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THOUGHT LEADERSHIP BRIEF

COVID-19 Series

COVID-19, City Lockdowns, and Air Pollution: Evidence from China

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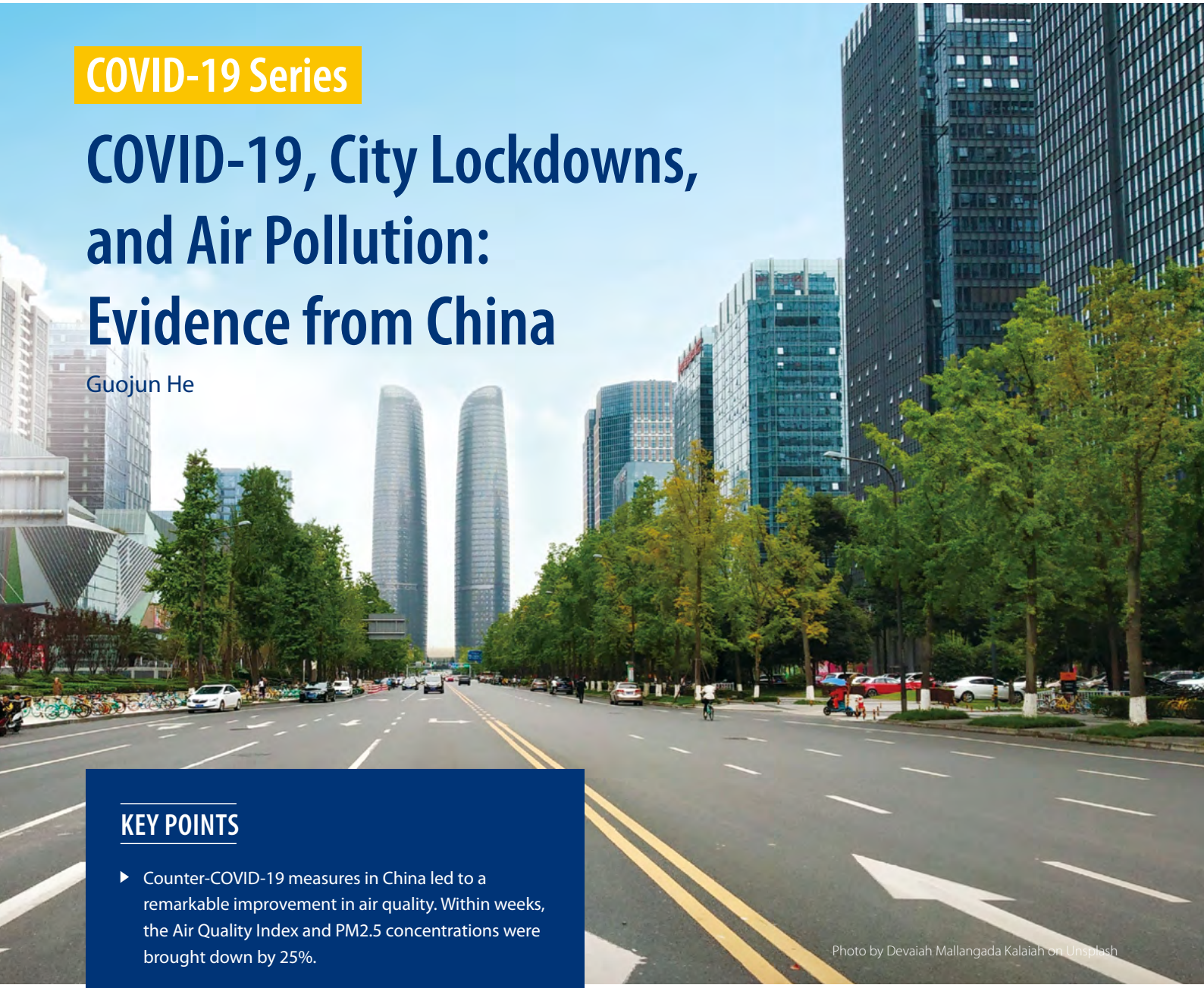

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KEY POINTS

- Counter-COVID-19 measures in China led to a remarkable improvement in air quality. Within weeks, the Air Quality Index and PM2.5 concentrations were brought down by 25%.
- Given what is known from other research by the authors on the impact of air pollution on mortality in China, we estimate that the counter-COVID-19 measures averted 24,000 to 36,000 premature deaths on a monthly basis.
- While the air quality improvement during this period was unprecedented, the air pollution levels during the lockdown remained high. This highlights that, without further reducing reliance on coal, it will be a real challenge for China to fully realize the potential health benefits of winning its "war against pollution".

