The Morbidity Cost of Air Pollution: Evidence from Consumer Spending in China

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3-sentence summary: A study shows that reducing air pollution in China can lead to significant health benefits. A reduction of fine particulate matter, $PM_{2.5}$ by 10 μg/m^3 (about 20% from the current level) could result in an annual saving of 60 billion Yuan (or around 1.5%) in healthcare expenditure. The health benefit from improved air quality proposed by recent national policies in China could justify large investments in cleanup activities.

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Due to increased pressure from economic development and lax environmental regulations, developing countries and especially emerging economies such as China and India are experiencing the worst air pollution in history. According to the global urban ambient air pollution database compiled by the World Health Organization (hereafter WHO) in 2016, the top twenty most polluted cities in terms of $PM_{2.5}$ are all from developing countries, including China, India, Iran, Pakistan, and the Philippines. An alarming 98% of cities in low- and middle-income countries with more than 100,000 residents fall short of meeting WHO's air quality guidelines. As urbanization continues and development pressure increases, air pollution could further deteriorate. This is especially concerning given the size of the population and the lack of access to adequate health care in these countries.

Figure 1: Average $PM_{2.5}$ Concentration for Major Chinese Cities, 2013-2015, μg/m^3

Notes: The WHO guideline for annual PM2.5 level is 10 μg/m3; U.S. EPA annual standard is 12.

Figure 1 maps the three-year average level of $PM_{2.5}$ for major Chinese cities from 2013 to 2015. The nationwide average is around 56 μg/m^3, and the air pollution for most cities is substantially worse than the annual standard of 12 μg/m^3 set by the U.S. Environmental Protection Agency (henceforth EPA), or the standard of 35 μg/m^3 set by the Chinese Ministry of Environmental Protection. Among the thirteen largest cities with a population greater than 10 million, the average PM2.5 concentration is 73 μg/m^3, 30% higher than the national average.

A rich literature from epidemiology, and more recently economics, has consistently shown a positive correlation between exposure to air pollution and an increase in mortality and morbidity risks in developed countries (Brunekreef and Holgate, 2002; Pope and Dockery, 2012). These findings have provided guidance on air quality regulations such as setting or tightening ambient air quality standards. Studies on the health impacts of particulate matters, for example, have led the U.S. EPA to establish standards for PM_{10} in 1987 and for $PM_{2.5}$ in 1997 (Dockery, 2009).

While policy makers in developing countries are increasingly aware of the negative impacts of air pollution on human health and the quality of life, and they have been adopting various environmental regulations, few such policies are based on rigorous empirical analysis using data from these developing countries. Instead, estimates of the dose-response relationships between pollution exposure and health outcomes using data from developed countries are often used as inputs for evaluating environmental regulations in developing countries. This is problematic given that the air pollution level in urban centers in developing countries is often an order of magnitude higher than that observed in developed countries.

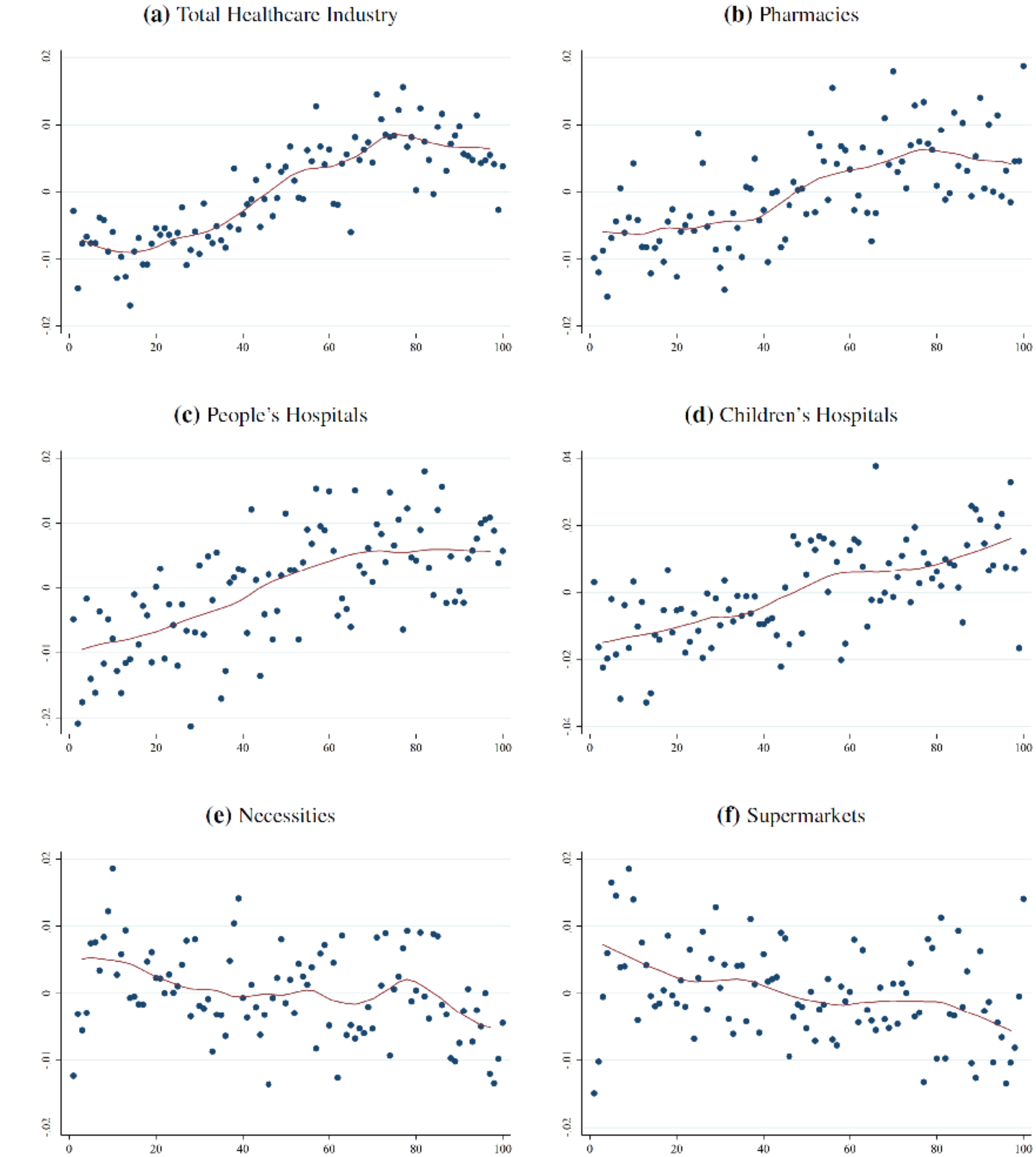
In a recent study by Barwick et al. (2018), we conduct one of the first national-level analyses of the impact of air pollution on health spending in a developing country context. The study provides a lower bound estimate of Chinese consumers' willingness-to-pay for improved air quality that can be used as an input for the cost-benefit analysis of environmental regulations. This study combines comprehensive hourly air pollution readings from all monitoring stations in

