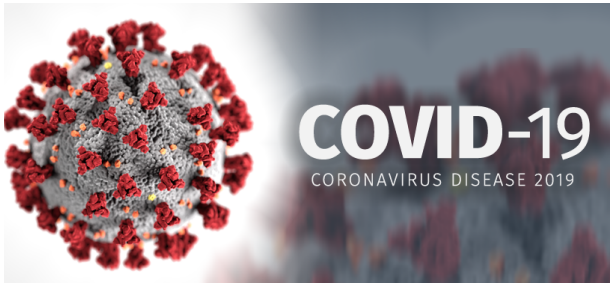

Effects of thermal inversion induced air pollution on COVID-19

Hannah Klauber

United Nations ESCAP - Online Research Symposium:
Tools for Determining the Causes of Air Pollution Affecting Thailand

Bangkok August 25-26th

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Mercator Research Institute on
Global Commons and Climate Change

1. Introduction

The link between air pollution and COVID-19

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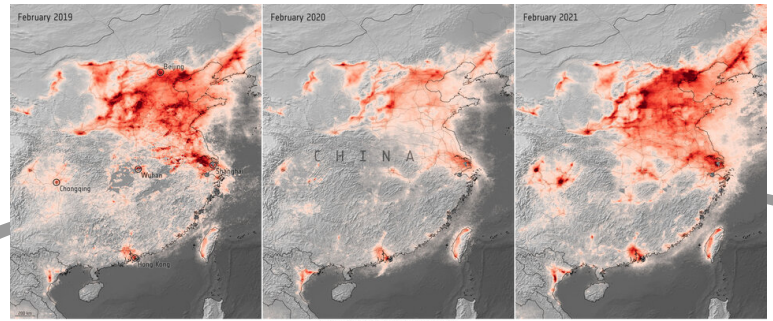
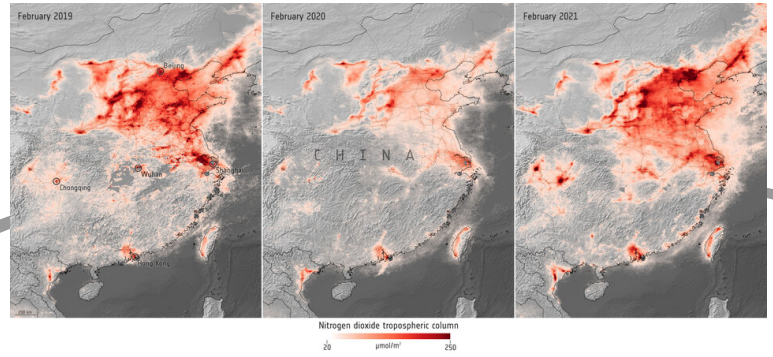


I) COVID-19 responses improved health by decreasing air pollution levels

(e.g. Chen et al. 2020; He et al. 2020)

COVID-19 → Health ← Air Pollution

The link between air pollution and COVID-19



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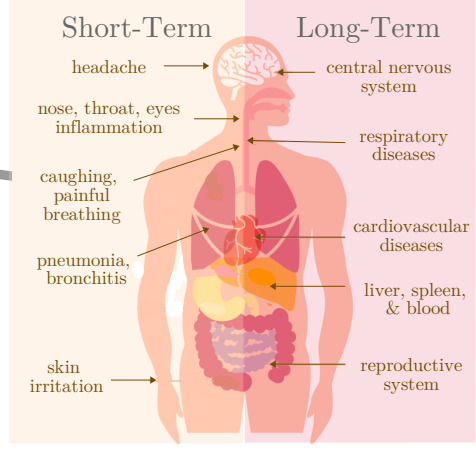

II) Long-run air pollution exposure is linked to pre-conditions that can exacerbate the course of COVID-19

(e.g. Wu et al. 2020; Analitis et al., 2006; Le Tertre et al., 2002; Dominici et al. 2003)

III) Short-term air pollution exposure leads to inflammatory reactions and lower immune responses to new infections

(e.g. Isphording and Pestel 2021, Persico and Johnson 2021,Travaglio 2021, Austin 2020)

