Clearing the Air: How Pollution Shapes Labor Supply in Bangladesh

Rida Hameed

Department of Economics, American University

November 7, 2026

Introduction

- Bangladesh is the most polluted country in the world: 79.9 $\mu g/m^3$ (2023 annual average)
  - More than twice the national standard (35 $\mu g/m^3$); 15$\times$ the WHO guideline (5 $\mu g/m^3$)
  - Pollution cost $\approx$ 3.9–4.4% of GDP in 2019
- Pollution harms labor markets through health
  - Presenteeism and absenteeism (Chang et al. 2016; Hanna & Oliva 2015)
  - Reduced productivity (Zivin & Neidell 2012; He et al. 2019)
- Rural areas are especially vulnerable, yet understudied (Chan et al. 2023)
  - Physically intensive, informal work; weak health infrastructure
  - Lower baseline health amplifies pollution effects

This paper

- Estimates the effect of $PM_{2.5}$ on rural labor supply in Bangladesh
  - IV using thermal inversions, satellite $PM_{2.5}$ and the BIHS household panel
  - A 10 $\mu g/m^3$ increase in $PM_{2.5}$ reduces monthly hours by **14.9%** ($\approx$ 16.4 hours, mean 109.9)
  - Larger for outdoor and farming workers; no significant gradient by gender, education or household income
- Mechanism: **workers' own health**, not caregiving
  - Pollution raises illness and respiratory symptoms among men and women alike; men work fewer days
  - No effect on the health of young children or the elderly; women in households with dependents do not cut hours more
- Robust to inversion strength, flexible weather, within-season trends, attrition, migration and two placebo tests

Related Literature & Contributions

1. Pollution reduces labor supply and productivity (Hanna & Oliva 2015; Aragón et al. 2017; Zivin & Neidell 2012)
2. Caregiving and health as channels (Kim, Manley & Radoias 2017; Huang et al. 2021; Han et al. 2023)
3. Thermal inversions as an instrument for pollution (Arceo, Hanna & Oliva 2016; Sager 2019; Jans et al. 2018)

This paper, by contrast:

- **Rural** labor supply in a developing country (prior work: urban / national / middle-income)
- High-resolution satellite data avoids sparse-monitor bias
  - Sparse coverage nationwide (8 monitors, all urban)
  - Often sited away from pollution hotspots
  - Data manipulation
- Direct test of mechanisms: **own health** rather than caregiving

Data

1. **Labor supply — Bangladesh Integrated Household Survey (BIHS, IFPRI)**
   - Nationally representative rural panel; 6,500 households, 325 PSUs; 3 waves (2011–12, 2015, 2018–19)
   - Monthly hours worked in the primary activity, ages 15–64; top 1% trimmed
   - Working sample: **32,940 observations of 16,103 workers in 5,877 households**
2. **Pollution — ACAG, Washington University in St. Louis (V5.GL.05.02)**
   - Satellite-derived monthly $PM_{2.5}$, $0.01^\circ \times 0.01^\circ$ ($\sim$1 km)
   - Matched to households by GPS coordinates to the pollution grid cell
3. **Thermal inversions — ECMWF ERA5 reanalysis**
   - Hourly, $0.25^\circ \times 0.25^\circ$ ($\sim 31 \times 31$ km), 37 pressure layers
   - Inversion when $T(925\,\text{hPa}) > T(1000\,\text{hPa})$; share of hours in the month
4. **Weather — ECMWF ERA5 reanalysis**
   - Temperature, precipitation, wind speed, surface pressure, relative humidity (0.25°), aggregated to monthly means

