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The effects of outdoor air pollution concentrations and lockdowns on Covid-19 infections in Wuhan and other provincial capitals in China

Preliminary version

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Abstract

Background: Covid-19 was first reported in Wuhan, China in Dec 2019. Since then, it has been transmitted rapidly in China and the rest of the world. While Covid-19 transmission rate has been declining in China, it is increasing exponentially in Europe and America. Although there are numerous studies examining Covid-19 infection, including an archived paper looking into the meteorological effect, the role of outdoor air pollution has yet to be explored rigorously. It has been shown that air pollution will weaken the immune system, and increase the rate of respiratory virus infection. We postulate that outdoor air pollution concentrations will have a negative effect on Covid-19 infections in China, whilst lockdowns, characterized by strong social distancing and home isolation measures, will help to moderate such negative effect .

Methods: We will collect the number of daily confirmed Covid-19 cases in 31 provincial capital cities in China during the period of 1 Dec 2019 to 20 Mar 2020 (from a popular Chinese online platform which aggregates all cases reported by the Chinese national/provincial health authorities). We will also collect daily air pollution and meteorology data at the city-level (from the Chinese National Environmental Monitoring Center and the US National Climatic Data Center), daily inter-city migration flows and intra-city movements (from Baidu). City-level demographics including age distribution and gender, education, and median household income can be obtained from the statistical yearbooks. City-level co-morbidity indicators including rates of chronic disease and co-infection can be obtained from related research articles. A regression model is developed to model the relationship between the infection rate of Covid-

19 (number of confirmed cases/population at the city level) and outdoor air pollution at the city level, after taking into account confounding factors such as meteorology, inter- and intra-city movements, demographics, and co-morbidity and co-infection rates. In particular, we shall study how air pollution affects infection rates across different cities, including Wuhan. Our model will also study air pollution would affect infection rates in Wuhan before and after the lockdown.

Expected findings: We expect there be a correlation between Covid-19 infection rate and outdoor air pollution. We also expect that reduced intra-city movement after the lockdowns in Wuhan and the rest of China will play an important role in reducing the infection rate.

Interpretation: Infection rate is growing exponentially in major cities worldwide. We expect Covid-19 infection rate is related to the air pollution concentration, and is strongly dependent on inter- and intra-city movements. To reduce the infection rate, the international community may deploy effective air pollution reduction plans and social distancing policies.

Keywords: Covid-19, infection rate, air pollution, lockdown, China

Research in context

Evidence on the relationship between air pollution and respiratory virus infection: Previous studies suggested that higher outdoor air pollution concentrations can increase the risk of respiratory virus infection. The relationship can be explained by (1) airborne transmission [1], and (2) exacerbated susceptibility [2]. As Covid-19 is a respiratory disease, we hypothesize that Covid-19 infections are closely linked to outdoor air pollution concentrations.

Evidence on factors affecting Covid-19 infections: A systematic review is conducted based on Covid-19 Open Research Dataset (CORD-19), which covers over 29,000 scholarly articles about Covid-19 and the Coronavirus family of viruses, and the literature that cover flu via Google Scholar. The following factors are closely correlated with Covid-19 infections:

- Biological factors: age, gender, …
- Social factors: lockdown, …
- Lifestyle factors: smoking, …
- Environmental factors: temperature, humidity, …

Added value of this study:

- To the best of our understanding, this is the first study that investigates the effects of outdoor air pollution concentrations and lockdown on Covid-19 infections in China.

Implications:

- Expected: Reducing air pollution can mitigate Covid-19 infections in Wuhan and the other 30 provincial capitals in China.
- Expected: Effective lockdown policies introduced in Wuhan and other parts of China, such as social distancing and home isolation measures that reduce inter- and intra-city movements, and subsequent human interactions, are critical for Covid-19 infection control.
- Expected: A study that investigates the underlying biomedical mechanisms that link air pollution with Covid-19 infection may be fruitful.