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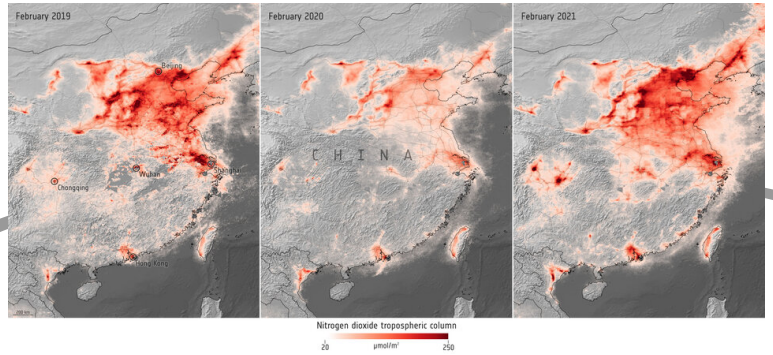
The link between air pollution and COVID-19



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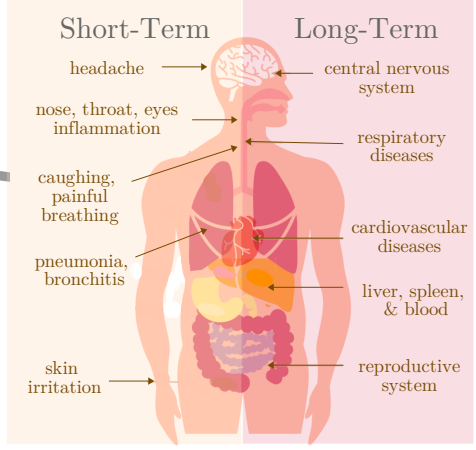
COVID-19 → Health ← Air Pollution



II) Long-run air pollution exposure is linked to pre-conditions that can exacerbate the course of COVID-19

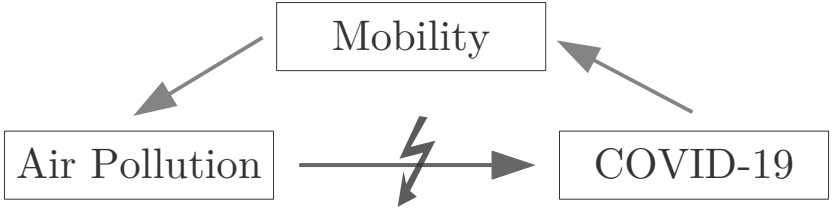
III) Short-term air pollution exposure leads to inflammatory reactions and lower immune responses to new infections

2. Method & Data

Problem: Air pollution is not randomly assigned to places, but results from different dimensions of human behavior, some of which cannot be measured

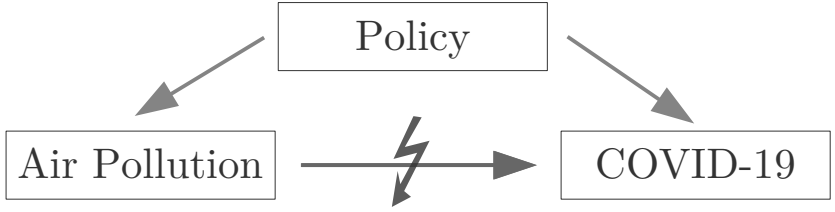
I. Reverse Causality:

Instead of air pollution causing a change in COVID-19 outcomes, it is really the other way around: the pandemic is causing changes in air pollution.



II. Omitted Variable Bias:

Instead of air pollution causing a change in COVID-19 outcomes, it is really the omitted variable that is driving the change.

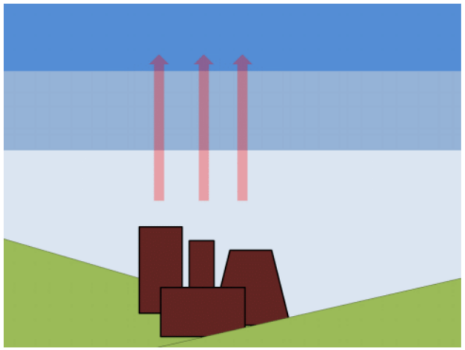


Solution: Only measure the link between air pollution that is quasi-randomly assigned and COVID-19 outcomes

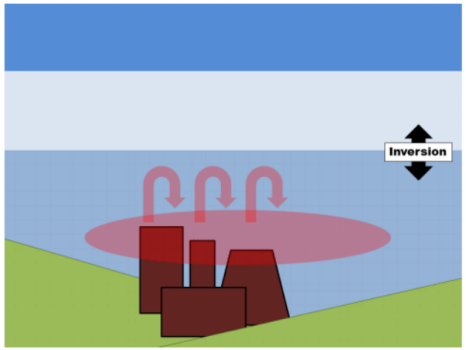
Common instruments:

- wind direction
- environmental regulation
- thermal inversions

Thermal inversions cause quasi-random changes in air pollution



(a) Normal conditions: Temperature decreases with altitude, pollutants rise and disperse



