Population burdens of air pollution around the world: Distributions, inequalities, and links to per capita GDP

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Scan me!

Introduction

- Air pollution exposure has been increasing over time, and it is a high-risk factor for global health (Gakidou et al., 2017).
- More than half of the global population is exposed to shallow-quality air, with PM 2.5 concentration more than 35 $\mu g/m3$ (Pirlea and Huang 2019; Shaddick et al. 2020).
- Scientific literature has shown air pollution inequalities in different dimensions, such as racial groups, income, and locations (Fairburn et al. 2019).
- Little evidence on the global analysis of air pollution distribution and disparities.

This paper

1. Uses satellite pollution and population data to analyze the global burden of pollution across and within locations, with population weighting.
2. Analyzes air pollution disparities across and within locations.
3. Investigates the correlation between GDP per capita and air pollution burden.

We contribute to the literature by analyzing inequalities in air pollution distributions across and within regions and countries, globally.

Data

1. Air pollution by aerosols is measured using Aerosol Optical Depth (AOD) data obtained from NASA Earthdata.
   - 3km x 3km cells ($\approx 0.027°$).
   - Multiple observations per day.
   - 0.1 indicates a clear sky, and 1 indicates very hazy conditions.
   - Aggregate cells to 1° latitude and longitude combinations.
2. Global-gridded population data from Socioeconomic Data and Applications Center (SEDAC).
   - Population count estimates by gender and 5-year age groups.
   - Use the 110km x 110km grid version (1° combination).
   - Gender and age groups are combined into a single demographic category.
3. National and subnational from the Gridded Global Datasets for GDP (Kummu, Taka, and Guillaume 2018).

Distributional statistics

- Population-weighted AOD distributions:

$$\mu_r = \sum_{c\in C_r} s_{c,r} \cdot a_c$$

- Excess burden of pollution:

$$e_{r,\text{global}} = \frac{\overbrace{\left(\frac{\left(\sum_{c\in C_r} s_c\right)\cdot \mu_r}{\mu_{\text{global}}}\right)}^{\text{Location } r \text{ pop-weighted pollution share}}}{\underbrace{\left(\sum_{c\in C_r} s_c\right)}_{\text{Location } r \text{ population share}}} - 1 = \frac{\mu_r}{\mu_{\text{global}}} - 1\ .$$

- Estimate a linear relationship between AOD measures and PM 2.5 levels. Then, we use the linear coefficient to transform AOD measures into PM 2.5 levels.

$$PM_{2.5it} = \alpha + \beta AOD_{it} + \epsilon_{it}$$

Percentile exposure

Using cell-level data on mean AOD exposure and population, we calculate the percentile pollution exposure as follows:

1. Sort cells from the lowest to the highest average AOD measure values.
2. Associate the population share with each cell.
3. Construct the CDF using population information.
4. Get percentile exposure by checking percentile and cell average AOD measure value associated.

Distributional results

- Asia is the region with the highest air pollution, and Oceania has the lowest burden.
- Africa exhibits the highest inequality in air pollution exposure, whereas Europe shows the least inequality.
- Average exposures vary dramatically across regions. Asia, the most polluted continent, experiences exposure levels 3.3 times higher than Oceania, the least polluted continent.
- Exposures vary dramatically within regions. Africa and Europe, respectively, 80/20 exposure ratios are 141% and 28%.

Figure 1. Population-weighted distribution of air pollution by aerosols, 2010.

