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Effects of COVID-19 Outbreak on the Air Quality in Major Chinese Cities and Their Policy Implications

1. Introduction

China's rapid economic development over the past three decades has come with an enormous rise in energy demand, and its energy-related carbon emissions grew by 6.9 times during the same period, which has turned China into the world's largest carbon dioxide emitter. Nowadays, the Chinese government has raised its awareness of environmental issues and pushed a series of air pollution control policies in the hope of fight against the air pollution issue and improve the quality of living for its citizens. Governments and media have identified massive manufacturing factories and transportation as the top two most significant emitting sectors that contributed to the level of air pollution. Stringent regulations on the emission standards of these sectors have been proposed to regulate their air pollutant emissions.

In January 2020, a novel coronavirus disease (COVID-19) outbreak first happened in Wuhan, Hubei Province, and then quickly spread to the whole country. The Chinese government posted one of the strictest emergency responses in human history by banning the traffic mobility in the entire country and issuing a large population quarantine order for people to stay at home and work from home. At the end of March 2020, new confirmed COVID-19 cases in China reported by the National Health Commission dropped to 20, and most Chinese provinces have lowered the level of emergency responses. People's producing and living patterns are getting back to normal, and the two significant emitting sectors, manufacturing, and transportation are also slowly recovering to regular status.

While facing this unprecedented domestic or even international pandemic due to the COVID-19 outbreak, several well-known media from both China and western countries have reported that the air pollution issue in China has been curbed during this lockdown period. Therefore, the overarching goal of this study is to examine the improvements in air pollution levels during this period due to the massive quarantine. Specifically, this study will 1) Investigate the air pollution level for different pollutants among the same period (1st quarter of the year) over the past six years in major Chinese cities including Wuhan and Beijing-Tianjin-Heibei region; 2) Compare the effects of this massive quarantine to the effects of previous environmental policies. Establishing a quantitative analysis of the changes of the air pollution over the year will allow the government and policymakers to better understand how different sectors, especially the transportation and heavy manufacturing sectors, contribute to the deterioration of air quality in China. This understand will allow the government and policymakers to exert appropriate policy instruments to address this issue as soon as possible.

Moreover, it is essential to address that the intention of this paper is not to justify the spreading of COVID-19 or even to promote the benefits of this outbreak. Instead, this lockdown period offers a great opportunity for researchers and policymakers to understand the relationship between environmental issues and the previous development path in China over the past decades. By comparing this natural control group with previous years, researchers can receive valuable insights between human activities and urban sustainable developments and eventually ensure the government to contribute to the betterment of the society in the future.

2. Methods

The first step of this study was to investigate the air pollution level for different pollutants among the same period (1^{st} quarter of the year) over the past six years in major Chinese cities. This study captured the changes in the average concentrations of six different major air pollutants including Carbon monoxide (CO), Nitrogen dioxide (NO_2), Ozone (O_3), Particular matters (PM2.5 and PM10), and Sulfur dioxide (SO_2). The selection of the cities considered multiple factors including population density, economic conditions and geological areas. Therefore, this study included the most economically developed cities in China (Beijing, Shanghai, and Hongkong) and major cities in each geological location such as Chengdu (Southwest) and Guangzhou (Southeast). Lastly, this study also included Wuhan, which was the center of this COVID-19 outbreak and had the longest lockdown period in China.

The air quality data for the 1^{st} quarter over the past six years for these six major cities was obtained from the Air Pollution: Real-time Air Quality Index (AQI) website[1]. All these datasets were downloaded as CSV files that could be processed in Python easily and the compiling process was based on 1) Each city has its own CSV file that contain the data over the same period; 2) Each CSV file contains the data for the six major pollutants and each of the pollutant is compiled into in own column, which makes it convenient for future analysis. In order to analyze and visualize these datasets, this study used Python 3 language on the Jupyter Notebook as the main tool. In the meanwhile, a wide range of Python Libraries such as NumPy, Pandas, and MatplotLib was used to visualize the data and contribute to the analysis. Furthermore, the line charts were chosen the diagrams demonstrated in this project since it can represent the trends of the AQI of each pollutant in different years over the same period. By looking at the difference between each line, which

[1] https://aqicn.org

represents the AQI in different years, we can visualize the changes over the years and the effects of the lockdown in 2020.