(b) Inversion episode: Warmer layer above, pollutants remain trapped near ground

Source: Sager et al. 2019

- Inverted atmospheric temperature layers trap pollutants close to the ground
- Well-proven strategy in the epidemiological and economic air pollution literature

(Firket 1931; Anderson 2009; Arceo et al. 2016; Hicks et al. 2016; Jans et al. 2018; Sager 2019; Bondy et al. 2020)

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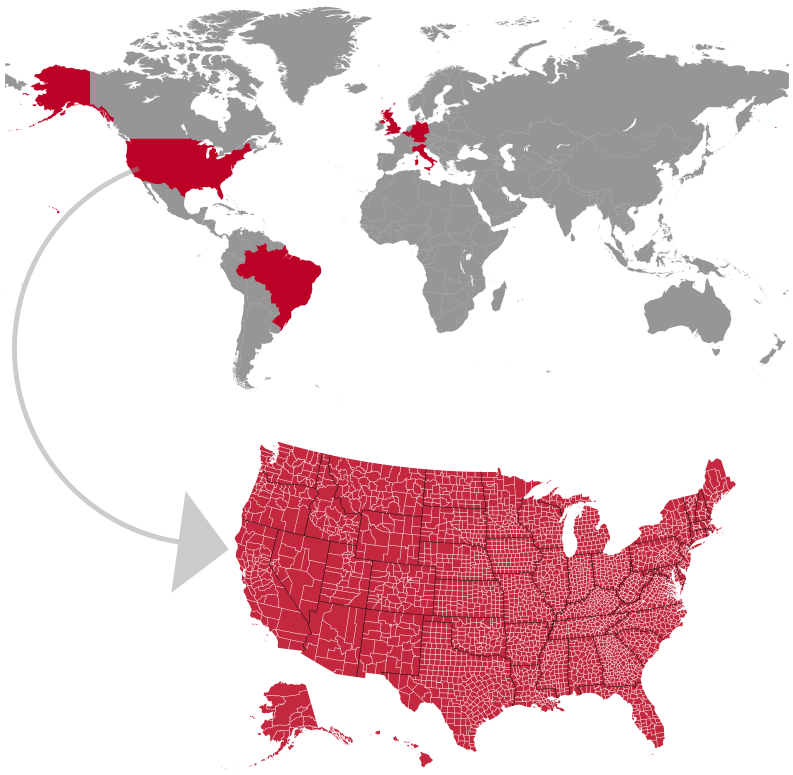
Estimating the effect of thermal inversion induced changes in air pollution on COVID-19 outcomes

- Sample: Belgium, Brazil, Germany, Great Britain, Italy and the USA
- Time frame: January - April in 2020
- Fixed-effect Poisson model (day and week level)

$$P_{iw} = \alpha_1 I_{iw} + \alpha_2 C_{i\overline{w}_{-1}} + W'_{iw}\gamma_1 + M'_{iw}\gamma_2 + H'_{iw}\gamma_3 + \sigma_i + \tau_w + \eta_{cm} + \epsilon_{iw} \quad (1)$$

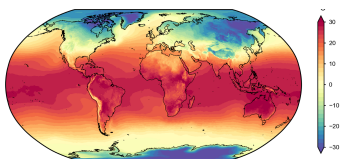
$$C_{i\overline{w}_0} = \beta_1 \widehat{P_{iw}} + \beta_2 C_{i\overline{w}_{-1}} + W'_{iw}\overline{\delta_1} + M'_{iw}\overline{\delta_2} + H'_{iw}\overline{\delta_3} + \sigma_i + \tau_w + \eta_{cm} + \mu_{iw} \quad (2)$$



Analysis

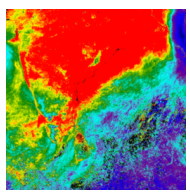
Weather Data

- European Centre for Medium-Range Weather Forecasts (ECMWF) – ERA5
- thermal inversions, temperature, total precipitation, humidity, wind speed,...
- hourly data at 37 different pressure levels, 31km resolution



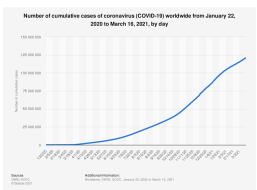
Pollution Data

- NASA, MODIS satellite-images – MCD19A2 V6
- daily mean, 1km resolution, excluding measurements with cloud cover
- Aerosol Optical Depth (AOD) as a proxy for PM2.5 concentration in the atmosphere



