Pollution, agricultural productivity, and development: Evidence from coal in plants in India*

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2023-01-03

Abstract

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Keywords:
JEL Codes:

*thanks to...

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1 Introduction

pollution could be bad for agriculture Marshall et al. (1997)

lower agricultural productivity near gold mines in Ghana (Aragón and Rud 2016); apparently lots of pollution - "The main identification assumption is that the change in agricultural productivity over time in both areas would be similar in the absence of mining." - within 20km - also finds suggestive evidence it's not all labor productivity changes

"Much of what we know about the marginal effect of pollution on infant mortality is derived from developed country data. However, given the lower levels of air pollution in developed countries, these estimates may not be externally valid to the developing country context if there is a non-linear dose relationship between pollution and mortality or if the costs of avoidance behaviour differ considerably between the two contexts. In this article, we estimate the relationship between pollution and infant mortality using data from Mexico. Our estimates for PM10 tend to be similar (or even smaller) than the US estimates, while our findings on CO tend to be larger than those derived from the US context." (Arceo, Hanna, and Oliva 2016)

We have known about the effects of pollution on human health for many years Pope III and Dockery (2006) good review on the effects of pollution early in life in Currie et al. (2014) - also in developing countries, where there is a consistent effect of exposure on infant mortality (Heft-Neal et al. 2018)

"Air pollution has both acute and chronic effects on human health, affecting a number of different systems and organs. It ranges from minor upper respiratory irritation to chronic respiratory and heart disease, lung cancer, acute respiratory infections in children and chronic bronchitis in adults, aggravating pre-existing heart and lung disease, or asthmatic attacks. In addition, short- and long-term exposures have also been linked with premature mortality and reduced life expectancy. These effects of air pollutants on human health and their mechanism of action are briefly discussed." Kampa and Castanas (2008)

worker productivity and cognitive function: - call center workers in China, and at common levels of pollution (Chang et al. 2019) - tests (Ebenstein, Lavy, and Roth 2016) - farm workers in California (Graff Zivin and Neidell 2012) - increase in extensive margin (Hanna and Oliva 2015) - manufacturing in China (He, Liu, and Salvo 2019); "We uncover statistically significant adverse output effects from more prolonged exposure, but effects are not large. A substantial +10 mug/m3 PM2.5 variation sustained over 25 days reduces daily output by 1 percent."

induces migration (Chen, Oliva, and Zhang 2022)

overall effects on agricultural productivity taking into accounts any changes in input allocation caused by the

Table 1: Remote sensing data sources

	shapefile	wind	pollution	agriculture	nightlights
source	Asher et al. (2021)	NCAR	Hammer et al. (2020)	Angopadhyay et al. (2022)	Asher et al. (2021)
geographic coverage	India	global	global	global	India
temporal coverage		daily	monthly	two seasons/year	yearly

NCAR: https://climatedataguide.ucar.edu/

increase in pollution.

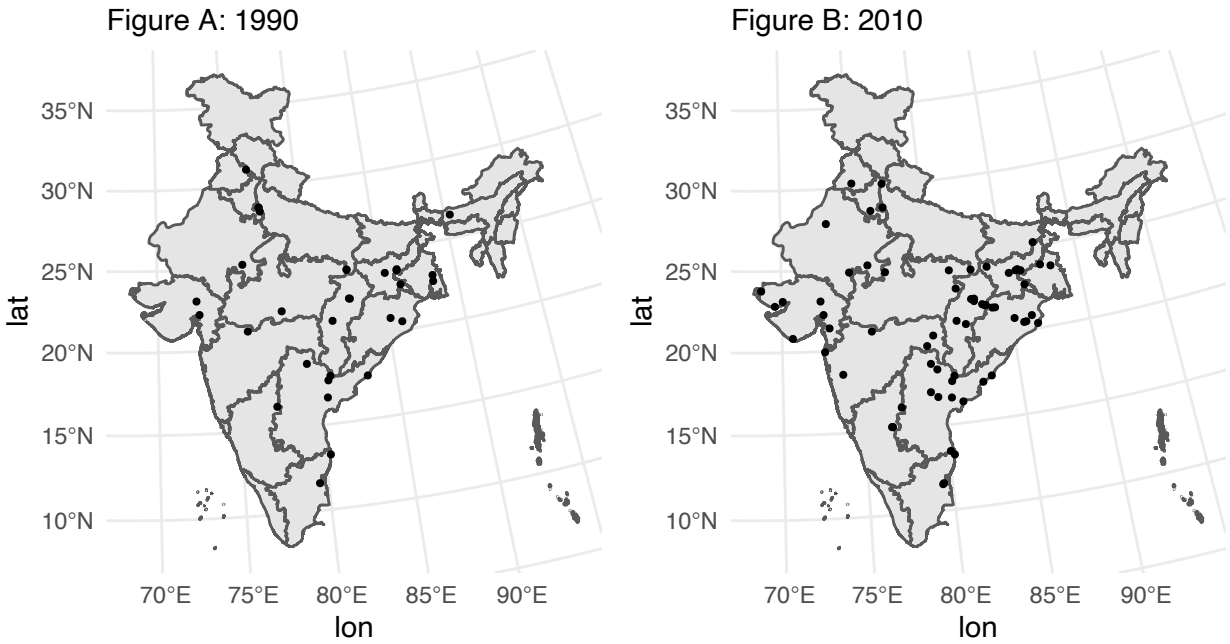
2 Data and methods

2.1 Data

Asher et al. (2021) Ag productivity: Gangopadhyay et al. (2022) PM estimates: Hammer et al. (2020)

