regulation period, we find that improved air quality during the regulation period significantly reduced the mortality rates in the regulated cities.

We make three primary contributions to the existing literature. First, while many previous natural experimental designs investigate the effects of permanent policy changes on air pollution (Chay et al., 2003; Chay and Greenstone, 2003b), our study explores the air quality variations triggered by temporary and strictly-enforced regulations. The enforcement of permanent air pollution regulations, such as the Clean Air Act in the United States, might be endogenous because, as citizens become aware of the potential health consequences of air pollution, they put political pressure on government to create specific policy instruments to respond to their concerns. In cities where people are more health conscious, the enforcement of air quality regulations might be stricter and the subsequent health improvements might be larger. In contrast, the strong pressure to improve air quality during the BOG08 came from the international community rather than within China. The level of air pollution in Beijing was the biggest concern of the International Olympic Committee in the bidding process for the 2008 Summer Olympic Games. The commitment to ensure good air quality in the Beijing metropolitan area and co-hosting cities during the BOG08 was key to winning the bid; and it became an important political task for the Chinese government. Starting in late 2007, the Chinese government implemented a series of stringent policies to reduce local and regional emissions in the greater Beijing metropolitan area to ensure good air quality during the BOG08. Among the aggressive regulations were setting higher emission standards, reducing traffic, halting large-scale construction projects, and shutting down polluting factories. The enforcement of the BOG08 regulations was strict and likely to be exogenous. The combination of these radical regulations led to a dramatic improvement in air quality in Beijing, its neighboring cities, and the co-host cities. For example, our results show that, during the BOG08 period, monthly PM_{10} concentrations in Beijing were reduced by approximately 30 percent in Beijing.

Second, to our knowledge, this study is the first to estimate the sub-chronic health effects of PM_{10} pollution on a national scale in China. Previously, a large number of epidemiological studies have examined the short-term associations between air pollution and mortality using daily data (see Aunan and Pan, 2004; Lai et al., 2013; Lu et al., 2015; Shang et al., 2013 for literature review). The estimates from these high-frequency time-series data offer insights on the acute effects of air pollution. For the long-run effect, Chen et al. (2013a) estimated the impact of air pollution on life expectancy using China's winter heating policy as a natural experiment. This study complements both lines of research by providing insights on how monthly variations in air pollution affect mortality. We find that air pollution has a significant impact on monthly mortality rate, with a 10 percent reduction in PM_{10} concentrations resulting in an 8 percent decrease in all-cause mortality rate. A back-of-envelope calculation shows that more than 285,000 premature deaths in urban China could be averted annually if PM_{10} concentrations were to decrease by 10 percent.

Third, by analyzing the most comprehensive monthly air pollution and mortality data ever assembled in China, we are able to estimate the heterogeneous effects of PM_{10} pollution by the cause of death, gender, and age groups. Our analysis shows that men and women are equally susceptible to air pollution risks. Air pollution has a larger impact on the most vulnerable groups: children under 10 years old and the elderly (ages 75 years and over). We also find that increased air pollution causes more old people to die from cardio-cerebrovascular and respiratory (CVR) diseases but not from non-CVR diseases. For infants and young children, we find the opposite: deaths from non-CVR diseases drive the main results.

We conduct a variety of robustness checks and find that they do not alter our conclusions. Weather conditions (temperature and precipitation) and socio-economic characteristics, which are typically confounding factors in associational studies, have little effects on our estimates. We conduct falsification tests using air-pollution-irrelevant (such as cancer and injury) mortality and show that the main findings are not due to our model choice or the underlying overall death patterns. The evidence suggests that our research design provides a credible basis for evaluating the air pollution effect.

The remainder of this paper is structured as follows. Section "Health effects of air pollution" reviews the literature on estimating the health effects of air pollution. Section "Air pollution regulations during the BOG08" discusses the air pollution regulations during the BOG08. Section "Data" describes the air quality data, mortality data and meteorological data. Section "Research Design and Model" addresses our research design and model. Section "Results" summarizes the main results, and Section "Robustness checks" checks their robustness. Section "Comparison with estimates from associational models" compares our results with those of traditional models and previous studies, and Section "Health benefits of air pollution reduction" provides a range of estimates on the monetary value of the averted deaths. Section "Conclusions" concludes.

Health effects of air pollution

The association between air pollution and human health has been recognized for more than half a century.[1] The majority of previous studies fall into the following categories: (1) time-series studies; (2) cross-sectional and cohort-based studies; (3) panel (fixed-effects) studies; and (4) natural experimental studies.

Time-series studies investigate whether daily or weekly fluctuations in air pollution are associated with changes in health outcomes (such as hospital admissions or deaths). Time series models are widely used in epidemiological studies.

[1] For example, during the London fog incident of 1952, extreme elevations of air pollution were found to be associated with markedly increased mortality rates (Logan, 1953).