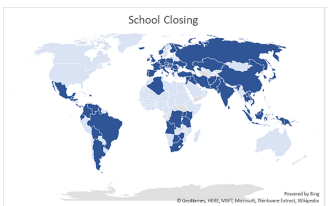
COVID Data

- Official sources available online
- Case numbers: GB, US, BR, BE, DE, IT
- Death numbers: US, BR, BE, DE



Mobility & Policy Data

- Oxford COVID-19 Government Response Tracker (OxCGRT): containment/closure and health system policies per country
- Facebook: location data from mobile devices



for every district and every day

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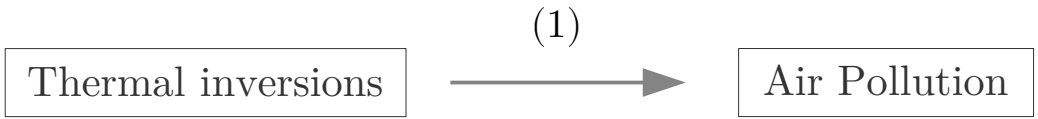
3. Results

I. Does short-term air pollution affect COVID-19 case and death numbers?



	logged *AOD*					
	three-week window			four-week window		
	(1)	(2)	(3)	(4)	(5)	(6)
inversion strength	0.0053***	0.0074***	0.0058***	0.0026***	0.0031***	0.0032***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0007)
F-statistic	93.51	163.95	104.39	17.08	23.08	25.61
Observations	101,046	101,046	101,046	65,569	65,569	65,569
Countries	BEL, BRA, DEU, GBR, ITA, USA			BEL, BRA, DEU, USA		
weather controls	yes	yes	yes	yes	yes	yes
containment controls		yes	yes		yes	yes
health system controls			yes			yes

The table reports regressions coefficients from six estimations of equation (1). In each panel control variables are added sequentially from left to right. The first set of controls contains weather variables only, the second set adds controls for COVID-related containment and closure policies (e.g. school closings and stay at home requirements), and the third set adds COVID-related health system policies (e.g. testing policies and contact tracing). All regressions include district, week and country-month fixed effects. Standard-errors clustered at the district level are in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1

Table 1: The effect of thermal inversions on ambient air pollution

An additional weekday with an inversion causes a **~3.4 – 4.0%-increase** in the weekly AOD level

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I. Does short-term air pollution affect COVID-19 case and death numbers?

	COVID-19 cases			COVID-19 deaths		
	three-week window			four-week window		
	(1)	(2)	(3)	(4)	(5)	(6)
predicted logged *AOD*	−0.023	1.018***	1.478***	4.015	4.577***	5.120***
	(0.317)	(0.189)	(0.276)	(2.607)	(1.741)	(1.632)
Observations	72,021	72,021	72,021	20,658	20,658	20,658
Countries	BEL, BRA, DEU, GBR, ITA, USA			BEL, BRA, DEU, USA		
weather controls	yes	yes	yes	yes	yes	yes
containment controls		yes	yes		yes	yes
health system controls			yes			yes

The table reports regression coefficients from estimations of equation (2). In each panel control variables are added sequentially from left to right. The first set of controls contains weather variables only, the second set adds controls for COVID-related containment and closure policies (e.g. school closings and stay at home requirements), and the third set additionally adds COVID-related health system policies (e.g. testing policies and contact tracing). In the left panel we control for the accumulated case number of the preceding week, in the right panel we control for accumulated death number of the preceding week. All regressions include district, week and country-month fixed effects. Standard-errors clustered at the district level are in parentheses.
Signif. Codes: ***: 0.01, **: 0.05, *: 0.1

Table 2: The effect of ambient air pollution on COVID-19 outcomes

With every 1%-increase in average AOD concentration, the case numbers grow by **1.5%**

With every 1%-increase in average AOD concentration, the death numbers grow by **5.1%**

Different effect magnitudes indicates a **change in the survival rate** of registered COVID-19 patients

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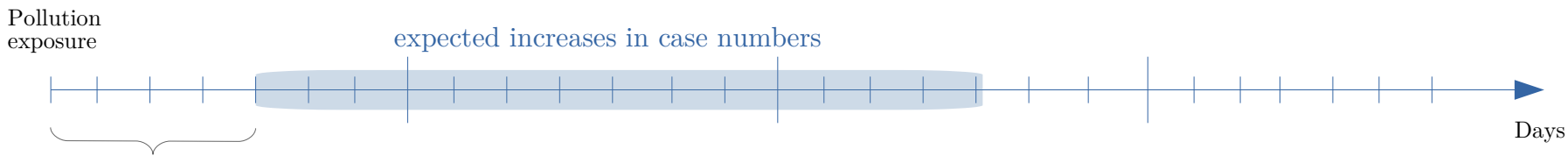
II. How does short-term pollution affect COVID-19 cases and deaths ?



