The impact of air pollution on labour productivity in France

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Note: The views expressed here are those of the authors and cannot be attributed to the OECD or its member countries.

Motivation

Motivation and main contribution

- **Motivation**
  - Increasing evidence on **subtle effects** of air pollution lowering individuals' **cognitive abilities**
  - Limited evidence (few studies, specific cases),...
  - ...in particular on heterogeneous effect across firms

- **Main Contribution**
  - **Country-wide** applicable estimation method (including both manufacturing and services firms)
  - Within a **low pollution setting**
  - Accounts for **firm-specific characteristics** on large set of firms
  - Evidence on the **cognitive channel** using matched employer-employee data

Main results

- Significant **negative impact** of air pollution on productivity
  - 10% increase in PM 2.5 leads to 1.5% decrease in labour productivity
- Driven by **service-intensive firms** and sectors with high share of **skilled workers**
  - In line with the expectation: air pollution affects cognitive skills, concentration, headache, and fatigue in non-routine cognitive tasks
- Compared to an estimation of the marginal abatement cost of PM 2.5 (Air Quality Directive 2008/50/EC), gains from labour productivity can largely offset the cost

Literature

Narrowly targeted settings, concern of their external validity:

- Worker output (Manufacturing site, China): He et al. (2019)
- N. of garments sewn (Garment factory, India): Adharyu et al. (2019)
- N. of boxes packed (Pear farm, California): Chang et al. (2016)
- Daily harvest (Berry farm, California): Graff Zivin and Neidell (2012)

- **Others:** Stock market returns (NY): Heyes et al. (2016); Scores in high-school examination (Israel): Ebenstein et al. (2016); Chess tournament (Germany): Künn et al. (2019); Real GDP (EU): Dechezlepretre et al. (2019)

- **Exception:** Value added per worker (Across manufacturing plants, China) Fu et al. (2021)

Data and Empirical model

Let's consider a basic estimation

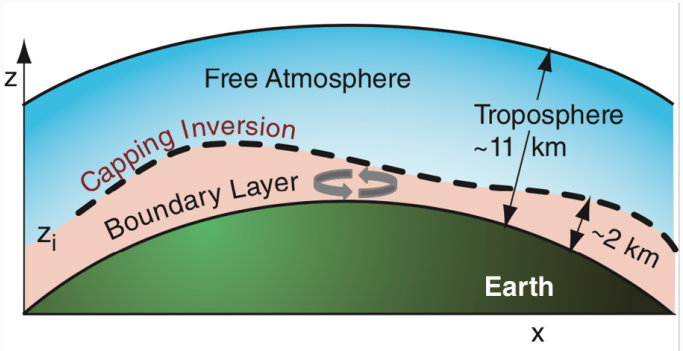
i for the establishment, s the sector, l the local labour market, and t the time.

$$LPROD_{i,s,l,t} = \beta_1 P_{l,t} + \gamma_l + \gamma_i + \gamma_{s,t} + \epsilon_{i,s,l,t}, \quad (1)$$

- $LPROD_{i,s,l,t}$: labour productivity (log)
- $P_{l,t}$: air pollution concentration
- γ_l, γ_i, $\gamma_{s,t}$: local labour market, establishment, and sector-time FE
- β_1: impact on productivity from a one-unit increase in pollution concentration (1 $\mu g/m^3$)
- **Simultaneity bias**: The higher the produced output within a region, the higher is the pollution level
  - **IV approach** (Planetary Boundary Layer Height, Wind Speed)

What is Planetary Boundary Layer Height? (PBLH)

- Distance between surface and inversion
- **Area of vertical exchange** of heat, water vapor, pollution
- **Inversely related** to air pollution through dispersion



Validity of Instrument - Relevance

- **Strong relationship** (PBLH - air pollution): Arya et al. (1998); Jacobson et al. (2002); Xiang et al. (2019)
- **Used by other papers**: Broner, Bustos, Carvalho (2012); Schwartz et al. (2017); Zhang, Wu and Liu (2020)

What is Planetary Boundary Layer Height? (ii)

Exogeneity

PBLH varies according to:

- Heating flux between the sun and the earth
- Unpredictable large-scale air movements
- Pressure divergence
- Horizontal movement of cold air under a warmer layer of air
- Aerosols reflecting sunlight **only** at extremely high levels of pollution, $\sim$ 100 times larger than French average (Rémy et al., 2015)

Exclusion restriction

No reason to believe that PBLH matters for well-being of workers

Why Wind Speed?