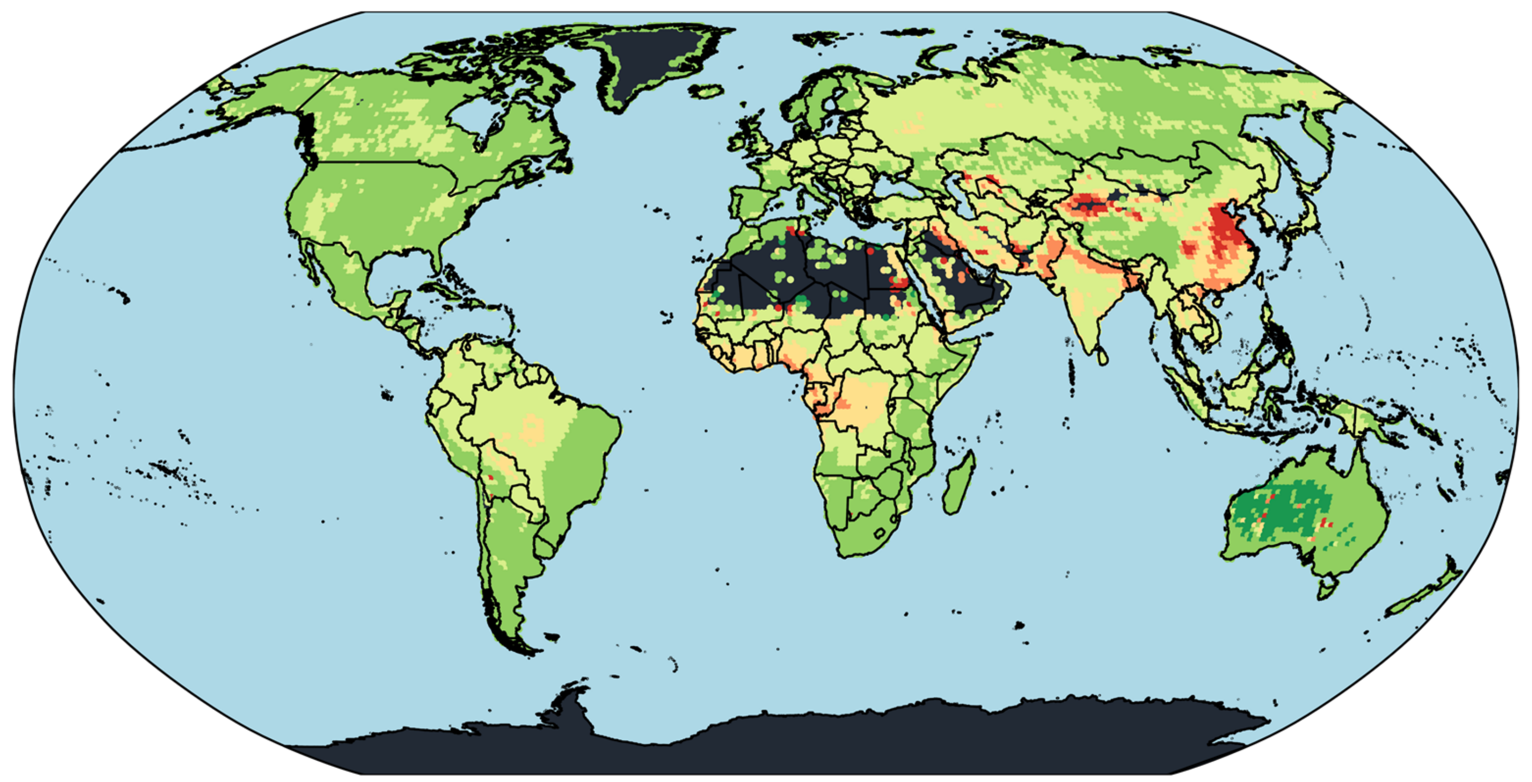


Figure 2. Population-weighted distribution of air pollution by region, 2010.