Data

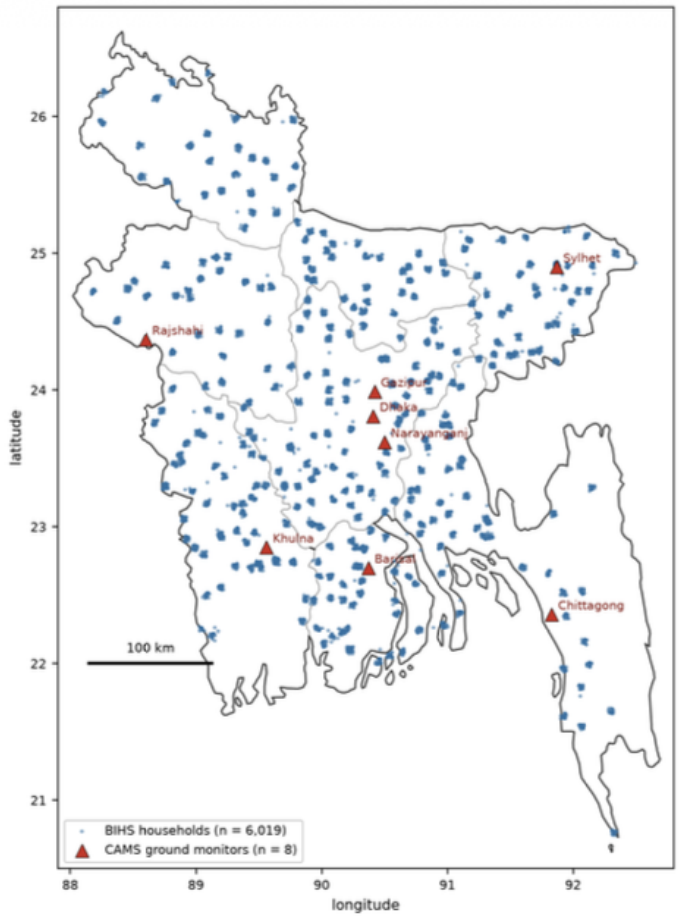
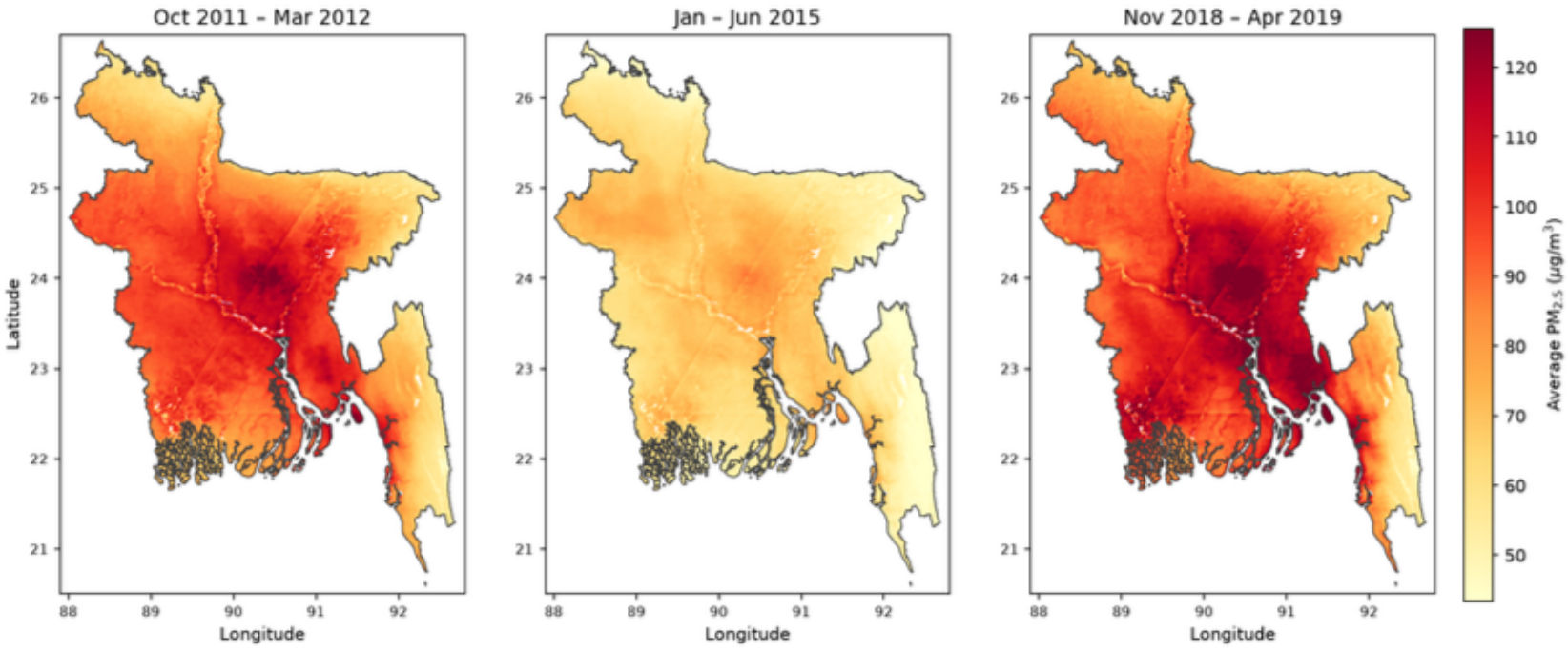