Capacity to **carry PM away** from a certain location - thus **inversely related** to pollution

- Wind speed generated by atmospheric pressures, highly variable within short time frames
- Used by numerous papers using wind as predictor for pollution (Herrnstadt and Muehlegger, 2015; Ward, 2015; Bondy et al., 2020)
- Wind speed should only affect productivity through the effect of pollution: since **focus on low wind speed** should be the case

Empirical model - Baseline estimation

i for the establishment, s the sector, l the local labour market, and t the time.

$$LPROD_{i,s,l,t} = \beta_1 \widehat{P_{l,t}} + \gamma_l + \gamma_i + \gamma_{s,t} + \epsilon_{i,s,l,t} \tag{2}$$

- $LPROD_{i,s,t}$: Labour productivity (log)
- $\widehat{P_{l,t}}$: Predicted air pollution (PM 2.5) based on PBLH and wind speed
- γ_l, γ_i, $\gamma_{s,t}$: local labour market, establishment, and sector-time FE

Data

2001 to 2018

- **Air pollution**
  - Van Donkelaar et al.: Satellite air quality data with surface air monitoring stations
  - Yearly, 0.01 degree resolution grid, PM 2.5

- **Establishment-level labour productivity and share of high-skilled workers**
  - FARE/ FICUS, One-establishment firms
  - DADS Panel, Occupation codes

- **Boundary Layer Height and Wind Speed**
  - Weather station data (ERA 5)
  - Daily, 0.25 degree resolution grid
  - Aggregated to yearly measure: Lowest bin of 12 for Wind, lowest percentile for PBLH

Results

Results (i)

Table 1: First stage estimation

Dependent variable:	(1) $P_{l,t}$	(2) $P_{l,t}$
$B_{l,t}$	0.043***	0.037***
	(0.01)	(0.01)
$W_{l,t}$	0.039***	0.032***
	(0.01)	(0.01)
$C_{l,t}$		0.021*
		(0.00)
Parameters of the regressions:		
N of observations	2,491,151	2,491,151
LLM FE	yes	yes
Sec-Time FE	yes	yes
Robust SE	yes	yes
Adjusted R2	0.89	0.91
F-statistics	71.51	86.43

Robust standard errors clustered at the zip code-year level and at the establishment in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Results (ii)

Table 2: The effect of predicted air pollution on labour productivity

Dependent variable:	$LPROD_{i,s,l,t}$	$LPROD_{i,s,l,t}$
$\widehat{P_{l,t}}$	-0.021***	-0.014***
	(0.03)	(0.01)
$C_{l,t}$		-0.007***
		(0.02)
Parameters of the regressions:		
N of observations	2,491,151	2,491,151
Temperature control	no	yes
LLM FE	yes	yes
Sec-Time FE	yes	yes
Establishment FE	yes	yes
Robust SE	yes	yes
Adjusted R2	0.63	0.72
Weak id. stat.	25.42	26.58
Hansen J stat. p-value	0.51	0.42

Robust standard errors clustered at the zip code-year level and at the establishment in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Results - Heterogeneity

PM2.5 **penetrates** deep into the **lungs and brain**:

- Inflammatory reactions
- **Reduction** of the transportation of **oxygen** to the brain
- Impacting **cognitive skills, concentration, headache, fatigue**

$\Rightarrow$ **High-skilled workers** executing **non-routine cognitive tasks**

$\Rightarrow$ Mainly in professional, managerial, technical, and creative occupations

