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Air pollution and infant mortality: A natural experiment from power plant desulfurization☆

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ABSTRACT

The paper estimates the effect of SO_2 pollution on infant mortality in Germany, 1985–2003. To avoid endogeneity problems, I exploit the natural experiment created by the mandated desulfurization at power plants and power plants' location and prevailing wind directions, which together determine treatment intensity for counties. Estimates translate into an elasticity of 0.07–0.13 and the observed reduction in pollution implies an annual gain of 826–1460 infant lives. There is no evidence for disproportionate effects on neonatal mortality, but for an increase in the number of infants with comparatively low birth weight and length.

1. Introduction

Health concerns are a primary rationale for air quality regulations such as the U.S. Clean Air Act and the German Federal Immission Control Act. These regulations considerably improved air quality. For example, Fig. 1 depicts the sulfur dioxide (SO_2) concentration in Germany in 1985–2003. Other developed countries experienced similar declines in SO_2 concentrations. But this general trend masks considerable heterogeneity. Many people are still exposed to high pollution levels and in developing countries air pollution is often getting worse. Even in Europe, SO_2 pollution is bound to rise as coal-based power generation experiences a revival. Therefore, knowledge of the health effects of previous air quality regulations and corresponding improvements in air pollution is of considerable interest.

Many studies investigate the effect of air pollution on *adult* mortality. Epidemiologists typically assess acute effects with time-series analyses and chronic effects of long-term exposure with cross-section and cohort studies. For example, SO_2 was significantly associated with mortality in a time-series analysis for London in 1958–1972 (Schwartz and Marcus, 1990), in a cross-section of groups of U.S. counties in 1970 (Mendelsohn and Orcutt, 1979), or in a large group of adult Americans followed over the period 1982–1998 (Pope et al., 2002). However, studies on *infant* mortality have clearer implications regarding the number of life-years lost and suffer less from uncertainty regarding life-time exposure (Chay and Greenstone, 2003b).

Omitted variables are an important concern in all these studies since air pollution depends on economic activity and other unobserved factors with independent effects on mortality. The concern

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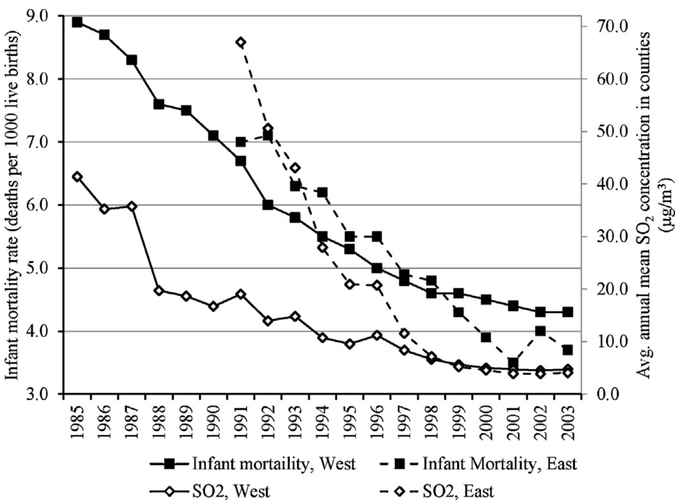

Fig. 1. SO_2 concentration and infant mortality in East and West Germany, 1985–2003.
Sources: Federal Statistical Office and Federal Environmental Agency.

is partially addressed in intervention analyses. Evidence of reduced SO_2 pollution and mortality following a ban on high sulfur fuel in Hong Kong in 1990 is certainly more convincing than evidence from other time-series analyses, but influences from other concurrent shocks cannot be ruled out without an adequate control group (Hedley et al., 2002). Such concerns sparked a recent interest among economists in natural experiments that allow researchers to identify the effects of air pollution on infant mortality (see Section 2 for a review).

This paper estimates the health benefits of an air quality regulation and uses regulation-induced changes in air pollution to identify chronic effects on infant mortality (similar to Chay and Greenstone, 2003a). Specifically, it estimates the effect of the mandated installations of scrubbers at power plants and the resulting reduction in SO_2 pollution on infant health with data from Germany in 1985–2003. Thereby, it contributes to the existing literature in two respects.

