GLOBAL RESEARCH IMMERSION PROGRAM FOR YOUNG SCIENTISTS

Increasing air pollution-related health inequality in China

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1. Motivation

Clean Air Actions (CAAs) in China since 2013 have successfully reduced heavy haze pollution in China. By 2020, China has achieved the first phase target of maintaining annual average fine particulate matter ($PM_{2.5}$) level below 35 μg m^{-3}, alleviating the air pollution-related health burdens. The clean air policies are not only supposed to reduce overall air pollution levels but also to promote environmental justice by ensuring equal protection from environmental hazards for all individuals. However, the impacts of CAAs on air pollution-related health inequalities and whether the benefits of CAAs are distributed equally across China remain unclear.

Therefor, this study aims to:

- assess the evolution of $PM_{2.5}$-related and ozone (O_3)-related health inequalities in the past two decades and near future;
- analyze the factors affecting such inequalities.

2. Methods

We combined historical gridded air pollution datasets, simulated future air quality from the Community Earth System Model (CESM), integrated exposure-response model (IER), and inequality indicators to estimate air pollution-related premature deaths and their spatial disparities in China. We then decomposed the health inequalities to examine the key drivers.

➢ Air pollution-related health impact assessment:

$$\Delta Mortality = y_0 \times Pop \times (1 - RR^{-1})$$

$$RR = f(PM_{2.5}\ or\ O_3)$$

ΔMortality: the health burden caused by air pollution; y_0: baseline mortality; *Pop:* population; *RR*: relative risk calculated by a function of air pollution levels.

➢ Inequality assessment:

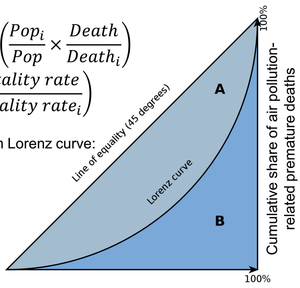
Theil index sensitive to the deviation between the mortality rate of individual and average:

$$Theil = \sum_i \frac{Pop_i}{Pop} \ln\left(\frac{Pop_i}{Pop} \times \frac{Death}{Death_i}\right) = \sum_i \frac{Pop_i}{Pop} \ln\left(\frac{Mortality\ rate}{Mortality\ rate_i}\right)$$

Gini index established from Lorenz curve:

$$Gini = \frac{A}{A+B}$$

Death: air pollution-related premature deaths



➢ Decomposition analysis:

Logarithmic Mean Divisia Index (**LMDI**) is applied to decomposed Theil index into four items: emission intensity (EI), energy intensity (EnI), GDP per capita (PGDP), and population growth.

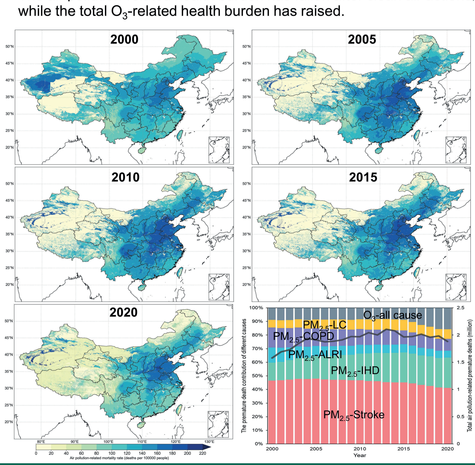
$$EI = \frac{Death}{EC} \qquad EnI = \frac{EC}{GDP} \qquad PGDP = \frac{GDP}{Pop}$$

EC: electricity consumption; y_0: baseline mortality; *GDP*: gross domestic product;

3. Results

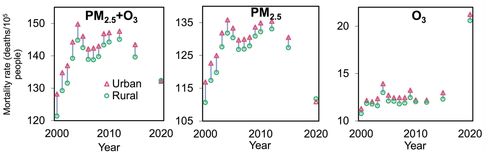
➢ Mortality estimation:

The air pollution-related health burden has fallen after clean air actions, while the total O_3-related health burden has raised.



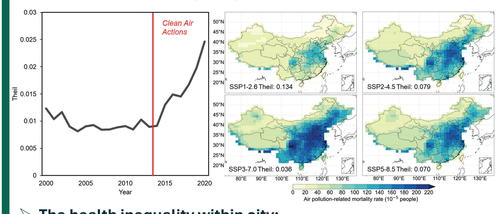
➢ Urban-rural difference:

The mortality rate is higher in urban than the rural due to higher population density and air pollution levels. But for $PM_{2.5}$, this urban-rural gap has been closed. Notably, the $PM_{2.5}$-related mortality rate is even higher in rural regions.



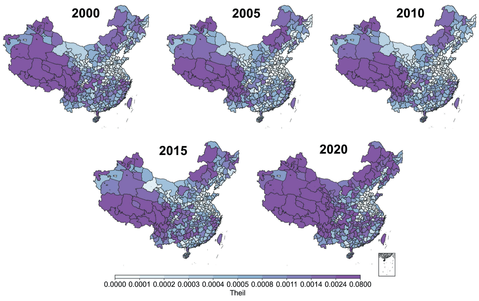
➢ The trend of health inequality:

The implementation of CAAs has exacerbated inequality, as indicated by the upward trend of the Theil index, which increased from approximately 0.01 during 2000–2014 to 0.025 in 2020. We projected that spatial disparities will further intensify under future Shared Socioeconomic Pathways (SSPs) in 2050.



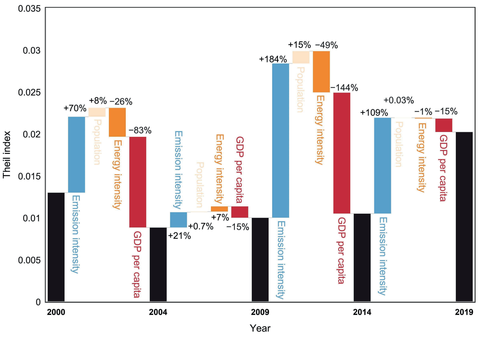
➢ The health inequality within city:

In addition to national level, we also calculated the health inequality of internal city. Apart from north China plain, the health inequalities of other regions are all worsen.



➢ Decomposition analysis:

Two of the four factors play the dominant role: the positive effects by emission intensity and the negative effects by GDP per capita. The difference in air pollution related health burden caused by unit energy use is the main factor leading to the uneven distribution of air pollution related health outcomes. Reducing economic disparities between regions is a good pathway for narrowing health inequality.



4. Conclusions

The air pollution-related health burden has fallen after clean air actions, while the total O_3-related health burden has raised. The air pollution-related health inequalities have been worsened after clean air actions and are projected to be increased under future scenarios (SSPs). The increasing spatial disparities of energy structure is the key factor leading the health inequality increase, while the closing gap of regional economic development is benefits for reduce such inequality. Green development is required.

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