Results - Firm-level heterogeneity (i)

Table 3: Firm-level heterogeneity: Share of high skilled workers

	1rst-stage ($P_{l,t}$)	2nd-stage ($LPROD_{i,s,l,t}$)
$B_{l,t}$	0.032***	
	(0.01)	
$W_{l,t}$	0.020***	
	(0.01)	
$HighSkilled_{i,t}$	-0.05	0.433***
	(0.01)	(0.10)
$\widehat{P_{l,t}}$		-0.021*
		(0.01)
$\widehat{P_{l,t}} * HighSkilled_{i,t}$		-0.041**
		(0.02)
N of observations	2,491,151	2,491,151

Results - Firm-level heterogeneity (ii)

Table 4: Firm-level heterogeneity: Share of services within total production

	1rst-stage ($P_{l,t}$)	2nd-stage ($LPROD_{i,s,l,t}$)
$B_{l,t}$	0.034***	
	(0.01)	
$W_{l,t}$	0.021***	
	(0.01)	
$ServiceIntensity_{i,s,l,t}$	-0.03*	0.017**
	(0.02)	(0.01)
$\widehat{P_{l,t}}$		-0.009
		(0.00)
$\widehat{P_{l,t}} * ServiceIntensity_{i,s,l,t}$		-0.023***
		(0.00)
N of observations	2,491,151	2,491,151

Results - Regional heterogeneity

Table 5: Heterogeneity in the effect of air pollution on labour productivity: Urban vs. rural

Dependent variable:	First-stage $P_{l,t}$	Second-stage $LPROD_{i,s,z,l,t}$	Second-stage $LPROD_{i,s,z,l,t}$
$B_{l,t}$	0.021***		
	(0.01)		
$W_{l,t}$	0.017***		
	(0.01)		
$Urban_{z,l,t}$	0.332***	0.336**	0.559*
	(0.01)	(0.02)	(0.03)
$ServiceIntensity_{i,s,z,l,t}$	0.02		0.094***
	(0.02)		(0.02)
$\widehat{P_{l,t}}$		-0.012*	0.014
		(0.02)	(0.01)
$\widehat{P_{l,t}} * Urban_{z,l,t}$		-0.021**	-0.015**
		(0.03)	(0.03)

Robustness Checks

- Geographical Sorting
- Confounding factors
- Summer vs. Winter Inversions
- Different Pollutants
- Non-linear effect of air pollution on productivity
- Multi-firm plants
- Reduced-form Results
- Placebo test