Figure 1: BIHS Household Sample and Ground-Monitor Coverage

Note: BIHS working-sample households (blue) and the **8 Department of Environment CAMS monitors** (red triangles). Households are rural and nationwide; monitors are sparse and urban — motivating satellite (ACAG) $PM_{2.5}$ data.

Data



Note: Average $PM_{2.5}$ over each survey window — Oct 2011–Mar 2012, Jan–Jun 2015, and Nov 2018–Apr 2019 — from the ACAG satellite grids (0.01°; van Donkelaar et al. 2021).

Identification Challenges

$PM_{2.5}$ is not randomly assigned $\Rightarrow$ OLS is biased. Four threats:

- **Simultaneity / reverse causality.** Industrial and labor activity generate pollution $\Rightarrow$ positive correlation with hours (Yamada & Narita 2025)
- **Residential sorting.** Richer, health-conscious households "vote with their feet" into cleaner areas; skilled workers cluster in polluted hubs (Freeman et al. 2019; Khanna et al. 2021)
- **Selection / avoidance.** Workers adjust hours as air quality deteriorates (Ye, Huang & Chen 2023)
- **Measurement error.** Sparse monitors (Bangladesh: 0.07/million), urban siting, and possible data manipulation (Gu, Bian & Elahi 2020)

Sign of the bias is ambiguous $\Rightarrow$ instrument with thermal inversions.

Thermal Inversions

Definition. A layer of warm air traps cooler air near the ground, trapping pollutants. Coded (ERA5) when $T(925\,\text{hPa}, \sim 760\,\text{m}) > T(1000\,\text{hPa}, \sim 110\,\text{m})$; instrument = share of hours in the month with an inversion.

- Alternative measure: *inversion strength* = monthly mean of $\max(T_{925} - T_{1000}, 0)$

Relevance. Inversions must strongly predict $PM_{2.5}$ conditional on controls.

Exclusion. Inversions are an upper-atmosphere condition workers do not observe: they affect hours *only* through air quality, conditional on weather.

Identifying assumption. Conditional on household FE, season×year FE, weather and individual controls, changes in inversions $\perp$ labor outcomes except through $PM_{2.5}$.

Empirical Specification: 2SLS

First stage:

$$\text{PM}_{2.5g,t-1} = \alpha_0 + \alpha_1 TI_{g,t-1} + \alpha_2 X_{i,t} + \alpha_3 W_{g,t-1} + \rho_h + \gamma_{s,y} + \varepsilon_{i,t}$$

Second stage:

$$\log(\text{Hours}_{i,t}) = \beta_0 + \beta_1 \widehat{\text{PM}_{2.5}}_{g,t-1} + \beta_2 X_{i,t} + \beta_3 W_{g,t-1} + \tau_h + \delta_{s,y} + \vartheta_{i,t}$$

- $\log(\text{Hours}_{i,t})$: log monthly hours worked
- $\text{PM}_{2.5g,t-1}$: monthly mean $\text{PM}_{2.5}$ in grid g, **one-month lag**
- $TI_{g,t-1}$: inversion frequency, same lag (IV)
- $X_{i,t}$: age, education, household size, marital status
- $W_{g,t-1}$: temperature, precipitation, wind, pressure, humidity
- ρ_h, τ_h: household FE; $\gamma_{s,y}, \delta_{s,y}$: season$\times$year FE
- SEs clustered at the thermal-inversion grid (179 cells)

Results: Impact of $PM_{2.5}$ on Labor Supply

	(1) $PM_{2.5}$ First Stage	(2) ln(Hours) Second Stage
Thermal Inversions	86.70***	
	(9.59)	
$PM_{2.5}$		−0.0149***
		(0.0049)
Controls	Yes	Yes
Household FE	Yes	Yes
Season×Year FE	Yes	Yes
Observations	32,940	32,940
N clusters	179	179
First-stage *F*	81.7	