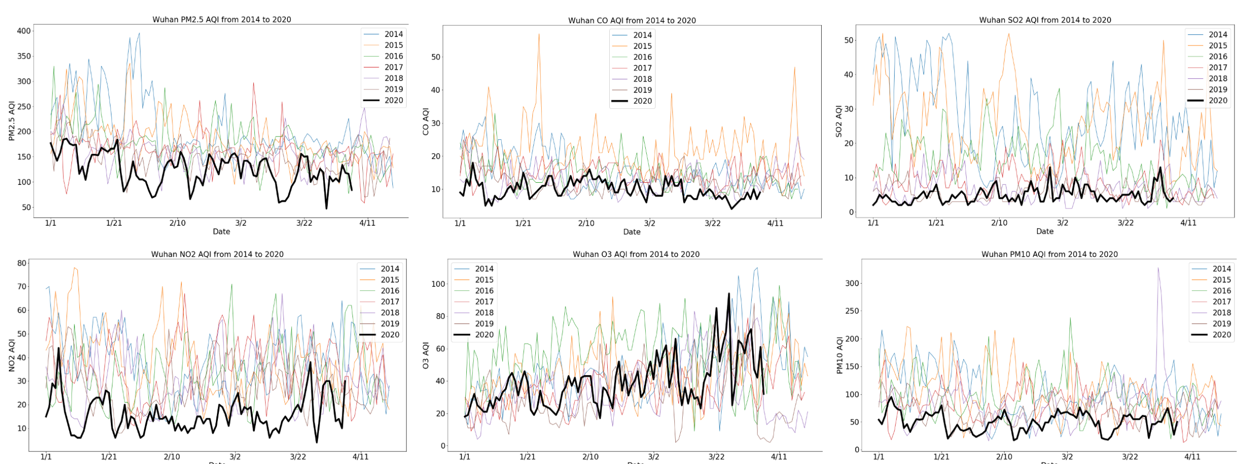
date	PM25	PM10	O3	NO2	SO2	CO
1/1/2014	252	151	21	69	40	22
1/2/2014	233	216	13	70	49	28
1/3/2014	252	173	29	52	51	22
1/4/2014	268	129	28	50	45	21
1/5/2014	189	164	40	59	49	26
1/6/2014	252	174	34	49	44	27
1/7/2014	274	144	34	33	12	30
1/8/2014	335	119	35	33	51	29
1/9/2014	278	163	24	45	46	32
1/10/2014	321	100	31	38	39	19
1/11/2014	245	67	38	30	22	13
1/12/2014	178	113	48	35	30	17
1/13/2014	233	189	16	54	45	25
1/14/2014	344	167	35	49	40	25
1/15/2014	305	125	41	40	35	18
1/16/2014	242	114	29	57	46	18
1/17/2014	199	176	36	57	40	21
1/18/2014	330	170	46	50	50	23
1/19/2014	317	163	37	59	48	21
1/20/2014	290	140	46	45	31	17
1/21/2014	241	111	45	41	35	15
1/22/2014	171	109	24	46	39	16