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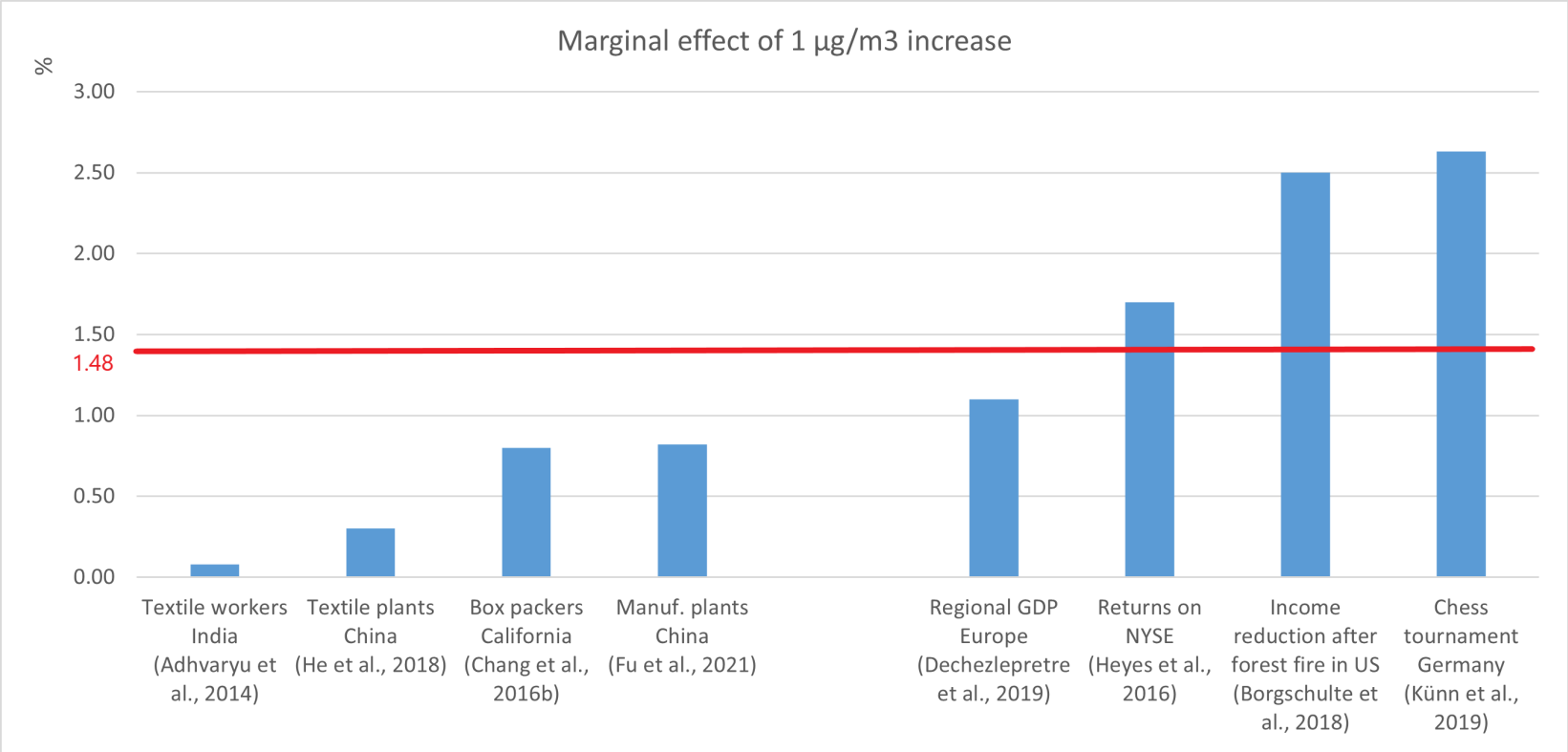
Conclusion

Comparison with existing studies

Figure 1: Effect of increase in PM 2.5 on productivity across existing studies



Conclusion

- Significant **negative impact** of air pollution on productivity
  - 10% increase in PM 2.5 leads to 1.5% decrease in labour productivity
- Driven by **service-intensive firms** and sectors with high share of **skilled workers**
- Comparison
  - Compared to an estimation of the marginal abatement cost of PM 2.5 (Air Quality Directive 2008/50/EC), gains from labour productivity can largely offset the cost (roughly 5x costs)

Thank you!

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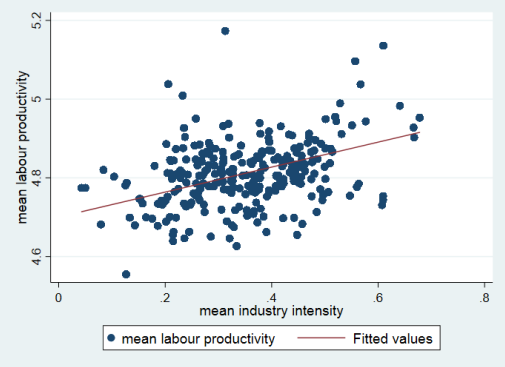
Appendix