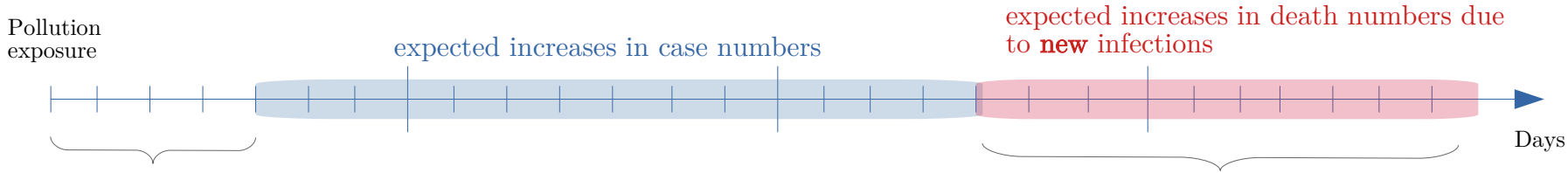
incubation time ~5 days,
reporting delay

(Abbott et al. 2020; Lauer et al. 2020)

symptom development ~12 days

(Lauer et al. 2020)

II. How does short-term pollution affect COVID-19 cases and deaths ?



incubation time ~5 days, reporting delay

(Abbott et al. 2020; Lauer et al. 2020)

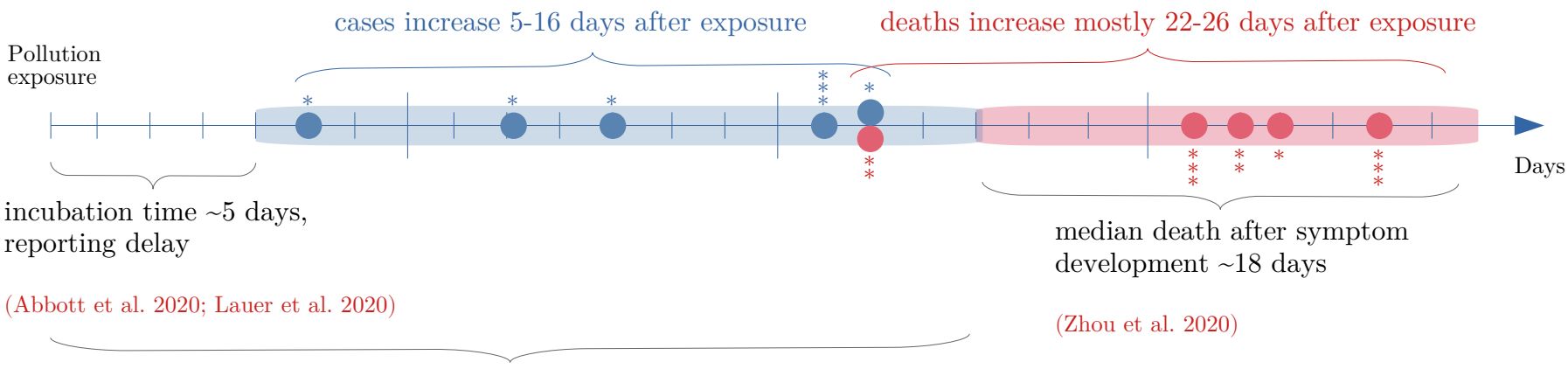
median death after symptom development ~18 days

(Zhou et al. 2020)

symptom development ~12 days

(Lauer et al. 2020)

II. How does short-term pollution affect COVID-19 cases and deaths ?



Increasing case numbers

Increasing death numbers

Significance level: ***: p< 0.01; **: p< 0.05; *: p<0.1

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5. Conclusion

- Combining satellite imagery and COVID-19 data, allows for covering a geographically diverse set of countries at high spatial and temporal resolution for an analysis with higher external validity than individual-country studies.

- Results indicate an important role of pollution exposure around the time of infection and during the pre-symptomatic phase. Pollution does not only increase COVID-19 patient numbers but decreases the rate of survival among them.

- Even short-term reductions in air pollution can help mitigate the spread and severity of COVID-19. Many short-term measures to curb air pollution are low regrets options, as long as they do not divert attention from the core measures needed to mitigate COVID-19 directly.

Thank You for Your attention!

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