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Identifying the main contributors of air pollution in Beijing

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ABSTRACT

Air pollution has become an emerging environmental issue in developing countries like China in the last two decades. Sulphur dioxide (SO_2) is one of the major air pollutants that poses significant risks in many areas undergoing a process of industrialization such as Beijing. Realizing the main factor causing environmental quality changes is the key to solving this problem. By using an extended version of IPAT model, this paper aims to identify the main contributors of air pollution in Beijing from 1989 to 2012. The result shows that the most influential factors affecting air pollution in Beijing are affluence and emission intensity. From analyzing the historical background, we conclude that the air pollution change in Beijing is heavily policy-driven.

1. Introduction

Air pollution is one of the most serious environmental issues in many developing countries (Kanada et al., 2013). Indoor air pollution produced by the combustion of biomass fuels as well as coal in poorly ventilated heating and cooking environments causes significant mortality and morbidity from respiratory diseases, particularly among children. Globally, urban air pollution is responsible for significant mortality every year, mostly as a result of heart and lung diseases (Bolund and Hunhammar, 1999). Another effect of urban air pollution is that it might induce biodiversity loss which may be irreversible (Bolund and Hunhammar, 1999). For example, it has been discovered long ago that air pollution has an influence on forest ecosystems throughout the temperate regions of the world. If the effect of air pollution exposure on some components of the ecosystem biota is inimical then a Class II relationship[1] is established (Smith, 1974). Although most recent attentions have been focused on reducing carbon dioxide (CO_2) emissions, due to concerns on global climate change, local air pollution is still a critical issue that poses an acute threat to both public health and natural ecosystems (BP, 2012; Chen et al., 2012; Chung et al., 2011; Kan et al., 2012; Lu et al., 2010; Smith et al., 2011; Streets and Waldhoff, 2000; Tang et al., 2010). Sulfur dioxide (SO_2) is one of the major air pollutants that poses significant risks in many developing countries undergoing a process of industrialization. Many studies have found that SO_2 pollution causes severe respiratory problems and significant ecosystem degradation due to acid rain formation (Guttikunda et al., 2003; Su et al., 2011).

Currently, air quality in China is becoming a world-concerning issue. Not only has it contributed to regional environment degradation, but also severely affected local residents' living quality. Especially, the air quality in Beijing and other megacities has become an urgent challenge to the Chinese government. The Chinese Ministry of Environmental Protection Data Center reports that out of the thirty one provinces and municipalities, Beijing is among the worst air quality provinces, ranked second to last (Liu, 2013). Realizing the main factor causing air quality changes is the key to solve this problem. Hao et al.'s study showed the high SO_2 emission induced a significant impact on the urban area (Hao et al., 2007). SO_2 reduction plays an increasingly significant role in improvement of air pollution in China due to its popular appearances in pollution abatement methods (Liu and Wang, 2013). To improve air quality, Beijing government has formulated plans to reform air-related administrative management systems and increase administrative efficiency. Beijing's twelfth five-year plan set the goal to have 80% of days achieving national Grade II or better air quality in Beijing (Jiang, 2014). The goal is to reduce major pollutant SO_2 by 8% by

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[1] "When exposed to intermediate dosage, individual tree species or individual members of a given species may be adversely and subtly affected by nutrient stress, reduced photosynthetic or reproductive rate, predisposition to entomological or microbial stress, or direct disease induction" (Smith, W.H., 1974. Air pollution—effects on the structure and function of the temperate forest ecosystem. Environmental Pollution (1970) 6, 111–129.).

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2015 (KPMG, 2011). Control measures such as fuel substitution, flue gas desulfurization, dust control improvement and flue gas denitration has greatly mitigated the SO_2 and PM10 pollution, especially alleviating the pressure on the urban area to reach the National Ambient Air Quality Standard (Hao et al., 2007).

Air quality is closely associated with human activities (Pehoiu, 2008). Up to now there have been many different approaches to measure the effects of human activities to the environment. Some researchers used both CO_2 and SO_2 as indicators of climate change and air pollution in Britain to measure environmental quality changes using a temperature matrix to perform a number of parallel analyses (Balling and Idso, 1992), others use IPAT (I = Impact, P = Population, A = Affluence, and T = Technology) model to analyze how different drivers (including economic development, income levels, urbanization and other socio-economic drivers) contribute to the growth of CO_2 emissions in China (Feng et al., 2009). Furthermore, Wang et al. (2013) has examined the impact factors of population, economic level, technology level, urbanization level, industrialization level, service level, energy consumption structure and foreign trade degree on the energy-related CO_2 emissions in Guangdong Province, China from 1980 to 2010 using an extended STIRPAT model which is a stochastic model of IPAT using regression on population, Affluence and Technology. Amongst the current approaches utilized by researchers, IPAT has become a popular tool to identify drivers of air pollution impacts due to its simplicity, transparency, and demand of less data.