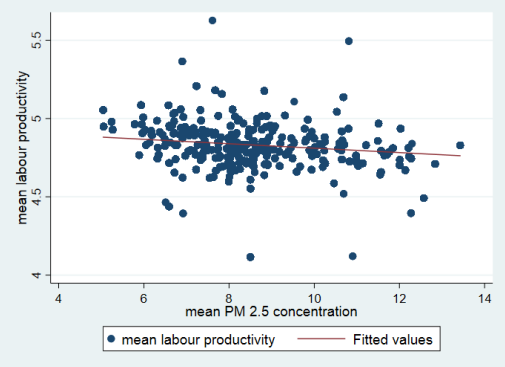
Appendix: Scatterplots Motivation

Figure 2: Scatter plots at local labour market level (2015)

Manufacturing share and productivity



Air pollution and productivity



Appendix: Zip Codes

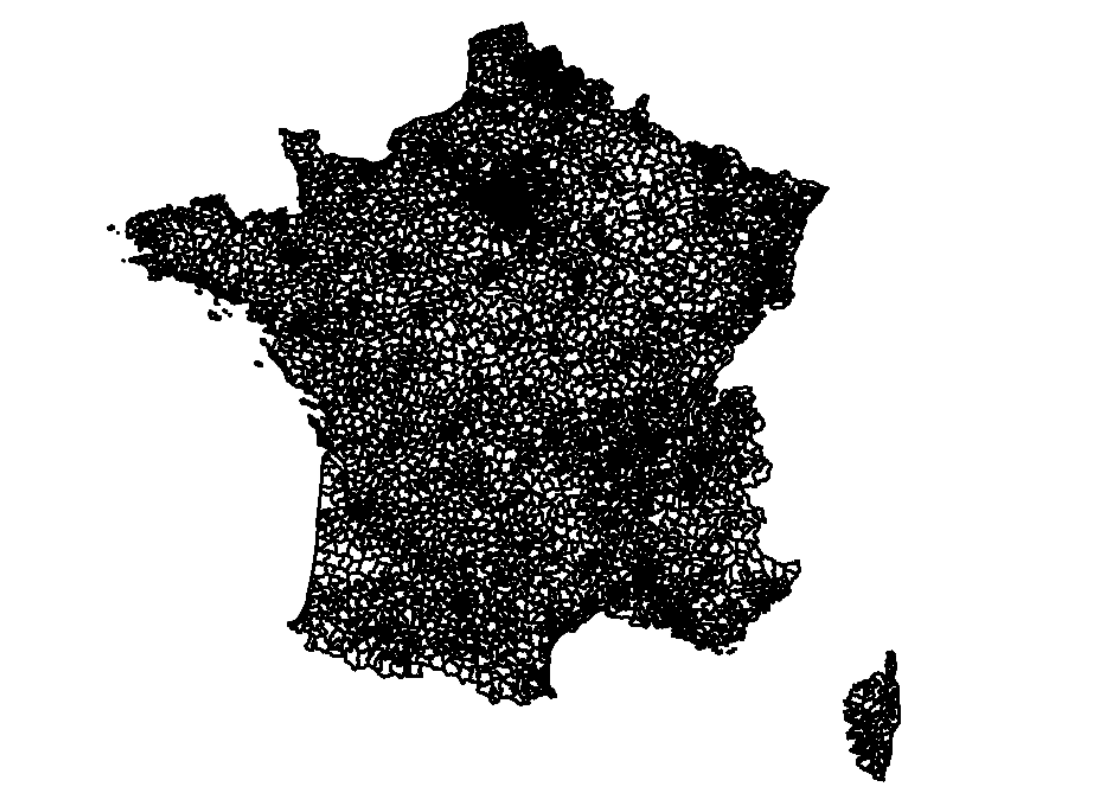
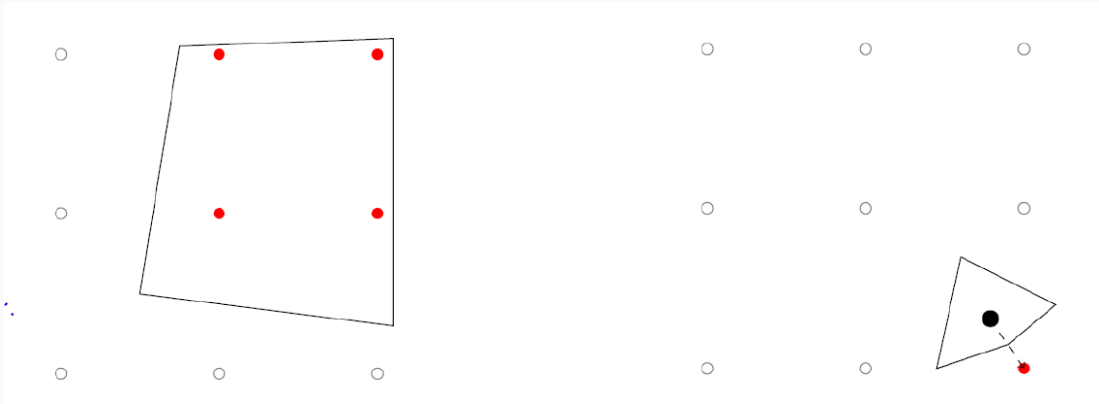