Table 1: Sample Dataset Used in this Study

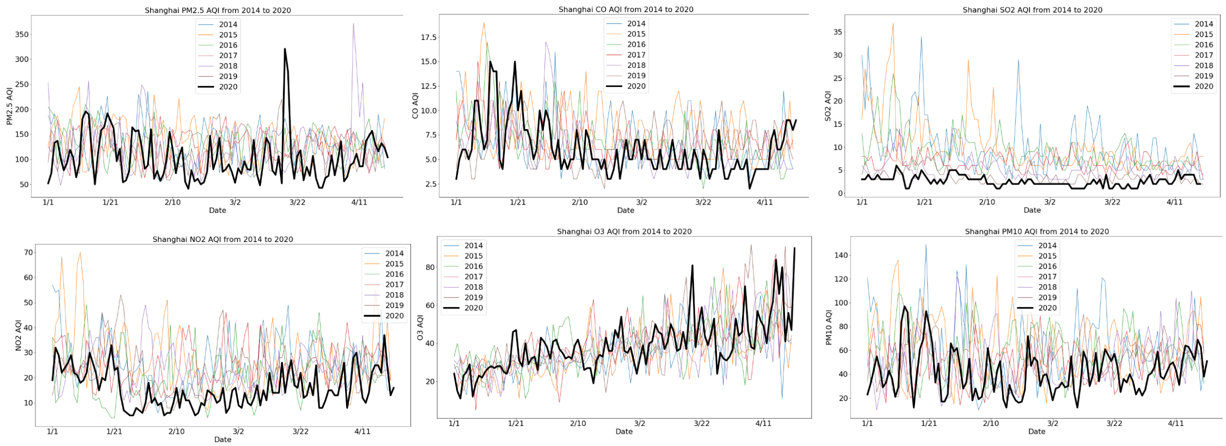
3. Results

(1) Air pollution levels for different pollutants in the 1st quarter over the past six years in major Chinese cities