China from 2013 to 2015 with health and non-health expenditure data from the universe of credit card and debit card transactions from 2.7 billion cards in China during the same period. Credit and debit cards accounted for fifty percent of private health expenditures in 2015.

Figure 2 illustrates that there is a positive correlation between spending in healthcare categories and air pollution within the same day, after removing baseline differences in both spending and air pollution across cities. By contrast, there is a negative correlation between air pollution and spending on necessities and at supermarkets, suggesting that consumers stay indoors during polluted days.

To establish whether there is a causal relationship between air pollution and spending, we make use of the fact that a large share of $PM_{2.5}$ in any given city comes from non-local sources due to its long-range transport property. Exploiting weather data on wind speed and direction in other areas, we construct for each city the amount of pollution that is imported from other areas (wind direction and speed illustrated in Figure 3). The weather conditions *elsewhere* serves as an exogenous shock to *local* pollution in our quasi-experimental research design. In Beijing, for example, about half of $PM_{2.5}$ during non-heating seasons originates from surrounding industrial cities on average and the share varies depending on the weather conditions such as wind direction and speed.

Figure 2: Short-term Relationship Between Air Pollution and Spending



Notes: Each dot denotes the in-group average residuals, partialing out city FEs, weekly FEs, city-specific time trends, city-specific seasonality, day-of-week FEs, dummies for holidays and working weekends, and weather controls (temperature, precipitation, wind speed). Groups are binned by percentiles of $PM_{2.5}$, which is depicted by the x-axis.