Figure 3: Zip codes of France

Appendix: Match of the Data

Figure 4: Data match



Source: Dechezlepretre et al., 2018

Note: Gridded data points are given by small circles and zip code boundaries are given by black polygons. In the left panel, several gridded data points overlie the zip code boundary (and are coloured red). The atmospheric conditions in the zip code boundary are taken as the average across all points that overlie the region. On the right, no gridded data points overlie the zip code boundary. In this case, we take observations from the closest gridded data point (shaded red) to the centroid of the polygon (shaded black) as representative of atmospheric conditions in the zip code boundary.

Geographical Sorting (i)

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Table 6: Robustness - Focus on old firms only

	$LPROD_{i,s,l,t}$ $Age > 10$	$LPROD_{i,s,l,t}$ $Age > 7$
$\widehat{P_{l,t}}$	-0.019***	-0.021***
	(0.001)	(0.001)
Parameters of the regressions:		
N of observations	1,271,255	1,565,171
LLM FE	yes	yes
Sec-Time FE	yes	yes
Establishment FE	yes	yes
Robust SE	yes	yes
Adjusted R2	0.74	0.74

Robust standard errors clustered at the zip code-year level and at the establishment in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Geographical Sorting (ii)

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Table 7: Robustness - Focus on local labour markets with constant population

	$LPROD_{i,s,l,t}$
$\widehat{P_{l,t}}$	-0.028**
	(0.001)
Parameters of the regressions:	
N of observations	1,144,747
LLM FE	yes
Sec-Time FE	yes
Establishment FE	yes
Robust SE	yes
Adjusted R2	0.74

Robust standard errors clustered at the zip code-year level and at the establishment in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Geographical Sorting (iii)

Back Test: Firms with perfect information would move if they would expect that air pollution is going to increase in the next years

Table 8: The effect of future air pollution on the probability of firm exit

Dependent variable:	$Prob.Exit_{l,2010}$	$Prob.Exit_{l,2010}$
$\bar{P}_{l,2011-2018}$	-0.002	-0.002
	(0.00)	(0.00)
$\bar{P}_{l,2011-2018} * HighSkilled_{i,t}$		-0.001
		(0.00)
$HighSkilled_{i,t}$		0.019
		(0.02)
N of observations	2,491,151	2,491,151
s-t FE, robust SE	yes	yes
Adjusted R2	0.01	0.01

Confounding factors

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Table 9: Effect of air pollution on productivity controlling for regional VA

Dependent variable:	First-stage $P_{l,t}$	Second-stage $LPROD_{i,s,l,t}$
$B_{l,t}$	0.027**	
	(0.01)	
$W_{l,t}$	0.008**	
	(0.01)	
$VA_{l,t}$	0.242***	0.164***
	(0.05)	(0.32)
$\widehat{P_{l,t}}$		-0.012*
		(0.18)
N of observations	2,491,151	2,491,151
i, s-t, l FE, robust SE	yes	yes
Adjusted R2	0.92	0.69