ISSUE

In December 2019, an unknown disease, later named COVID-19, was identified in Wuhan, China. Within three months, the disease had affected more than 100 countries. The explosion of COVID-19 cases around the world has made it a global pandemic with devastating consequences. To contain the virus, many countries have adopted dramatic measures to reduce human interaction, including enforcing strict quarantines, prohibiting large-scale private and public gatherings, restricting private and public transportation, encouraging social distancing, imposing curfews, and even locking

down entire cities. While the economic costs of enforcing these preventive measures are undoubtedly enormous, these measures could unintentionally bring about substantial social benefits. Among them, locking down cities could significantly improve environmental quality, which would partially offset the costs of these counter-COVID-19 measures.Gaining a more complete picture of the benefits and costs of city lockdowns in response to COVID-19 thus requires accurate quantitative assessments of the environmental benefits of the counter-COVID-19 measures.

We focus on China for two reasons. First, China was hit hard by the COVID-19 outbreak, and the Chinese government launched draconian countermeasures to prevent the escalation of infections. Nearly one-third of Chinese cities were locked down in a top-down manner, and various types of economic activities were strictly prohibited. In these cities, individuals were required to stay at home; unnecessary commercial operations and private and public gatherings were suspended; all forms of transportation were largely banned (both within a city and across cities); and mandatory temperature checking could be found in most public facilities. Second, China also suffers greatly from severe air pollution, with some estimates suggesting that air pollution is associated with an annual loss of nearly 25 million healthy life years. If locking down cities significantly improved the air quality in China, the implied health benefits would be an order of magnitude larger than in countries with lower initial pollution levels.

ASSESSMENT

Using timely and comprehensive air quality data for China, we show that counter-COVID-19 measures led to a remarkable improvement in air quality. Within weeks, the Air Quality Index and PM2.5 concentrations were brought down by 25%. The effects are larger in colder, richer, and more industrialized cities. We estimate that such improvement would avert 24,000 to 36,000 premature deaths from air pollution on a monthly basis.

We collect data on local governments' lockdown policies city by city from news media and government announcements. Each lockdown was implemented by the city government and had to be approved by the provincial government. Because the disease prevalence varied greatly across different regions, the terms and requirements of the lockdown also differed across provinces and cities. We define a city as locked down when all three of the following preventive measures were enforced: 1) prohibition of unnecessary commercial activities in people's daily lives, 2) prohibition of any types of gathering by residents, 3) restrictions on private (vehicle) and public transportation. Figure 1 presents a map of the location of locked down cities. The map shows that, in most cities near Wuhan, the strict lockdown was enforced. However, there is considerable variation in the lockdown status for cities that are far away from Wuhan. Following our definition, 95 out of 324 cities were locked down during our study period.

Figure 1. Map of the Locked-down Cities

Notes: This map shows which cities were locked down during the COVID-19 pandemic. The blue diamond represents locked-down cities. Overall, 95 out of 324 cities were locked down. The orange triangle indicates Wuhan city, where COVID-19 was first identified in China.