First, the paper provides evidence on infant health effects of air pollution and air quality regulations for another highly developed country than the U.S. Thus, the results help us to understand if and to what extent pollution-mortality relationships found in one context can the transferred to different contexts. While there are no reasons to expect differences in biological dose-response relationships, effects of ambient air pollution also depend on medical care consumption and avoidance behavior, which affects the relationship between ambient air pollution and individual exposure (Graff Zivin and Neidell, 2013). In this regard, Germany and the U.S. may differ along several relevant dimensions. For example, there may be differences in medical care utilization. Pre-natal care can improve infant health and thereby reduce susceptibility to air pollution, good access to medical care after birth allows for timely measures against health problems. Despite a huge increase in Medicaid eligibility of pregnant women in the U.S. in the 1980s, a large share of the population is still uninsured and many eligible women enroll late in their pregnancies (Currie and Gruber, 1996; Gruber, 1997). In contrast, health insurance coverage in Germany is near universal and frequent screenings of infants are statutorily regulated. Similarly, the extent to which individuals can avoid exposure to pollutants may also differ across countries and will depend on such diverse factors as building design with large regional differences in airtightness of houses or typical activity patterns of pregnant women and parents (Ashmore and Dimitroulopoulou, 2009).

Second, the paper analyzes the effect of SO_2 pollution. Of course, different pollutants may be correlated (Lleras-Muney, 2010) and the regulation may have affected several pollutants. However, as I explain in more detail in Section 3, the German situation analyzed in this paper is particularly well-suited to specifically isolate exogenous variation in SO_2 pollution. A federal regulation mandated the installation of scrubbers at power plants and left local authorities or operating companies little room for discretion. Power plants are the main source of SO_2 and the predominant scrubbing technology removes SO_2 but not other pollutants. Regulation of TSP was already in place and new regulation of nitrogen oxides (NO_x) was generally not binding, affected different sources, and required different compliance measures. Further, I find that the estimated effect of desulfurization at power plants affected SO_2 concentration but not NO_x concentration. Therefore, I present not only reduced form effects of the policy but also use it to instrument SO_2 pollution.

Looking at SO_2 is interesting for several reasons. First, toxicity differs across pollutants. Second, pollutants differ in the extent to which ambient air pollution translates into individual exposure. For example, the correlation between outdoor and indoor air pollution is lower for SO_2 than for other pollutants (Ashmore and Dimitroulopoulou, 2009). Third, the existing evidence on the effects of SO_2 on infant mortality is inconclusive and suffers from omitted variables (see Section 2 for a review). Given that SO_2 pollution is the focus of many air quality regulations and that there is considerable evidence for effects of SO_2 on adult mortality and on adverse pregnancy outcomes (for a review, see Šram et al., 2005), the lack of convincing evidence on the effects of SO_2 pollution on infant mortality is regrettable and this paper aims to fill this void.

The most important finding is that the air quality regulation had beneficial effects on infant health: Infant mortality decreases with predicted reductions in SO_2 concentration due to desulfurization at power plants. The sharp and simultaneous drops in SO_2 pollution and in infant mortality between 1987 and 1988 in Fig. 1 anticipates this result. Assuming that the air quality regulation only affected infant mortality through its effect on actual SO_2 concentrations, I use the regulation-induced changes in SO_2 concentration to estimate the effect of SO_2 pollution on infant mortality. According to fixed-effects regressions of infant mortality rates on SO_2 concentration, 0.026 infant lives (per 1000 live births) are saved for every 1 $\mu g/m^3$ reduction in SO_2 concentration. In instrumental variable regressions with the predicted regulation-induced reductions in SO_2 concentrations as an instrument, the effect amounts to 0.045 infant lives. Since most of the variation in SO_2 concentration is the result of the air quality regulation, the fixed-effects and instrumental variable estimates are similar and both estimates are informative about the health effects of the regulation.

The point estimates translate into an elasticity of 0.07–0.13. The results are similar in subperiods and the West German subsample but not the East German subsample. The estimates are robust to controls for local economic and demographic development, weather, TSP pollution, reunification effects, and rural/urban trends. The instrumental variable estimates are also robust to the inclusion of county-specific time trends, the fixed-effects estimates less so. There is no evidence for strongly disproportionate effects of SO_2 on neonatal mortality, but evidence for effects on the number of infants with comparatively low birth weight and, in particular, length. Thus, although poor fetal development due to exposure during gestation seems to affect infant health, it is unlikely to be the main biological mechanisms through which SO_2 affects infant mortality.

The remainder of the paper is organized as follows. Section 2 briefly reviews the related literature. Section 3 introduces the pollution data and the strategy to instrument SO_2 concentrations.