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Neglected environmental health impacts of China's supply-side structural reform

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ABSTRACT

"Supply-side structural reform" (SSSR) has been the most important ongoing economic reform in China since 2015, but its important environmental health effects have not been properly assessed. The present study addresses that gap by focusing on reduction of overcapacity in the coal, steel, and iron sectors, combined with reduction of emissions of sulfur dioxide (SO_2), nitrogen oxide (NO_x), and fine particulate matter ($PM_{2.5}$), and projecting resultant effects on air quality and public health across cities and regions in China. Modeling results indicate that effects on air quality and public health are visible and distributed unevenly across the country. This assessment provides quantitative evidence supporting projections of the transregional distribution of such effects. Such uneven transregional distribution complicates management of air quality and health risks in China. The results challenge approaches that rely solely on cities to improve air quality. The article concludes with suggestions on how to integrate SSSR measures with cities' air quality improvement attainment planning and management performance evaluation.

1. Introduction

While President Trump's announced withdrawal from the Paris Agreement garnered much international attention in June 2017, few outside China noticed an announcement by the Chinese National Reform and Development Commission (NRDC) concerning China's progress toward reduction of overcapacity in coal, steel, and iron – one of the four tasks of the ongoing "supply-side structural reform" (SSSR) in that country. SSSR was first proposed by the Chinese government in 2015, as a major response to the slowing of economic growth in the country since 2007 (marked as the "new normal") and an opportunity to optimize the supply side of the economy. Major tasks identified included cutting overcapacity in coal, steel, and iron; reducing housing inventory; lowering leveraged corporate and industrial financing; cutting corporate costs; and improving weak economic links between increasing new demands and short supply. Different from the deindustrialization (mainly expressed with the declines of industrial outputs and employment) that took place in many industrialized countries since 1980s and 1990s (Feinstein, 1999; Koistinen, 2013), SSSR in China is a government-initiated, organized, and enforced reform package that was considered revolutionary for the country's socialist market economy practices and theories.

In 2015, the State Council set targets for 2020 to reduce production capacity by 150 million tons of crude steel and 800 million tons of coal. Provincial and local governments responded immediately to this call with detailed implementation plans. According to NRDC, the annual targeted reductions in production capacity set for 2016, 45 million tons of steel and 250 million tons of coal, were already overachieved by October of that year. By May 2017, another 32 million tons of steel, and 69 million tons of coal production capacities were reduced, to a cumulative 51% and 40%, respectively, of the targets by 2020, a positive sign for full achievement of the overall targets.

In China until now, the social, economic, and sectoral impacts of this countrywide reform have attracted most of the attention. The reform's environmental and health effects have not yet been properly studied, however. Where environmental protection has been brought into discussions, the focus has been on how more stringent environmental regulations could aid the realization of the SSSR targets; nor has

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there yet been systematic quantitative assessment of environmental and health impacts (MEP, 2016). This was mainly due to SSSR being primarily an economic policy that did not involve the Ministry of Environmental Protection directly in its formulation and implementation. Although such a major policy should be subject to strategic environmental assessment, the latter is only encouraged, not enforced, according to the new Environmental Law (Zhang et al., 2015). The present study aimed to begin to address that gap by focusing on the reduction of overcapacity in the coal, steel, and iron sectors; combined with reduction of emissions of sulfur dioxide (SO_2), nitrogen oxide (NO_x), and fine particulate matter ($PM_{2.5}$); and projecting resultant effects on air quality and public health across cities and regions in China. While efforts and costs to reduce overproduction capacities were local, local air quality also can be affected by atmospheric transport of pollution from distant sources (Zhang et al., 2017). Such quantitative assessments are important sources of evaluating the effectiveness of SSSR efforts. They contribute, as well, to a more balanced understanding of impacts of such structural reforms on air quality and public health across the country.

2. Material and methods

This study uses an integrated framework to trace the policies-to-impacts path to assess the environmental and health benefits of China's SSSR. To the best of our knowledge, this is the first study to evaluate the national environmental and health benefits of this top priority policy of China. In this study, we apply a four-step approach: 1) inventorying the projected reduction in overproduction capacity and 2) air pollutant emissions, respectively; and projecting expected resultant 3) concentrations of air pollutants and 4) health impacts by 2020.

2.1. Data source

For the SSSR policy, the base and target years are 2014 and 2020, respectively. The baseline emission data for each province in 2014 are cited from the *China Statistical Yearbook on Environment 2016* (http://www.stats.gov.cn). Data on the reduction of production capacity of coal, steel and iron by 2020 were collected from the government website of each province, and summarized in Table S1 in the *Supporting Information*. Spatial distribution of the planned production capacity reduction is illustrated in Fig. S1 in the Supporting Information.

