Journal of Cleaner Production 172 (2018) 743–757

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

How harmful is air pollution to economic development? New evidence from $PM_{2.5}$ concentrations of Chinese cities

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ARTICLE INFO

Article history:
Received 13 March 2017
Received in revised form
7 September 2017
Accepted 18 October 2017

Keywords:
Air pollution
$PM_{2.5}$ concentrations
Economic development
Simultaneous equations model
Chinese cities

ABSTRACT

In recent years, haze pollution has frequently shrouded most regions of northern and eastern China. Air pollution has drawn increasing attention at home and abroad. However, the potential negative impacts of environmental pollution on economic development have long been ignored. Considering the possible effect of economic growth on environmental pollution, the conventional ordinary least squares (OLS) estimation may suffer from endogeneity biases caused by possible bilateral causality. In this paper, using city-level panel data for the period between 2013 and 2015, the influence of $PM_{2.5}$ concentrations on per capita GDP is estimated through a carefully designed simultaneous equations model for the first time. To control for fixed effects, a series of time dummies and region dummies are also introduced. The estimation results indicate that haze pollution indeed has a significantly negative impact on economic development. On average, as of 2015, when other conditions are equal, an increase of 5 $\mu g/m^3$ in $PM_{2.5}$ concentrations may cause a decrease of approximately 2500 yuan in GDP per capita. In addition, the results suggest that sustainable economic growth may help reduce $PM_{2.5}$ concentrations, which in turn benefits economic development.

1. Introduction

Ever since the beginning of the "reform and opening up", China's economy has been growing at a breakneck pace. However, at the same time, China's environmental quality has deteriorated remarkably, particularly evident by the notorious haze pollution that has occurred frequently in many northern and eastern regions of China in recent years. In other words, there seems to be a tradeoff between economic growth and the deterioration of environment, which can also be observed in many developing countries and newly industrialized countries. On one hand, economic growth puts pressure on the environment inevitably due to an increasing population, industrialization and dynamic economic activities. On the other hand, the environment may have a feedback effect on social-economic activities (Lopez, 1994; Pao and Tsai, 2010; Azam, 2016). Specifically, Lopez (1994) treated the environment as an important input factor of production, whereas Azam (2016) explicitly explored and verified the negative effects of environmental deterioration on economic development using multinational panel data. In recent years, air pollution has become increasingly serious and drawn more and more attention in many

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https://doi.org/10.1016/j.jclepro.2017.10.195
0959-6526/

developing countries, such as the so-called BRICS, which is the acronym for an association of five major developing countries with relatively rapid economic growth rates in recent years: Brazil, Russia, India, China and South Africa. As for China, haze pollution, of which the main component is fine particles (i.e., $PM_{2.5}$), has posed a great threat to residents' health and even sustainable economic development. Some studies have investigated the causes of haze in China. For instance, Li and Zhang (2014) found that excluding meteorological conditions, an unsustainable economic development model plays an important role in the formation of haze pollution. Weather and meteorological conditions to a great extent affect air quality (Yang et al., 2017). Moreover, there is evidence that the concentrations of $PM_{2.5}$ in many northern Chinese cities apparently have seasonal patterns: the concentrations tend to be higher in the winter due to household heating, whereas the concentrations are generally lower in the summer when coal consumption is considerably lower. Specifically, because China's economic development heavily relies on the consumption of fossil energy, especially coal, pollutant emissions have ballooned as the economy has boosted (Hao et al., 2015). In addition, automobile exhaust contributes significantly to the formation of haze (Zheng et al., 2005; Wang et al., 2006). The total number of private cars has reached 172 million by 2015, and in some large cities such as Beijing, Shanghai, Shenzhen and Tianjin, the number exceeded 2 million.

Maintaining the sustainability of economic growth is a large challenge to many emerging countries. Some early studies have noted that environmental deterioration may limit or even reduce economic activities (Barbier, 1994; Pearce and Warford, 1993). Literally speaking, pollution may affect economic development directly and indirectly through its influences on public health and productivity. For instance, there has been evidence that air pollution is directly associated with respiratory and cardiovascular diseases, such as lung cancer (Tie et al., 2009) and asthma (Neidell, 2004). Among the various types of air pollutants, particulate matters receive special attention because they are the main contents of haze pollution, which has recently appeared in may northern and eastern areas of China, including the Chinese capital city of Beijing and the most economically prosperous megacity of Shanghai. Some studies have found that haze pollution is negatively linked to respiratory and cardiopulmonary diseases (Pope et al., 2002; Dockery and Pope, 1994). Additionally, the findings of some research indicate that exposure to a certain level of $PM_{2.5}$ concentrations is significantly associated with mortality in the long run (Dockery et al., 1993; Pope et al., 1995; Jerrett et al., 2005) and even in the short run (Din et al., 2013). Using data from European and American cities indicates, some researchers also found that the mortality rate rises remarkably when human beings are exposed to PM_{10} for 24 h (Katsouyanni et al., 2001; Samet et al., 2000). Another study indicates that Asian cities also report an increase in the rate of mortality when PM_{10} concentrations are higher (HEI International Oversight Committee, 2004).