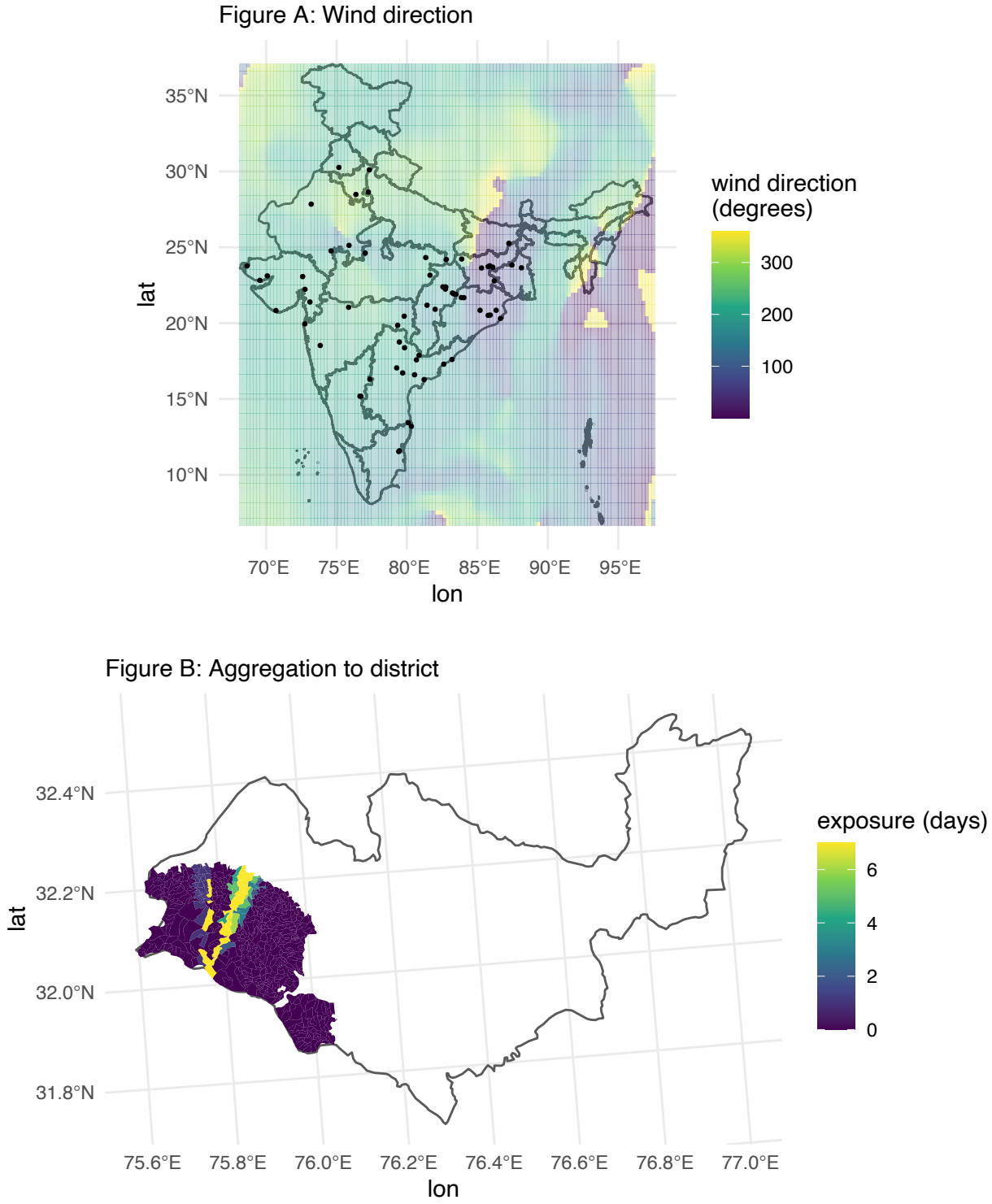
2.2 Methodology

Figure 1: Coal plants in India from 1990 to 2010



Note: The top figure shows the location of coal plants in 1990. The bottom figure shows the location of coal plants in 2010.

Figure 2: Wind direction and aggregation examples (2010-01-01)



Note: The top figure shows the average wind direction on January 1st, 2010. The points are the location of coal plants on that date. The bottom figure shows the distribution of pollution exposure in a specific district – Kangra district in Himachal Pradesh – on the same date.