1. Introduction

- Background of Covid-19 epidemic: The first case of Covid-19 infection was reported in Wuhan, China in Dec 2019
  - Highly contagious
  - Large number of asymptotic cases exist in the community. Since they are infective, but not easily detected, leading to substantial underestimation of Covid-19 infection rate. A statistical method that accounts for the asymptotic cases, and the associated infection models that recover the true number of Covid-19 infections are needed for rigorous Covid-19 infection modeling.
- Previous studies about Covid-19 infections examined the following:
  - Biological factors: age, gender, etc., from clinical studies [3, 4]
  - Social factors: lockdowns have been implemented at different scales across China [5]
  - Lifestyle factors: smoking [21]
  - Other factors
- The effect of outdoor air pollution concentrations on Covid-19 infections is yet to be examined:
  - Previous studies suggested that air pollution and/or weather conditions may increase the risk of influenza infection [6-14]
  - Such relationships were also observed in SARS and MERS [15, 16]
  - Recent work suggested that meteorological conditions are associated with Covid-19 spread [17, 18]
  - Recent evidence suggested that the Covid-19 virus can stay in air for at least half an hour and aerosol transmission is possible [19, 20]

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- Recent work demonstrated that smokers have higher risks of Covid-19 infection, implying that indoor air pollution can be a risk factor [21]
- As of to date, no rigorous study has yet been done to investigate the effect of outdoor air pollution concentrations on Covid-19 infections in Wuhan and the rest of China.

- To fill this gap, we examined the relationship between outdoor air pollution concentrations and Covid-19 infections in China, while accounting for the inconsistencies in Covid-19 case reporting and the potential impacts of lockdowns on 31 provincial capitals in China, including Wuhan.

2. Methods

2.1 Unit of analysis and data collection

- 31 provincial capital cities in China, including Wuhan, the epi-center of Covid-19 outbreak
- Period covered: 1 Dec 2019 to 20 Mar 2020 (starting from the official date of the first case [4, 22, 23])
- Data collected on a daily basis at the city level

2.2 Data sources

- Covid-19 infection: no. of daily confirmed cases from a popular online platform which aggregates the cases reported by the Chinese national/provincial health authorities
- Environmental factors: daily city-level air pollution and meteorology data from the Chinese National Environmental Monitoring Center and the US National Climatic Data Center
- Social factors: inter- and intra-city movements from Baidu
- Clinical factors: co-morbidity indicators, including the rates of chronic disease and co-infection. Chronic diseases rate and co-infection rate can be obtained from relevant medical literature [24]
- Demographic factors: population size, age, gender, socio-economic status from official statistical yearbooks

2.3 Covid-19 infection estimation modeling

- Estimating Covid-19 infections using observational data
  - Confirmed cases: Recover the no. of confirmed Covid-19 cases after the official re-adjustment of “confirmed cases” definition in China, using the discontinuity test based on the assumption of normal distribution.

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- Total cases: Based on [25], estimate the total number of infections, including the confirmed cases and the asymptotic cases.

- A regression model is used to examine the relationship between outdoor air pollution concentrations and Covid-19 infections
  - Variables: The dependent and independent variables are selected based on Covid-19 Open Research Dataset (CORD-19) and other relevant influenza studies.
  - The variable lockdown is included in our regression model to capture its effect on Covid-19 infections.
  - Concept model: Covid-19 infection rate = Intercept + Air pollution + Meteorology + Demographics + Co-morbidity + Co-infection + Lockdown + Error term

3. Results

- Testing our hypothesis: The effects of outdoor air pollution concentrations (e.g., $PM_{2,5,\ 10}$, NO_2, SO_2, O_3, CO) and lockdowns on Covid-19 infections are statistically significant

4. Discussions

- Research significance:
  - To the best of our understanding, this is the first study that investigates the effects of outdoor air pollution concentrations and lockdowns on Covid-19 infections in China, from a public health and environmental perspective.
  - We develop a statistical method to readjust the number of confirmed Covid-19 cases shortly after the lockdowns in China, in order to reduce the inconsistency and bias in relation to no. of officially reported confirmed cases in Wuhan and other parts of China as a result of an abrupt change in the definition of "confirmed cases", using the discontinuity test, based on the assumption of normality.
  - We develop an infection model that accounts for both the confirmed cases, and the potential no. of asymptotic cases in 31 provincial capital cities in China.
  - In our infection rate regression model, we have accounted for confounding factors such as lockdowns (which can have effects on both outdoor air pollution and infection rate), socio-economic variation, co-morbidity, co-infection, etc.
- Implications:
  - Reducing air pollution can mitigate Covid-19 infections in Wuhan and the remaining 30 provincial capitals in China.

- Effective lockdown policies such as measures that reduce inter- and intra-city movements are critical for Covid-19 infection control.
- A study that investigates the underlying pathological pathway linking Covid-19 infection with outdoor air pollution may be fruitful.

- Comparison study with previous findings on infection rates:
  - Discovery of new additional factors that may significantly affect Covid-19 infection rate: demographics, co-morbidity, co-infection, lockdowns.
  - Similarities and differences as compared to previous influenza-related findings

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