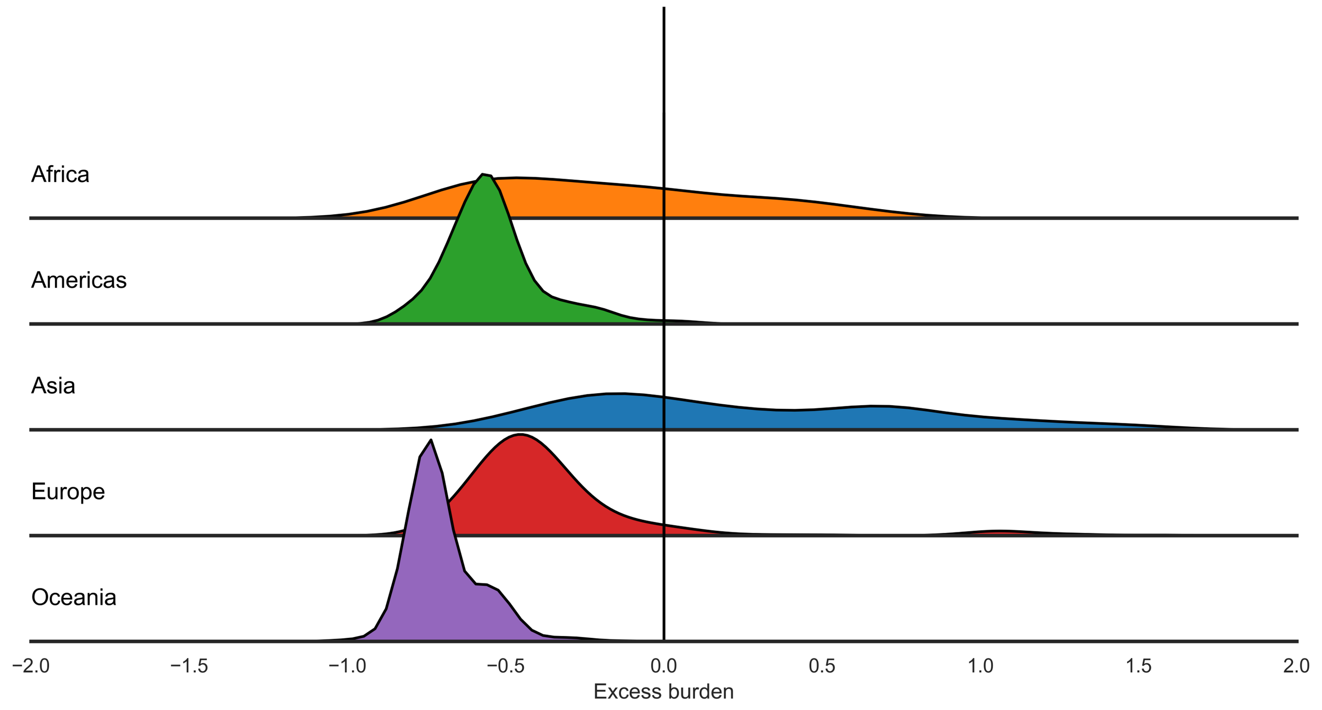
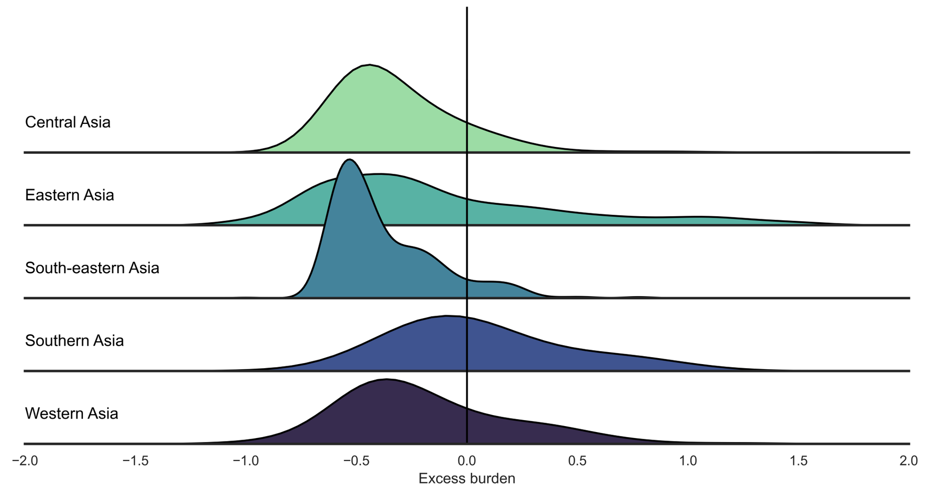
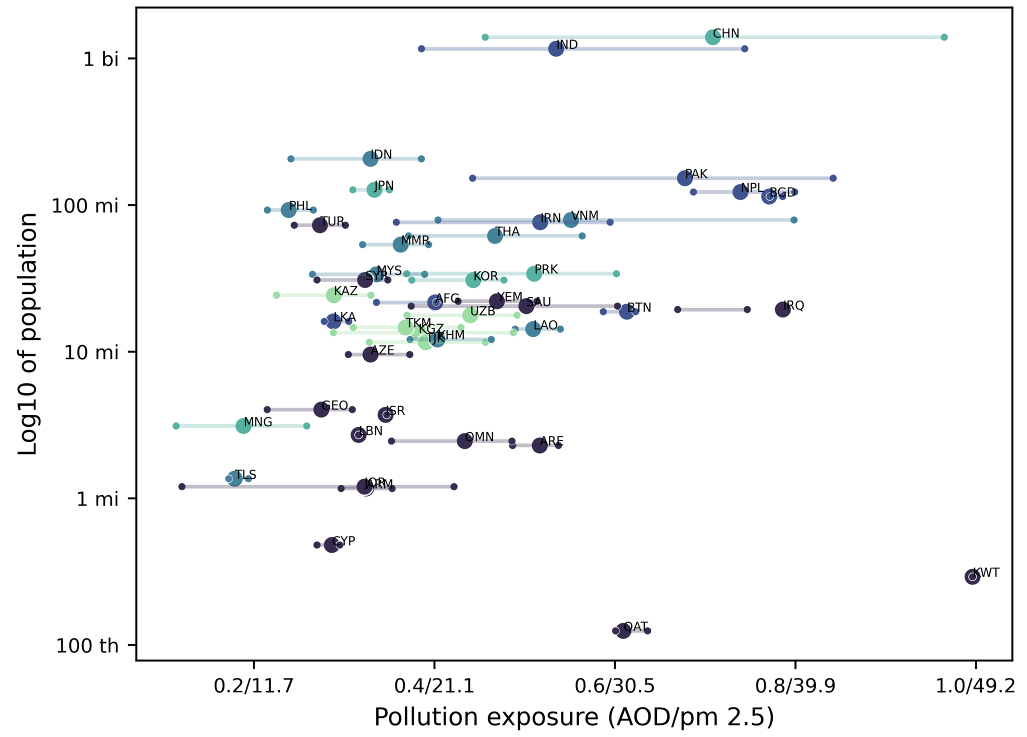