Table 2: Wind direction and particulate matter

	1998-2015		2002-2013	
	(1)	(2)	(3)	(4)
wind	0.045***	0.014***	0.063***	0.015***
	(0.004)	(0.001)	(0.005)	(0.002)
fixed effects:				
village	Yes	Yes	Yes	Yes
month	Yes	No	Yes	No
district-month	No	Yes	No	Yes
observations	22,345,092	22,345,092	14,896,728	14,896,728

Note: Standard errors are in parentheses and are clustered at the village level.
* p<0.10 ** p<0.05 *** p<0.01

Table 3: Wind direction and agricultural productivity

	all			monsoon	winter
	(1)	(2)	(3)	(4)	(5)
wind	-0.003***	-0.003***	-0.0007***	-0.002***	-0.003***
	(0.0002)	(0.0002)	(9.21e-5)	(0.0002)	(0.0003)
rain (z)		0.029***	0.009***	0.082***	0.016***
		(0.0004)	(0.001)	(0.002)	(0.0004)
fixed effects:					
village-season	Yes	Yes	Yes	No	No
year	Yes	Yes	No	Yes	Yes
district-year-season	No	No	Yes	No	No
village	No	No	No	Yes	Yes
observations	2,391,533	2,375,337	2,375,337	1,259,123	1,116,214

Note: Standard errors are in parentheses and are clustered at the village level.
* p<0.10 ** p<0.05 *** p<0.01

3 Results

4 Conclusion

Table 4: Pollution and agricultural productivity, IV estimates

	all			monsoon	winter
	(1)	(2)	(3)	(4)	(5)
particulate matter	-0.021***	-0.020***	-0.033***	-0.013***	-0.024***
(PM 2.5, '000s)	(0.001)	(0.002)	(0.005)	(0.001)	(0.003)
rain (z)		0.004**	0.002	0.086***	-0.016***
		(0.002)	(0.002)	(0.002)	(0.004)
fixed effects:					
village-season	Yes	Yes	Yes	No	No
year	Yes	Yes	No	Yes	Yes
district-year-season	No	No	Yes	No	No
village	No	No	No	Yes	Yes
observations	2,391,533	2,375,337	2,375,337	1,259,123	1,116,214
first stage:					
wind	0.143***	0.126***	0.022***	0.155***	0.105***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.004)
rain (z)		-1.23***	-0.235***	0.301***	-1.36***
		(0.010)	(0.018)	(0.015)	(0.009)

Note: Standard errors are in parentheses and are clustered at the village level.
* p<0.10 ** p<0.05 *** p<0.01

Table 5: Heterogeneity in the effects of pollution on productivity

	>p(50)	<=p(50)	all		
	(1)	(2)	(3)	(4)	(5
wind	-0.003***	-0.032***	-0.004***	0.0004	-0.0001
	(0.0002)	(0.002)	(0.0003)	(0.0005)	(0.001)
rain (z)	0.031***	0.030***	0.029***	0.029***	0.029***
	(0.0006)	(0.0005)	(0.0004)	(0.0004)	(0.0004)
wind x rain			0.0005***		
			(6.67e-5)		
wind squared				-0.0002***	
				(3.54e-5)	
wind x starting yield					-0.001**
					(0.0006)
fixed effects:					
village-season	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes
observations	1,115,694	1,259,643	2,375,337	2,375,337	2,371,364

Note: Standard errors are in parentheses and are clustered at the village level.
* p<0.10 ** p<0.05 *** p<0.01

Table 6: Wind direction and labor allocation

	all	all	self	wage	farm	non-farm
wind	-0.021	-0.027*	0.008	-0.034**	0.035*	-0.061**
	(0.015)	(0.015)	(0.017)	(0.016)	(0.019)	(0.025)
controls	No	Yes	Yes	Yes	Yes	Yes
fixed effects:						
district	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
varying slopes:						
year (by district)	Yes	Yes	Yes	Yes	Yes	Yes
observations	899,045	898,856	898,856	898,856	898,856	898,856

Note: Standard errors are in parentheses and are clustered at the district level. Control variables include female, age, age squared, and (years of) education.
* p<0.10 ** p<0.05 *** p<0.01

Table 7: Wind direction and nightlight growth

	(1)	(2)
wind (lagged)	-0.080***	-0.083***
	(0.015)	(0.015)
rain (z, lagged)		-0.035***
		(0.002)
fixed effects:		
village	Yes	Yes
year	Yes	Yes
varying slopes:		
year (by village)	Yes	Yes
observations	2,146,715	2,146,715

Note: Standard errors are in parentheses and are clustered at the village level.
* p<0.10 ** p<0.05 *** p<0.01

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Table A1: Agricultural productivity and pollution leads

	(1)	(2)
wind (lag)	0.004***	0.0006*
	(0.0007)	(0.0003)
wind	-0.002***	-0.0007***
	(0.0004)	(0.0002)
wind (lead)	-0.004***	-0.0001
	(0.0001)	(9.8e-5)
rain (z)	0.021***	0.008***
	(0.0005)	(0.001)
fixed effects:		
village-season	Yes	Yes
year	Yes	No
district-year-season	No	Yes
observations	1,979,635	1,979,635

Note: Standard errors are in parentheses and are clustered at the village level.
* p<0.10 ** p<0.05 *** p<0.01

Appendix A