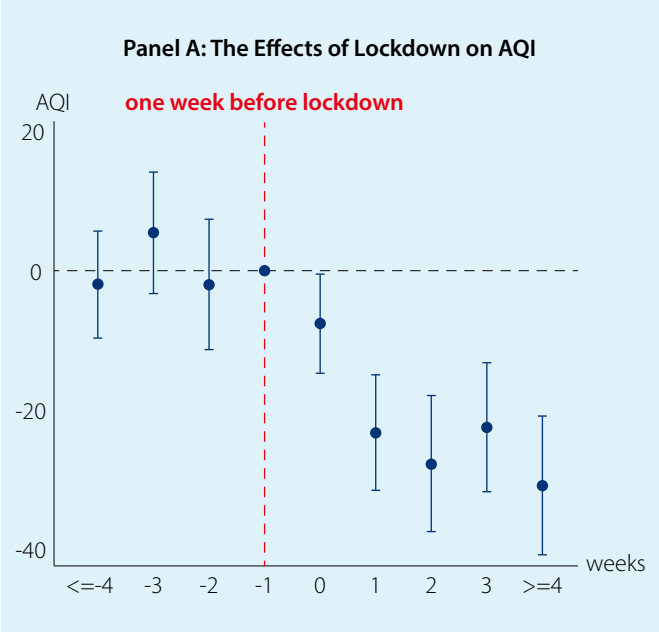
Because the risk of disease transmission differed substantially across different locations and different periods, the timing of the lockdowns also varied. We thus estimate a set of difference-in-differences (DiD) models to quantify the impact of a city's lockdown on air pollution. Our empirical analysis uses comprehensive air quality data collected from 1,600 monitoring stations covering all the prefectural cities in China. We aggregate the station level data to the city level and further combine them with weather variables, including temperature, precipitation, and snow. The air quality data are collected from the Ministry of Ecology and Environment, and the weather data are collected from the Global Historical Climatology Network of the U.S. National Oceanic and Atmospheric Administration.

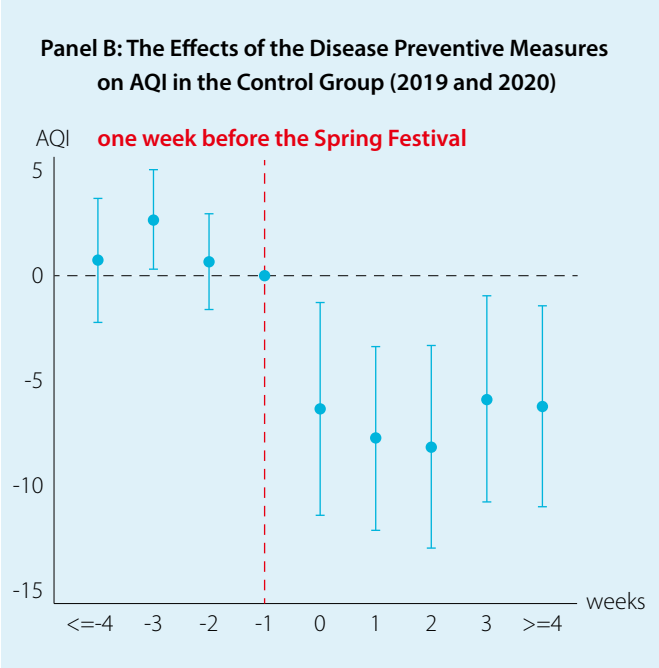
We find that lockdowns indeed improved air quality. Compared to cities without formal lockdown policies, the weekly Air Quality Index (AQI) and PM2.5 concentration in the locked down cities declined by 19.4 points (18%) and 13.9 μg/m3 (17%) respectively. To address the concern that cities without formal lockdown policies might also have been affected by the preventive measures (e.g., all cities extended the Chinese Spring Festival holiday, required social distancing, and urged people to stay at home), we estimate another set of DiD models, comparing the changes in air pollution levels in these (no-lockdown) cities before and after the Spring Festival relative to the previous year; we find that in these cities the AQI and PM2.5 decreased by 8.8 points (7%) and 8.4 μg/m3 (8%). The overall improvement in both AQI and PM2.5 due to the counter-COVID-19 measures is estimated to be around 25% in locked down cities and 7~8% in other cities.

