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Air pollution and healthcare expenditure: Implication for the benefit of air pollution control in China

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ABSTRACT

Quantitating the health effects of air pollution is important for understanding the benefits of environmental regulations. Using the China Urban Household Survey (UHS) Database, this paper estimated the effect of air pollution exposure on household healthcare expenditure. To address potential endogeneity concerns, we performed household healthcare expenditure regressions using an instrumental variables (IV) strategy based on spatial air pollution spillovers. Our research revealed that a 1% increase in yearly exposure to fine particulate matter ($PM_{2.5}$) corresponds to a 2.942% (95% confidence interval: 1.084%, 4.799%) increase in household healthcare expenditure. The estimates suggest that the 13th Five-Year Plan for Ecological and Environmental Protection (the 13th FYP) would reduce annual national healthcare expenditure by 47.36 Billion Dollar (95% confidence interval: 17.45 Billion Dollar, 77.25 Billion Dollar), which accounts for 0.64% (95% confidence interval: 0.24%, 1.04%) of China's gross domestic product (GDP).

1. Introduction

Air pollution causes substantial adverse impacts on human health and the environment, particularly in developing countries and emerging economies like China (Xu et al., 2013) and India. Long-term exposure to fine particulate matter ($PM_{2.5}$) is considered to be a reason for cardiovascular mortality, and negative respiratory impacts, such as diminished lung function and the development of asthma (Burnett et al., 2014; Crouse et al., 2012; Pope III et al., 2011; Pope III and Dockery, 2006). The latest Global Burden of Disease (GBD) study finds that $PM_{2.5}$ is the most frequent cause of environment-related deaths worldwide, causing approximately 2.9 million premature deaths globally in 2013 (Brauer et al., 2015; Forouzanfar et al., 2015). The health harm from air pollution leads to increased healthcare expenditures as well as labor productivity losses, which have large social costs and cause immense economic pressure (Anand, 2004; Li et al., 2015; Liu, 2017). Effects on human health dominate the "cost of inaction" associated with air pollution, representing approximately 90% of the total social costs related to air pollutants (OECD, 2008).

Both policymakers and economists consider the social cost caused by air pollution to be one of the obstacles to economic development. Accurately estimating the influence of air pollution is crucial to the establishment of effective air quality regulations. Overestimating the effects of air pollution could lead to over-regulation, which could hinder economic growth. On the other hand, if the effects of air pollution are underestimated, numerous people could be left unprotected and considerable, and unnecessary economic welfare losses could occur (He et al., 2016). A growing study has consistently shown a positive association between exposure to air pollution and mortality, including infant mortality (Arceo et al., 2016; Chay and Greenstone, 2003; Greenstone and Hanna, 2014; Knittel et al., 2016) and life expectancy (Chen et al., 2013; Ebenstein et al., 2017; Yin et al., 2017). In particular, for China, Yin et al. (2017) estimated the adverse effects of particulate air pollution on mortality in 38 large cities in 27 provinces of China. Chen et al. (2013) and Ebenstein et al. (2017) estimated that the air pollution in northern China resulting from the Huai River policy led to a massive loss in life years. Mortality, or morbidity, costs are typically valued using concepts such as the value of a statistical life (VSL). For example, the World Bank (2007) used 1 Million Yuan (0.14 Million Dollar) as a conservative VSL estimate in China given the premature deaths and chronic illness caused by outdoor air pollution. In addition, researchers also applied the willingness to pay (WTP) approach, which infers social cost based on the trade-off between air pollution and prices among consumers' choice decisions (e.g., housing and defensive products). For instance, Chay and Greenstone (2005) capitalized total suspended particulates (TSPs) into housing values,

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which estimated the average marginal WTP for clean air. Freeman et al. (2018) used migration data to estimate the WTP of clean air in China. Zhang and Mu (2016) and Ito and Zhang (2016) valued the WTP for air pollution in China using the sales records for face masks and air purifiers, which can prevent health damage associated with outdoor and indoor air pollution, respectively.

The current literature on the social cost of air pollution primarily focuses on mortality risk (Chen et al., 2013; Ebenstein et al., 2017; Yin et al., 2017), contemporaneous costs, and the WTP (Chay and Greenstone, 2005; Freeman et al., 2018; Ito and Zhang, 2016; Zhang and Mu, 2016). However, there is limited literature on the healthcare expenditures associated with air pollution, which are an important component of its social cost. Failure to consider the healthcare expenditures resulting from air pollution may lead to the underestimation of air pollution's social cost. The biophysical impacts associated with air pollution directly affect economic activities such as healthcare expenditures. On the one hand, air pollution leads to direct medical expenses such as healthcare goods and services, which impose heavy financial burdens. On the other hand, if pollution exposure is inevitable, individuals can mitigate the adverse health effects through pharmaceutical or medication usage (Deschenes et al., 2017). These planned pollution-averting activities reflect individuals' trade-offs between the cost of preventive measures and the benefits of reduced pollution exposure. Several recent studies address the healthcare expenditures associated with air pollution. Deschenes et al. (2017) estimated the healthcare investments for air quality associated with the Nitrogen Oxides Budget Program using the purchase of insurance-related medication and hospital admissions records as indicators. Barwick et al. (2017) established a healthcare expenditure dataset for clean air based on credit and debit card transactions at all hospitals, pharmacies, and other healthcare facilities in China.