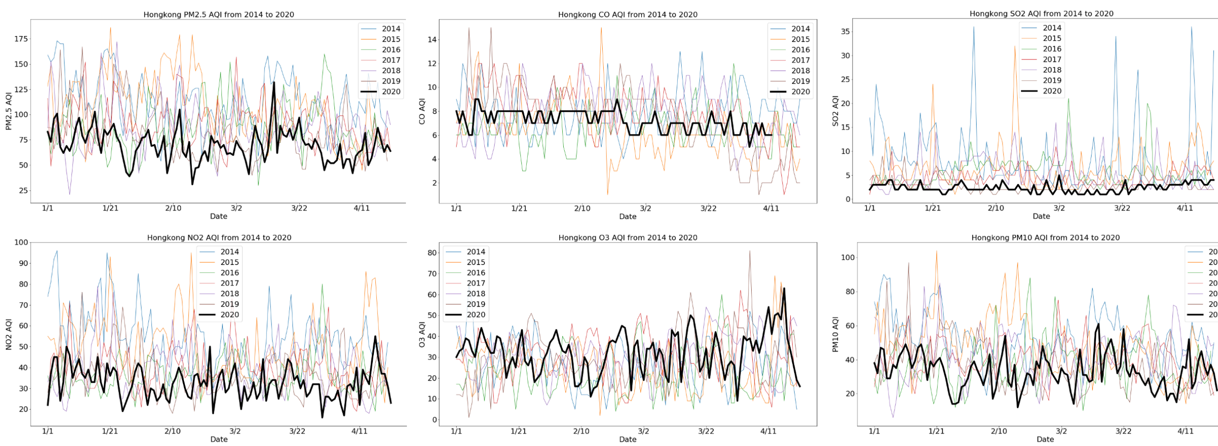
(a) Wuhan



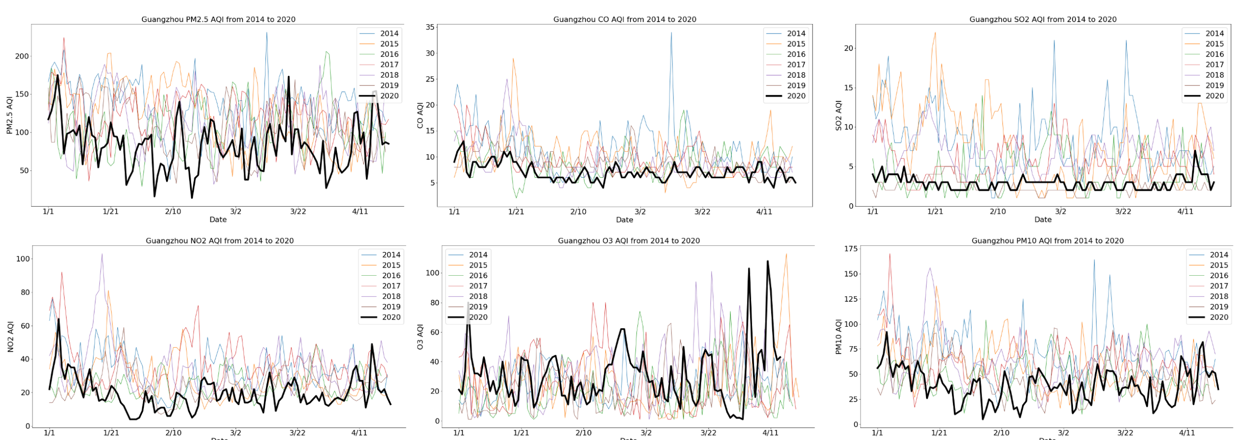
(b) Shanghai



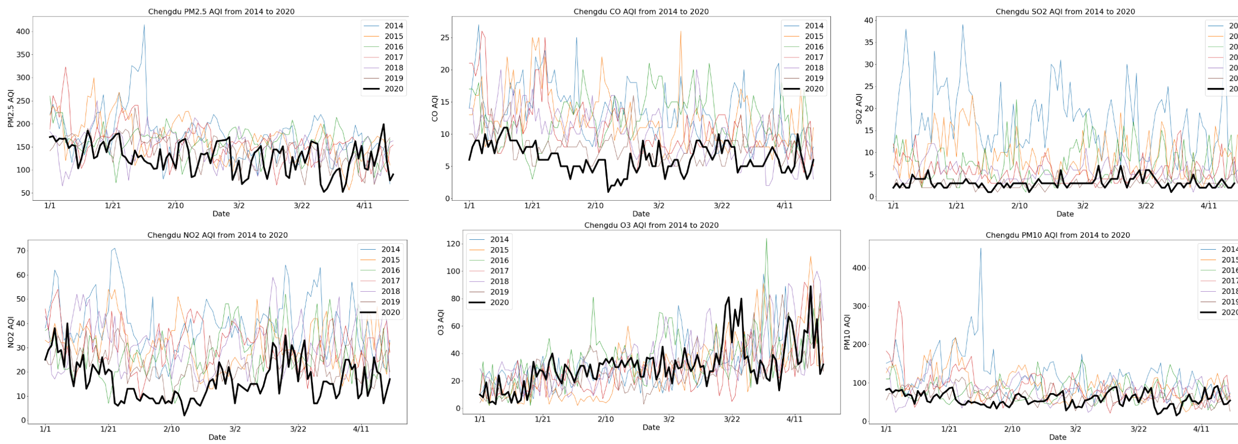
(c) Hongkong



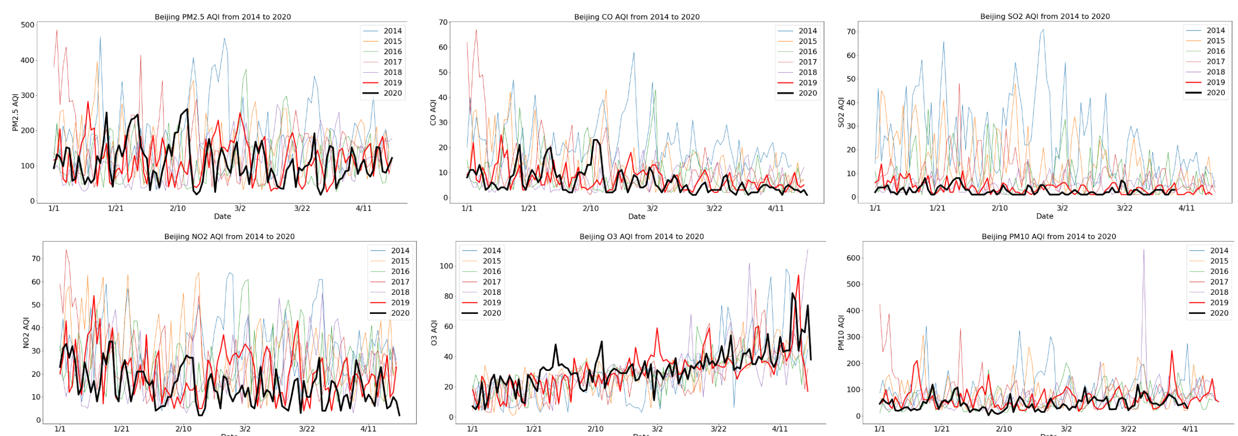
(d) Guangzhou



(e) Chengdu



(f) Beijing

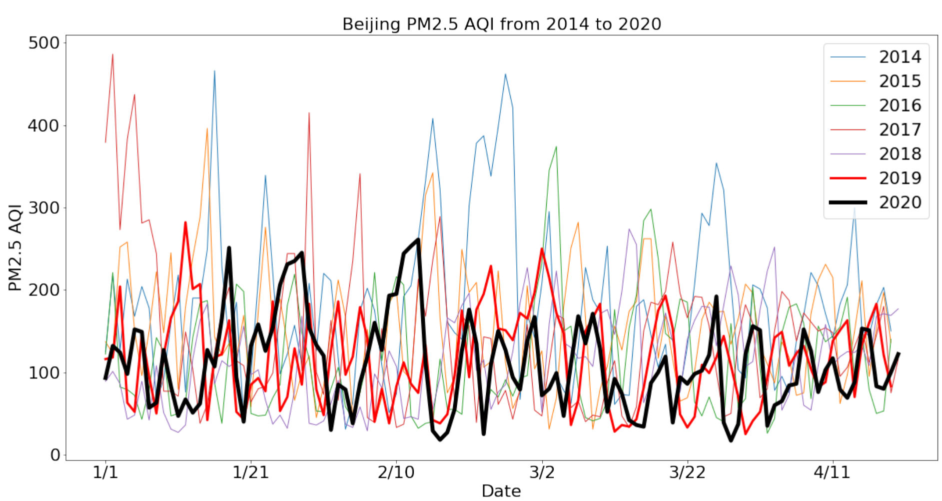


Based on the graphs for each pollutant in each city above, it is clear to see that the line represents the year 2020's data (dark black line) is on average much lower than that of the previous years. It is also essential to notice that in January 2020, most of the pollutants had around the same level in every city as in January 2019. However, the downward trend started to show up at the end of January when the lockdown period started in most of the cities in China. Moreover, this study verified the findings received by cross examining with other articles that received similar trends based on data from previous years (Kong et al., 2016).

(2) Compare the effects of this massive quarantine to the effects of previous environmental policies

Specifically, this study analyzed the air pollution trends in Beijing by comparing the AQI for 2020 to that in 2019 because since 2018, the Chinese government have implemented an enormous project by switching the central heating system in northern China from the traditional coal-fire burning system to the natural gas burning system. From the graph below, we can see that PM2.5 level in Beijing in 2020 (dark black line) was relatively similar to that in 2019 (bright red line), which are both lower on average than that of the previous years. This similarity also applies to other major pollutants in Beijing.

This is a significant finding because it demonstrated that the impacts of effective policy instruments can be similar (although not as effective) to that of a massive lockdown that essentially controlled the transportation and heavy manufacturing sectors. Therefore, it is essential for the Chinese government to propose effective environmental policies such as policy incentives to the installation of renewable energy sources. Moreover, China can also apply a market mechanism in address the environmental issues such as launching national cap-and-trade market for not only carbon emissions but also other major air pollutants.