Through applying an extended IPAT model, this paper aims to identify the main contributors of environmental quality changes in Beijing. In this research, sulphur dioxide (SO_2) is used as the indicator of air pollution.

2. Data and method

Population, Gross Domestic Product (GDP), GDP by industries and energy consumption data are collected from Beijing Statistical Yearbooks, and SO_2 emission data are obtained from Beijing Municipal Environmental Protection Bureau.

The IPAT identity is a widely recognized formula for analyzing the effects of human activities on the environment (York et al., 2003). The *IPAT* equation could be used to determine which single variable is the most damaging to the environment, as well as recognizing that increases in population and affluence could, in many cases, be balanced by improvements to the environment offered by technological systems (Chertow, 2001).

The limitation of using the original *IPAT* model is that it only includes three aggregate factors; population, affluence, and technology, respectively. However, it has been broadly discussed that economic structure is also a key driver for air pollution (Brizga et al., 2013). In addition, technology could be further disaggregated into energy intensity (energy consumption per unit of economic output) and emissions intensity (emissions per unit of energy consumption) (York et al., 2003). In this research, we develop an extended version of *IPAT* model to analyze the contributing factors to environmental quality changes: population, affluence, economic structure, energy intensity and emission intensity.

In this study, the quantitative analysis is focused on how different variables contribute to SO_2 emissions I, impact on Beijing's air pollution:

This extended *IPAT* method can reveal the main driving factors have contributed to the environment pollution and it is expressed as:

$$I = P \times A \times S \times IEn \times IEm \tag{1}$$

here, I is SO_2 emissions; P refers to the size of the resident population in Beijing; A is per capita GDP; S presents economic structure/industrialization (share of industrial GDP); IEn is energy intensity which shows how much energy is put into one unit of industrial GDP; and IEm is emission intensity which represents how much the SO_2 emissions result from one unit of energy consumption.

To facilitate understanding and analysis, converting all variables to logarithmic form allows seeing the respective contributions as a share of the total impacts. These modifications yield the following models (Feng et al., 2009):

$$\log I = \log P + \log A + \log S + \log IEn + \log IEm \tag{2}$$

$$\Delta\log I = \Delta\log P + \Delta\log A + \Delta\log S + \Delta\log IEn + \Delta\log IEm \tag{3}$$

$$\log\frac{I_t}{I_1} = \log\frac{P_t}{P_1} + \log\frac{A_t}{A_1} + \log\frac{S_t}{S_1} + \log\frac{IEn_t}{IEn_1} + \log\frac{IEm_t}{IEm_1} \tag{4}$$

Where script *t* is a time in the future and script *1* is the original time being compared with. This final equation comprised of addition can show how much impact is contributed by each sector.

In this study, the timeframe is set from 1989 to 2012 to see the progression of population, GDP, emission of SO_2 and how has it affected air quality in Beijing.

3. Results/interpretation

The results of this research are classified into six time frames: 1989–1995 (the relaxed immigration policy after Open-Door Policy), 1995–1999 (Asia economic crisis), 1999–2003 (after the economic crisis and closing of small factories), 2005–2008 (pre-Olympics), 2009–2012 (post Olympics). There are three visual representations. One is the variation in percentage in relation to its previous year (Fig. 1). Another is the trend of each variable and how it changes overtime (Fig. 2a–f). The third one is the percentage contribution of each variable for the six time periods (Fig. 3 and Table 1).

3.1. Relaxed immigration policy after open-door policy 1989–1995

From 1989 to 1995 population and affluence contributed the most to air pollution, being 264% and 367%, while the economic structure and emission intensity had ameliorated this by 284% and 219%. Thus, the overall impact in this period decreased by 9%.

The economic openness of China began in the provinces of the South-East. The creation of “Special Economic Zones” and of “Open Economic Zones” was the master piece of the open-door policy. During 1989 to 1995, migrants tended to concentrate in three main regions: the Pearl River Delta,[2] the Yangtse Delta,[3] and the area around the Bohai Gulf,[4]including Beijing (Renard et al., 2011). In 1995, to stimulate the economy and development of the city, Beijing released “Urban household registration management

[2] A low-lying area surrounding the Pearl River estuary where the Pearl River flows into the South China Sea. This paper refers to the part within the Guangdong Province.

[3] Triangular shaped river delta area that drains into the East China Sea. This paper refers to the part within Shanghai, Jiangsu Province.

[4] The innermost gulf of the Yellow Sea on the coast of Northeastern and North China and has close proximity to Beijing.