Today China is the world's biggest producer and consumer of coal, and relies on coal power for approximately 70% of its energy, with 45% used for the industrial sector and the remainder used to generate electricity (NEA, 2011). The burning of coal is the main source of air pollution. Most coal in China is mined in the less populated western and northeastern regions, and the coal consumption is concentrated in the populated eastern and central China regions. Therefore the inter-provincial redistribution of coal in consumption is important to calculate the reduction of air emissions from SSSR on coal. In this study, the reduction of coal production at the supply side was transformed into the reduction of coal consumption using the inter-province coal trading matrix in China (Tian et al., 2014), and the result was summarized in Table S2 in the Supporting Information. Based on reduction of coal, steel, and iron capacity, the abatement of air pollutant (NO_x, SO_2, $PM_{2.5}$) emissions were calculated and is summarized in Table S3 in the Supporting Information.

2.2. Inventory of air pollutant emissions

To avoid repeated calculation of emissions from industrial coal combustion, the air emissions from steel and iron production only focused on the iron-making and steel-making processes, and the emissions from coking and other coal burning processes in steel and iron production were calculated under the coal combustions. Details on the air emissions calculation are described below.

(1) Sulfur dioxide (SO_2)

In China, coal combustion is the largest atmospheric pollution source. It was estimated that in all kinds of air emission sources in China, about 87% of SO_2 and 67% of NO_x were emitted from coal combustion (Xu et al., 2000). Emission of SO_2 from coal combustion depends on the sulfur content, boiler type, conversion rate of sulfur, and desulfurization efficiency of air emission control devices. The coefficient of SO_2 emission was calculated as:

$$E_{SO2} = 2 \times 1000 \times C_s \times P \times (1 - \rho_{so2}) \tag{1}$$

where,E_{SO2}: emission coefficient of SO_2 (kg/ton)C_s: sulfur content in coal (%)P: sulfur conversion rate (%)ρ_{SO2}: desulfurization efficiency (%)

Based on a large amount of measured and statistical data in China, Wang and Zhang (2012) report that the conversion rate of sulfur in coal combustion ranges from 80% to 85%. In this study, the average between 80 and 85% was used to calculate the SO_2 emission, and 80% and 85% was used as the low and high bound estimation respectively in the uncertainty analysis. In China, the development of specific desulfurization devices was still in the stage of exploration and demonstration, and there was a considerable gap to meet the requirements of practical application (Wang and Zhang, 2012). The wet dust scrubbers that are currently widely used for industrial boilers can make full use of its own emissions of alkaline substances (alkaline substances in the boiler wastewater and boiler ash), and achieve a general desulfurization efficiency of 20%–30% (Wang and Zhang, 2012). The desulfurization efficiency can be further improved by adding additional alkaline substances. Therefore in inventory studies of SO_2 emission, the desulfurization efficiency is usually set between 10 and 50% (Wang and Zhang, 2012). In this study, 30% is used to calculate the average SO_2 emissions, and 10% and 50% are used as the lower and upper bound in uncertainty analysis.

The SO_2 emission factor for coal combustion with different sulfur content was calculated utilizing Eq. (1). In this study, because the coal reduction goals were broken down into provinces, the sulfur content in coal in each province was used, and the SO_2 emission factors of typical sulfur content were summarized in Table S4 in the Supporting Information. The provincial sulfur contents in coal were investigated by China Coal Processing & Utilization Association in 2012 (Sun and Ye, 2012), and their published data are cited and summarized in Table S2.

For SO_2 emissions from iron and steel manufacturing processes, Ma et al. (2012) summarize the SO_2 emission factors in operation units in China iron and steel industry. The values of the key units, including sintering (1.374 kg/ton), pelletizing (0.395 kg/ton) and iron making (0.837 kg/ton), were used to calculate SO_2 emissions from iron and steel manufacturing (Ma et al., 2012).

(2) Nitrogen oxide (NO_x)

The NO_x emissions were calculated using the empirical NO_x emission coefficients (equivalent to NO_2). For coal combustions, the empirical NO_x emission coefficients are cited from Wang and Zhang's (2012) nationwide investigations on coal fired boilers. For iron and steel manufacturing, the NO_x emission coefficients are cited from Duan et al. (2013). These data are summarized in Table S5 in the Supporting Information. Because it was difficult to obtain the information on the percentage of each boiler type in coal combustions, the average value was used to estimate the NO_x emission from coal combustion, and the higher and lower bound were used in the uncertainty analysis.

(3) Particulate matter ($PM_{2.5}$)

Fine particulate matter emission ($PM_{2.5}$) was calculated according to the *Guideline for Primary Fine Particulate Matters Emission Inventory* released by the China Ministry of Environmental Protection (MEP, 2014). The primary $PM_{2.5}$ emission from coal combustion was