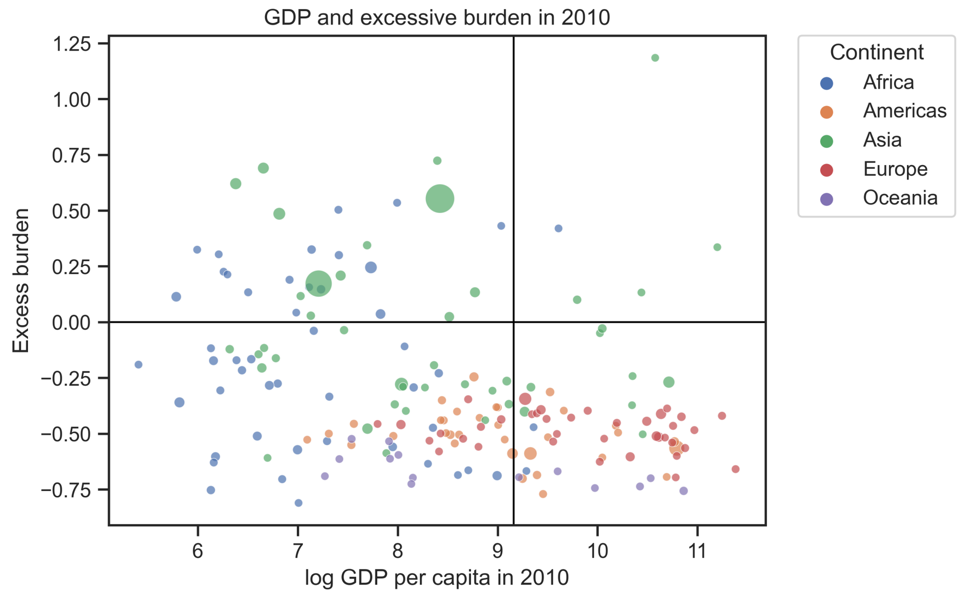
Figure 3. Population-weighted distribution of air pollution by aerosols in Asia, 2010.





Air pollution by aerosols and GDP per capita

Figure 4. Global association between air pollution by aerosols and GDP per capita, 2010.



Conclusions

- Global exposure disparities substantial along multiple location dimensions:
  - Average exposures vary dramatically across regions.
  - Exposures vary dramatically within regions.
- There is an overall negative correlation between GDP per capita and air pollution, but patterns differ across regions.

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