As for China, in recent years, haze pollution has become increasingly severe and drawn broad attention at home and abroad. Currently, air pollution is no longer a problem for certain cities or regions but a national issue. According to the annual Air Quality Guideline of World Health Organization (WHO), the safe threshold values are10 $\mu g/m^3$ and 20 $\mu g/m^3$ for the annual mean $PM_{2.5}$ and PM_{10} concentrations, respectively (WHO, 2006). However, in 2015, in only 1 out of 367 Chinese cities (i.e., Nyingchi City in Tibet) was the air quality good enough, with the concentrations of $PM_{2.5}$ and PM_{10} being below the safe threshold values suggested by the WHO. Even if the standard is relaxed to the 24-h mean of $PM_{2.5}$ (25 $\mu g/m^3$), only 25 of all 367 cities were qualified in terms of air quality in 2015. As shown in Fig. 1, the majority of the 147 cities that reported urban air quality in 2014 had $PM_{2.5}$ concentrations higher than 49 $\mu g/m^3$, which is approximately twice as high as the WHO guidelines. Fig. 1 indicates a clear pattern for China's haze pollution: the cities in the Beijing-Tianjin-Hebei region (including Megacities of Beijing and Tianjin and Hebei province) suffer from the most serious air pollution, the $PM_{2.5}$ concentrations in the Yangtze River Delta region (including Shanghai, Jiangsu and Zhejiang) are also substantially high, and southern China (e.g., Guangxi, Guangdong and Hainan) has fairly good air quality (although the $PM_{2.5}$ concentrations of the cities in south China are still considerably higher than the WHO's safety standard). Compared with other countries, China's $PM_{2.5}$ pollution is also very significant. Fig. 2 depicts the average $PM_{2.5}$ concentrations in 2008 and 2014 and corresponding average annual growth rates in seven developed countries and Poland, which is also a transition economy and has a similar per capita GDP as China. As shown in Table 2, China had the highest $PM_{2.5}$ concentrations in both 2008 and 2014, and the gap in $PM_{2.5}$ concentrations between China and the selected developed countries is considerable. Even compared with Poland, China is much more polluted. In 2008, China's $PM_{2.5}$ concentrations were 1.6 times Poland's level, and this ratio rose to 2.3 in 2014. Moreover, except Canada (for which the $PM_{2.5}$ concentrations growth rate was very near zero), China is the only country seeing a positive growth rate during this period.

Extant studies have pointed out that health conditions may influence family income (Smith, 1999) and therefore may further affect residents' affordability of quality health care. Moreover, almost all socio-economic activities are restricted or limited when there is haze pollution. For instance, schools may have to be suspended and factories may need to stop manufacturing.[2] The forced restrictions on socio-economic activities may affect the amount of time invested in economic activities and therefore social wealth and residents' income. Besides, a number of rich and middle-class Chinese have been moving away from or seriously considering to leave the serious polluted cities in China, which may cause the capital outflow and brain drain and eventually damage local economic growth (Graff Zivin and Neidell, 2013).[3] In summary, haze pollution not only does harm to human beings but also has serious negative impacts on the sustainable development of China's economy.[4] Some recent studies have evaluated the health damage and corresponding economic costs of air pollution in China (Zhang et al., 2007; Hou et al., 2010; Huang et al., 2012; Matus et al., 2012; Chen et al., 2017). Using different approaches, the existing estimations indicate that the economic loss incurred by air pollution through its negative effects on public health was considerably high and accounted for at least 0.7% of GDP. Therefore, it is high time to curb haze pollution and reverse its unfavorable growing trend. In fact, the Chinese government has already taken some initial steps to control the emission of air pollutants, especially $PM_{2.5}$. According to the 13th Five-Year Plan (2016–2020), the average concentrations of

[2] For more information on the restrained social-economic activities when there is haze pollution, one can refer to a series of media reports, including http://edition.cnn.com/2015/12/07/asia/china-beijing-pollution-red-alert/(accessed 07/08/2017).

[3] Recently there have been a growing number of media reports about the phenomenon that China's environmental pollution has begun to drive high-quality labor force and rich people to less polluted areas or leave China entirely. For instance, one could refer to http://www.nytimes.com/2013/11/23/world/asia/urbanites-flee-chinas-smog-for-blue-skies.html?pagewanted=all and http://www.atimes.com/article/housing-education-immigration-healthcare-how-does-smog-alter-chinese-lifestyles/(accessed 07/08/2017).

[4] There has been some anecdotal evidence for the harm of air pollution to residents' health and economic growth in China. For instance, one can refer to http://www.abc.net.au/news/2016-02-09/beijing's-air-quality-improving-but-not-without-cost/7146360 and http://www.cfr.org/china/chinas-environmental-crisis/p12608 (accessed 07/08/2017).