PM2.5 Levels in Beijing Over the Years

4. Discussion

(1) Future Directions for Environmental Policies to Address Air Pollution in China

This study has shown that the transportation and heavy manufacturing sectors are the two major sectors that lead to the air pollution in China. However, the transportation sector is difficult to tackle due to the rapid urban expansion and increase in the household income in China will lead to a higher number of vehicles in China in the future. Typically, changes in transportation sector take longer to implement because the government usually used policy incentives to slowly change the behaviors instead of putting hard regulations. Therefore, the government should pay more attention on the heavy manufacturing industry. In March 2017, the Premier Li Keqiang has emphasized the need to reduce the national excess production capacity, including carbon-intensive coal and steel production. China's 13th Five Year Plan has specified a 15% reduction in energy consumption intensity and 18% drop in carbon dioxide emissions intensity. Furthermore, China is also pushing forward its renewable energy development. The share of coal in China's every mix has dropped by 9% from 2005 to 2015 and the non-fossil power generation has almost tripled. For example, the solar power capacity in China has increased by about 82% in 2016.

(2) Substitution Effects between Renewable Energy and Coal-fired Generation

It is important to notice that the substitution effect between the renewable and the coal-fired generation is not merely a "one-on-one" case in which the increase in wind and solar capacity replaces the equal amount of electricity generated from coal. Researchers from Peking University have found that in China, each unit of alternative energy displaces 0.231± 0.078 units of fossil-fuel-generated electricity, which is twice the global average level (Hu and Cheng, 2017). This is mainly attributed to the rapid increase in the demand for electricity during fast industrialization and urbanization over the past 15 years. To increase the utilization of renewable energy sources, a country has to either reduce the usage of coal-fired generation or bring about more demand in electricity, or both (Dong et al., 2018). However, since 2014, the increase in the need for electric power has slowed down due mainly to an economic deceleration in China, and the pressure for supply to meet the demand growth has also been lessened. Therefore, the Chinese government should seize this opportunity to push harder on phasing out coal power generation to accelerate its clean energy revolution and further decarbonize the electricity sector. Policy instruments such as a policy integrating carbon taxes, non-fossil fuels, and energy efficiency and advanced technologies, including better electricity storage systems should be applied together to cut coal consumption and greenhouse gas emissions in China.

5. Conclusion

The results from this study showed that there was a clear downward trend of all the major air pollutants in major cities in China after the massive lockdown due to the COVID-19 compared to that of the previous years. This study has also analyzed the impacts of effective environmental policies to that of the massive lockdown and found out that effective environmental policies can also create similar effects and the Chinese government should keep focusing on making optimal decisions to address environmental issues by proposing effective policies. Therefore, it is essential for China to replace the traditional fossil fuel burning industries and systems with cleaner technologies such as renewable energy or natural gas. In the meanwhile, the Chinese government should not ignore about the substitution effects between renewable energy system and coal-fired burning system to better address the environmental issues in China.

6. Reference

Dong, C., Y. Qi, W. Dong, X. Lu, T. Liu, and S. Qian. 2018. Decomposing driving factors for wind curtailment under economic new normal in China. Applied Energy 217:178–188

Chen, K., M. Wang, C. Huang, P. L. Kinney, and A. T. Paul. 2020. Air Pollution Reduction and Mortality Benefit during the COVID-19 Outbreak in China. medRxiv:2020.03.23.20039842.

Times (2020). Global Air Pollution Has Fallen Due to the Coronavirus Outbreak, but Experts Warn It Isn't a Silver Lining. Retrieved from https://time.com/5812741/air-pollution-coronavirus/

Kong, L., J. Xin, W. Zhang, and Y. Wang. 2016. The empirical correlations between PM2.5, PM10 and AOD in the Beijing metropolitan region and the PM2.5, PM10 distributions retrieved by MODIS. Environmental Pollution 216:350–360.

Ye Qi and Jiaqi Lu, "China's Coal Consumption Has Peaked," Brookings Institute. January 22, 2018. Link: https://www.brookings.edu/2018/01/22/chinas-coal-consumption-has-peaked/

Hu, Y., and H. Cheng. 2017. Displacement efficiency of alternative energy and trans-provincial imported electricity in China. Nature Communications 8.