In this paper, we attempted to examine the impact of ambient air pollution on healthcare expenditure in China by combining average annual satellite-based $PM_{2.5}$ with a household healthcare expenditure survey. Firstly, we calculated the link between ambient air pollution and family healthcare expenditure by leveraging the ordinary least square (OLS) approach and instrumental variables (IV) strategy. Secondly, we examined the heterogeneity in healthcare expenditure by using household level demographic variables, and then we checked the robustness of results by changing the parametric specification and pollutants in constructing the IV. Finally, we discussed the health benefits of pollution control and estimated a lower bound for the social cost by revealing the healthcare expenditure resulting from air pollution.

2. Method and data

2.1. Method

Following a health production function in Grossman (1972), health is a commodity and consumers are willing to invest in their health. Different from the production function of general goods, the health production function includes pollution factors having a negative impact on the health output. Similar to the previous literature (Barwick et al., 2017; Deschênes et al., 2017), a framework of health production function in our research as given:

$$h = h(a, c) \tag{1}$$

where h is household's healthcare expenditure, and it depends on a and c. a is the ambient concentration of the pollutant and c is the capacity to invest such as household income level and social development level.

To express the marginal healthcare expenditure for air pollution m_a, we rearrange the total derivative of Eq. (1) to give the following expression for the partial effect of ambient pollution on healthcare expenditure:

$$m_a = \partial h/\partial a = dh/da + (\partial h/\partial c)*(\partial c^*/\partial a) \tag{2}$$

The paper's primary empirical goal is to estimate the marginal healthcare expenditure based on dh/da and $\partial c^*/\partial a$. In addition, if c is preset (i.e., keeping investment ability at a subsistence level, and $\partial c^*/\partial a = 0$), as suggested by Barwick et al. (2017), then the expression for marginal healthcare expenditure is the same as dh/da.

The key causal relationship of interest here is the effect of $PM_{2.5}$ on healthcare expenditure, net of any potentially confounding factors. Following the framework of health production, we apply the OLS regression equation to identify this relationship:

$$ln(Hlthexp_{ict}) = \beta + \beta_1 ln(PM_{2.5ct}) + A_{ict}\Gamma + X_{ct}Y + \theta_t + \theta_c + \varepsilon_{ict} \tag{3}$$

where $Hlthexp_{ict}$ is the healthcare expenditure of household i in county c and year t, $PM_{2.5ct}$ is the ambient $PM_{2.5}$ concentration in county c and year t, A_{ict} is a vector of the observable household attributes, and X_{ct} is a vector of county-level characteristics. θ_t is a year-fixed effect that can flexibly control for standard time-varying shocks, such as those induced by any healthcare or environmental policy changes during our sample period. θ_c is a county-fixed effect that can also control for the underlying differences in health and pollution that vary by geography. ε_{ict} is a mean-zero stochastic term. β is a constant term representing the intercept of the linear equation. β_1 is a coefficient we focus on that stands for the marginal effect of ambient $PM_{2.5}$ concentration on household expenditure. Γ and Y are the vectors of coefficients for household attributes and county-level characteristics. All the data except the discrete variables were applied after a logarithmic transition (the value plus one if the original data equals zero). The non-independence of observations was addressed by using a “cluster-robust” estimator with the different counties acting as clusters.

This research focused on household healthcare expenditure generated by $PM_{2.5}$. Nevertheless, one primary concern is that some factors correlated with air pollution, especially weather and social-economic level, may also affect household healthcare expenditure. Therefore, we included potentially confounding regional variables that can also affect residents' healthcare expenditures, such as weather variables (days of extremely low or extremely high temperature) (Chung et al., 2017; Curriero et al., 2002), economic variables (GDP per capita), and the number of medical beds per 10,000 inhabitants (Bed), which represent the level of medical service a person receives. We also considered the effect of household characteristics including income (Income), the number of household members (Numhou), the number of individuals who completed college (Numcoll), as well as the number of older people (age $>$ 60) (Numage) and the number of children (age $<$ 15) (Numyouth) within each household that might influence healthcare expenditures (Gerdtham et al., 1992; Hitiris and Posnett, 1992; Newhouse, 1977). In addition, we also controlled for household cigarette consumption (Cigaret) since the evaluation of health associated with air pollution would be largely discounted if this or other individual risk factors were not taken into account (Pope and Dockery, 2013).

However, accurately calculating pollution's causal effect on healthcare expenditures is complicated due to well-documented challenges, especially the issue of endogeneity. Endogeneity can arise from a series of sources, including unobservable variables that affect both pollution and healthcare expenditure, such as a local economic boom (Zabel and Kiel, 2000) and the intensity of local environmental regulation enforcement (Selden and Song, 1995). Moreover, measurement errors in pollution exposure from satellite-based data cannot be neglected. To address the endogeneity concern, we calculated the link between ambient air pollution and family healthcare expenditure by leveraging an IV strategy with two exogenous spatial $PM_{2.5}$ spillover variables: air pollution from an upwind area and the influence of sandstorms which referenced the previous literature (Barwick et al., 2017; Chen, 2015; Deryugina et al., 2016; Zheng et al., 2014). To be specific, the $PM_{2.5}$ level in a given county is first predicted using the $PM_{2.5}$ concentrations in other regions, taking wind direction and wind