Individual and one-month-lag weather controls in both stages. SEs clustered at the thermal-inversion grid. First-stage F is the cluster-robust Kleibergen–Paap F. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

- 1 SD in inversions $\rightarrow +2\,\mu g/m^3$ $PM_{2.5}$ ($\approx$2.1% of mean 94.2).
- $10\,\mu g/m^3$ $PM_{2.5}$ $\rightarrow -14.9\%$ monthly hours ($\approx$16.4 hrs vs. mean 109.9).
- *Larger* than 3–6% estimates from urban and national samples (Aragón et al. 2017; Kim et al. 2017; Fan & Grainger 2023)

Heterogeneity

	(1) Baseline	(2) Gender	(3) Education	(4) Income	(5) Outdoor	(6) Occupation
$PM_{2.5}$	-0.0149^{***}	-0.0069	-0.0136^{***}	-0.0134^{***}	-0.0098^{**}	-0.0133^{***}
	(0.0049)	(0.0043)	(0.0049)	(0.0047)	(0.0044)	(0.0043)
$PM_{2.5}\times$Male		-0.0003 (0.0009)				
$PM_{2.5}\times$Primary educ.			0.0000 (0.0015)			
$PM_{2.5}\times$Secondary+			-0.0012 (0.0013)			
$PM_{2.5}\times$Middle inc.				0.0013 (0.0016)		
$PM_{2.5}\times$High inc.				0.0003 (0.0015)		
$PM_{2.5}\times$Outdoor					$-$**0.0024**** (0.0011)	
$PM_{2.5}\times$Wage labor						**0.0025**** (0.0012)
$PM_{2.5}\times$Salaried						0.0020 (0.0017)
$PM_{2.5}\times$Business						**0.0028**** (0.0011)
$PM_{2.5}\times$Other occ.						-0.0021 (0.0032)
First-stage F	81.7	41.0	27.7	27.1	40.8	16.5
Observations	32,940	32,940	32,940	32,940	32,940	32,933

Base categories: female, no schooling, low income, indoor, farming. $PM_{2.5}$ and its interaction are both instrumented (inversions and inversion $\times$ moderator). All columns include controls, household and season $\times$ year FE. SEs clustered at the thermal-inversion grid. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

- **Outdoor & farming:** outdoor effect -0.0122, $\sim$25% larger than indoor; farmers cut hours more than wage, salaried and business workers — consistent with greater exposure.
- **Gender, education & income:** interactions small and insignificant — no gradient.
- **Composition:** the gender column is about half the baseline because pollution raises women's share of workers by 5.6 pp; men and women respond alike (interaction -0.0003).

Mechanisms: Workers' Own Health

	(1) Persistent cough	(2) Any respiratory symptom	(3) % of days ill (0–100)	(4) Any illness	(5) Diarrhea (placebo)
Panel A. All workers					
$PM_{2.5}$	0.0050**	0.0055**	0.84***	0.0126***	0.0008
	(0.0021)	(0.0022)	(0.21)	(0.0030)	(0.0008)
Mean of dep. var.	0.116	0.121	24.3	0.415	0.019
Panel B. Differences by gender					
$PM_{2.5}$ (women)	0.0053**	0.0058***	0.82***	0.0123***	0.0008
	(0.0021)	(0.0022)	(0.21)	(0.0030)	(0.0008)
$PM_{2.5} \times$ Male	−0.0004	−0.0004	−0.04	−0.0001	0.0000
	(0.0003)	(0.0004)	(0.04)	(0.0005)	(0.0002)
First-stage F (A / B)	75.0 / 37.6	75.0 / 37.6	75.0 / 37.6	75.0 / 37.6	75.0 / 37.6
Observations	32,419	32,419	32,419	32,419	32,419

Four-week illness module. 2SLS with baseline controls, household and season × year FE. SEs clustered at the thermal-inversion grid. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

- $10\,\mu g/m^3$ $PM_{2.5}$ → **+12.6 pp any illness**, +5.5 pp respiratory symptoms, +8.4 pp days ill (≈2.3 more days in four weeks).
- Placebo (diarrhea) unaffected; health effects are **the same for men and women**.