Figure 3: Wind-Pollution Vector Field, Dec. 5, 2013

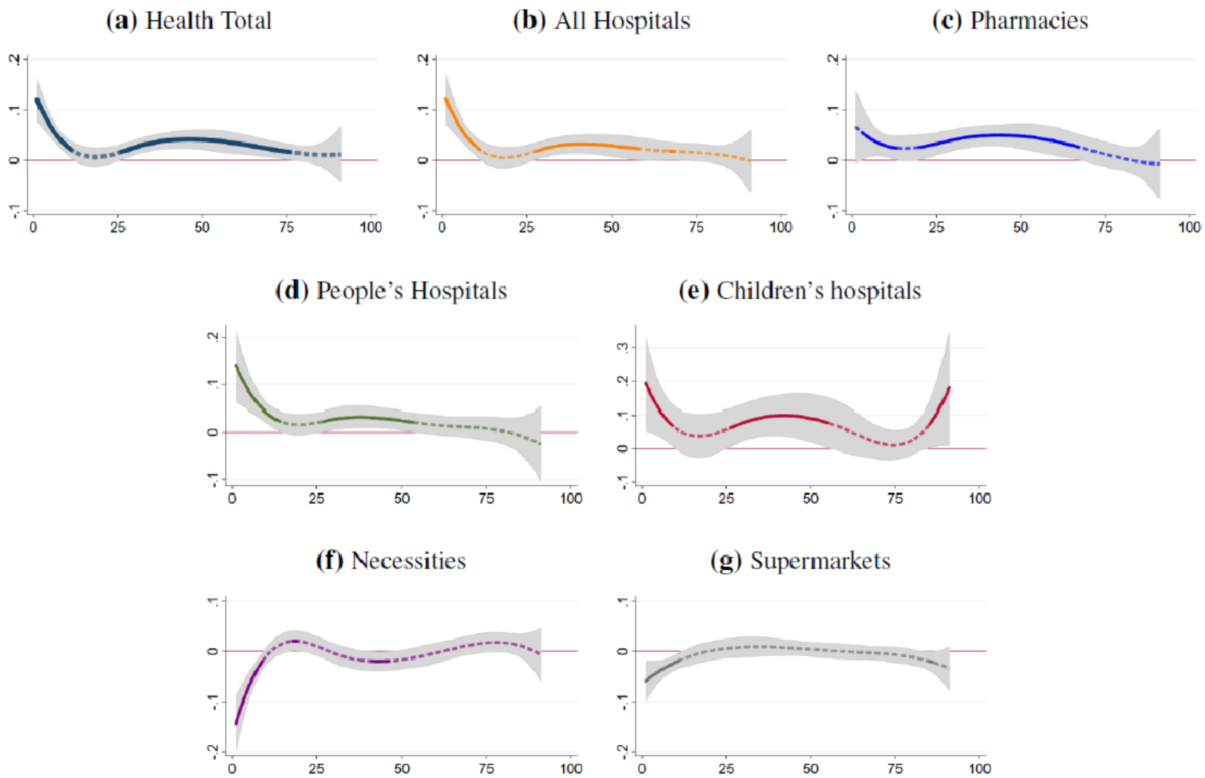
Notes: Each arrow's width indicates the level of $PM_{2.5}$ concentration of the origin city. Length of the arrow captures wind speed, rescaled to match the distance that pollutants would travel in a day. Direction of the arrow indicates the direction to which the wind blows from the origin.

Utilizing the exogenous shocks from non-local weather conditions, our analysis then estimates the longer-run impact of $PM_{2.5}$ on health spending. Figure 4 depicts the time path of the estimated causal impact on health spending from a 10 μg/m^3 increase in $PM_{2.5}$. Solid segments of the line indicate statistical significance at the 5% level. Health spending increases significantly during the first two months post exposure to air pollution, resulting in a 2.65% rise for a 10 μg/m^3 increase in $PM_{2.5}$ concentration. These findings are robust and survive the inclusion of a host of explanatory variables to control for confounding factors.

Only 23% of the higher spending occurs in the first week after exposure. Most of the spending increase materializes over the course of two to three months. This is consistent with the fact that the health impact of pollution is persistent. Particularly worrisome is that spending in children's hospitals is two to three times more sensitive to pollution than that of other health categories –

children are among the most vulnerable to air pollution. Finally, we also find a negative impact of PM2.5 on non-healthcare spending in the short-term, suggesting that consumers alter their activities (e.g., stay indoor more) in response to elevated air pollution.

Figure 4: Long-term Impact of Air Pollution on Health Spending



Notes: The y-axis indicates the percentage change in the number of transactions per 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentration. On the x-axis, 0 refers to current pollution, 50 refers to pollution 50 days ago, etc. Solid line indicates significance at the 5% level. Gray areas are 95% confidence intervals.

Pollution is extremely costly: Given the sheer size of national health care expenditures, a 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentration leads to a 60 billion *yuan* ($9 billion) increase in annual health spending. This estimated impact does not include the cost associated with loss in productivity and reduced quality of life and only provides a lower bound for the true social cost.

The Chinese central government spent five billion and ten billion *yuan* in 2013 and 2014, respectively, on reducing air pollution. The National Plan on Air Pollution Control, developed for the first time as a national policy by the State Council in 2013, sets a goal of reducing $PM_{2.5}$ by 25%, 20%, and 15% in 2017 relative to the 2012 levels in Beijing-Tianjin-Hebei, the Yangtze River Delta, and the Pearl River Delta regions, respectively. These regions account for 5% of land area but 23% of population and 40% of national output**.** Our findings suggest that these targeted reductions would generate significant health spending savings and substantial economic benefits.

References

Brunekreef, B., & Holgate, S. T. (2002). Air Pollution and Health. *The Lancet*, 360(9341), 1233-1242. http://www.sciencedirect.com/science/article/pii/S0140673602112748

Panle Jia Barwick, Shanjun Li, Deyu Rao, Nahim Bin Zahur (2018). Air Pollution, Health Spending and Willingness to Pay for Clean Air in China, Cornell University Working Paper. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2999068

Pope III, C. A., & Dockery, D. W. (2006). Health Effects of Fine Particulate Air Pollution: Lines That Connect. *Journal of the Air & Waste Management Association*, 56(6), 709-742. http://www.tandfonline.com/doi/abs/10.1080/10473289.2006.10464485

Dockery, D. W. (2009). Health Effects of Particulate Air Pollution. *Annals of Epidemiology*, 19(4), 257-263. http://www.sciencedirect.com/science/article/pii/S1047279709000337