The effect of a lockdown differs considerably across different types of cities. We find that the richer, more industrialized, and colder cities experienced larger reductions in air pollution levels. For example, we estimated that the lockdown reduced the AQI by more than 30 points in cities with more manufacturing output, which is three times larger than its impact on cities with lower manufacturing output. We examine city-by-week panel data in 324 Chinese cities from the period of January 1st to March 1st, which covers several weeks before and after the introduction of city lockdowns. During this period, the average AQI is 74, with a standard deviation of 42. The PM2.5 concentration is 52 μg/m3, five times higher than the WHO standard (10 μg/m3 for annual mean, and 25 μg/m3 for a daily mean). Cities that were locked down were, on average, more polluted than the control cities before the lockdowns. This is likely because Wuhan and its neighboring cities are generally more polluted than cities that are far away. We also see a sharp decline in AQI after the lockdown.

Figure 2. The Effects of Lockdown Before and After its Implementation

Notes: Panel A compares the difference in air pollution levels between lockdown cities and non-lockdown cities before and after the lockdown implementation. Panel B compares air pollution levels in the non-lockdown cities before and after the Spring Festival between 2019 and 2020.





RECOMMENDATIONS

The remarkable improvement in air quality has three important implications. First, it could potentially bring about massive health benefits. A back-of-the-envelope calculation based on our previous research shows that the improved air quality induced by the counter-COVID-19 measures could avert 24,000 to 36,000 premature deaths on a monthly basis,which is an order of magnitude larger than the number of deaths caused directly by COVID-19 in China. Because air pollution also affects morbidity, productivity, and defensive expenditure (e.g., air filters), the implied benefits could be even greater if such improvement could be sustained. Second, our findings confirm the intuition that traffic, industrial, and business activities are important sources of air pollution. This provides a benchmark for future environmental regulation and highlights the necessity to control emissions from these sources when business goes back to normal. Finally, while the air quality improvement during this period was unprecedented, the air pollution levels during the lockdown remained high. For example, the PM2.5 concentration in locked down cities was still more than four times higher than WHO considers safe (10 μg/m3 for the annual mean), even though almost all non-essential production and business activities were suspended. This finding suggests that other sources of air pollution continue to contribute significantly; in particular, the coal-fired winter heating system could be the primary polluting source during our study period. Our research highlights that, without further reducing its reliance on coal, it will be a real challenge for China to fully realize the potential health benefits of winning its "war against pollution".

We conclude by pointing out some caveats of this study. First, we only consider the short-term effects of city lockdowns. As cities resume normal activities, the health benefits of air quality improvement could be offset in the longer term. Second, we examine the effect of city shutdowns on outdoor air quality and do not account for indoor air quality. More people likely spent their time indoors during the lockdown. If indoor air quality is worse than outdoor air quality (e.g., some areas rely heavily on inefficient coal-fired stoves for heating), the beneficial effects from better outdoor air quality could be reduced. Finally, our calculation of the averted number of deaths is not based on actual mortality data, which are not yet available. If COVID-19 or city lockdown affects mortality through other channels, the overall mortality costs could be higher or lower, depending on how different channels are affected. For example, medical resources in many cities ran short immediately after the disease outbreak, thus patients could die because they were unable to receive timely and proper treatment. The counter-virus measures also negatively affected the economy and employment, which are detrimental to population health. In such cases, more excess deaths could be caused by economic consequences than were saved by reduced pollution. On the other hand, COVID-19 may have increased individuals' awareness of their health conditions and made people practice good hygiene. This could significantly reduce deaths from other diseases, particularly influenza. While estimating the overall mortality cost of COVID-19 and city lockdown is beyond the scope of our paper, future research on these issues is warranted to understand the full implications of the COVID-19 pandemic.

Guojun He is an economist working on environmental, development, and governance issues. Currently, he is an assistant professor appointed jointly at Division of Social Science, Division of Environment and Sustainability, and Department of Economics at The Hong Kong University of Science and Technology. He is also a faculty affiliate of HKUST Institute for Emerging Market Studies and Institute for Public Policy. In addition, Prof He holds a concurrent appointment at the University of Chicago's interdisciplinary Energy Policy Institute (EPIC) and serves as the research director of its China center (EPIC-China).

Prof He's research tries to address some of the most challenging problems faced by developing countries and seeks to produce empirically-grounded estimates for optimal policy design. The majority of his work focuses on understanding the benefits and costs of environmental policies, while he also has a broader research interest in development and governance issues.

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