Summer vs. Winter Inversions

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Table 10: The effect of seasonal BLH and wind speed on air pollution

Dependent variable:	First-stage $P_{l,t}$	First-stage $P_{l,t}$	Second-stage $LPROD_{i,s,l,t}$
$B_{l,t}^{Summer}$	0.154***	0.153***	
	(0.00)	(0.00)	
$B_{l,t}^{Winter}$	0.060*	0.065*	
	(0.00)	(0.00)	
$W_{l,t}$		-0.090***	
		(0.00)	
$\widehat{P_{l,t}}$			-0.010***
			(0.00)
N of observations	2,491,151	2,491,151	2,491,151
i, s-t, l FE, robust SE	yes	yes	yes
Adjusted R2	0.88	0.88	0.63

Different Pollutants

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Table 11: The effect of predicted air pollution (PM 10) on labour productivity

Dependent variable:	First-stage $PM10_{l,t}$	Second-stage $LPROD_{i,s,l,t}$
$B_{l,t}$	0.003**	
	(0.01)	
$W_{l,t}$	0.002**	
	(0.01)	
$\widehat{PM10}_{l,t}$		-0.038*
		(0.51)
N of observations	2,491,151	2,491,151
i, s-t, l FE	yes	yes
Robust SE	yes	yes
Adjusted R2	0.85	0.70
F-statistics	10.28	

Non-linear effect of air pollution on productivity

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Table 12: The non-linear effect of predicted air pollution on labour productivity

Dependent variable:	First-stage $P_{l,t}$	First-stage $P^2_{l,t}$	Second-stage $LPROD_{i,s,l,t}$
$B_{l,t}$	0.032**	0.014**	
	(0.21)	(0.14)	
$W_{l,t}$	0.021**	0.013**	
	(0.14)	(0.11)	
$\widehat{P_{l,t}}$			0.010**
			(0.11)
$\widehat{P^2_{l,t}}$			-0.008**
			(0.00)
N of observations	2,491,151	2,491,151	2,491,151
i, s-t, l FE	yes	yes	yes
Robust SE	yes	yes	yes
Adjusted R2	0.88	0.88	0.70

Multi-firm plants

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Table 13: The Effect of Predicted Air Pollution on Labour Productivity

	$LPROD_{i,s,l,t}$
$\widehat{P_{l,t}}$	-0.028***
	(0.0018)
N of observations	5,345,407
i, s-t, l FE	yes
Robust SE	yes
Adjusted R2	0.0036

Robust standard errors clustered at the zip code-year level and at the establishment in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Reduced form estimation

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Table 14: Reduced-form results: The effect of PBLH and wind speed on labour productivity

Dependent variable:	$LPROD_{i,s,l,t}$	$LPROD_{i,s,l,t}$	$LPROD_{i,s,l,t}$
$B_{l,t}$	-0.003***	-0.003***	-0.003***
	(0.00)	(0.00)	(0.00)
$W_{l,t}$	-0.002***	-0.003*	-0.003*
	(0.00)	(0.00)	(0.00)
$C_{l,t}$			-0.00
			(0.00)
N of observations	2,491,151	2,491,151	2,491,151
LLM FE	no	yes	yes
Sec-Time FE	yes	yes	yes
Establishment FE	yes	yes	yes
Robust SE	yes	yes	yes
Adjusted R2	0.70	0.70	0.70

Placebo test

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Table 15: The effect of randomised air pollution on labour productivity

Dependent variable:	First-stage $P_{l,t}$	Second-stage $LPROD_{i,s,l,t}$
$B_{l,t}$	0.082	
	(0.05)	
$W_{l,t}$	0.0113	
	(0.07)	
$\widehat{P_{l,t}}$		-0.003
		(0.01)
N of observations	2,491,151	2,491,151
i, s-t, l FE; robust SE	yes	yes
Adjusted R2	0.90	0.73