Mechanisms: Margins of Labor Supply

	(1) Log hours per day	(2) Log days worked	(3) % of days unable to work
Panel A. All workers			
$PM_{2.5}$	-0.0125^{**}	-0.0024	0.07
	(0.0049)	(0.0020)	(0.06)
Panel B. Differences by gender			
$PM_{2.5}$ (women)	-0.0039	-0.0030	0.06
	(0.0041)	(0.0019)	(0.06)
$PM_{2.5} \times$ Male	0.0006	$\mathbf{-0.0009}^{**}$	$\mathbf{0.02}^{**}$
	(0.0009)	(0.0004)	(0.01)
First-stage F (A / B)	81.7 / 41.0	81.7 / 41.0	79.7 / 40.0
Observations	32,940	32,940	32,162

2SLS with baseline controls, household and season $\times$ year FE. SEs clustered at the thermal-inversion grid. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

- Shorter working days in Panel A largely reflect **composition**: the effect disappears once gender is controlled for.
- **Men work fewer days**: implied reduction of 3.9% per 10 μg/m^3 ($p = 0.055$); women, equally ill, keep working.

Mechanisms: Caregiving

	Morbidity of dependents				Log monthly hours	
	(1) Any dependent ill	(2) Child under 5 ill	(3) Child under 5 with cough	(4) Elderly member ill	(5)	(6)
$PM_{2.5}$	0.0036	0.0037	0.0041	0.0028	-0.0147^{***}	-0.0076^{*}
	(0.0034)	(0.0032)	(0.0027)	(0.0022)	(0.0051)	(0.0045)
$PM_{2.5} \times$ Susceptible hh					-0.0003	0.0015
					(0.0012)	(0.0012)
$PM_{2.5} \times$ Female						0.0014
						(0.0013)
$PM_{2.5} \times$ Susceptible $\times$ Female						-0.0025
						(0.0017)
Mean of dep. var.	0.319	0.240	0.137	0.109	4.221	4.221
First-stage F	81.7	81.7	81.7	81.7	39.9	20.1
Observations	32,940	32,940	32,940	32,940	32,940	32,940

Dependents: children aged 5 and under and adults aged 65 and over (47% of the sample live with one). All $PM_{2.5}$ terms instrumented. Baseline controls, household and season $\times$ year FE. SEs clustered at the thermal-inversion grid. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

- Pollution does **not** raise illness among young children or the elderly.
- Hours fall no more in households with dependents, and women in these households do not cut hours more $\Rightarrow$ **no evidence of a caregiving channel**.

Robustness Checks

Panel A: Baseline and specification checks				
	(1) Baseline	(2) Inversion strength	(3) Weather in $t-1$ and t	(4) Within-season trend
$PM_{2.5}$	-0.0149^{***}	-0.0179^{**}	-0.0212^{**}	-0.0160^{***}
	(0.0049)	(0.0088)	(0.0085)	(0.0053)
First-stage F	81.7	29.9	28.9	75.4
Observations	32,940	32,940	32,940	32,940
Panel B: Sample checks and placebo tests				
	(5) Attrition indicator	(6) Excl. migrant households	(7) Placebo: future inversions	(8) Placebo: randomly assigned
$PM_{2.5}$	-0.0152^{***}	-0.0147^{*}	-0.0081	-0.0071
	(0.0050)	(0.0076)	(0.0066)	(0.0055)
First-stage F	77.9	34.1	84.4	52.2
Observations	32,940	23,998	32,940	32,940

2SLS of log monthly hours on one-month-lag $PM_{2.5}$; individual and weather controls, household and season × year FE; SEs clustered at the inversion grid (179 cells). F = Kleibergen–Paap. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

- **Robust:** **negative and significant** in every specification (-0.0147 to -0.0212).
- **Attrition:** inversions do not predict leaving the panel (-0.013, s.e. 0.227).
- **Placebos (7–8):** small and insignificant.

Conclusion

- Pollution reduces labor supply in rural Bangladesh
  - A 10 μg/m^3 rise in $PM_{2.5}$ $\rightarrow$ $\sim$14.9% fewer monthly hours; negative across all robustness checks
  - Larger for outdoor and farming workers; no significant differences by gender, education or household income
- Mechanism: **workers' own health**, not caregiving
  - More illness and respiratory symptoms for men and women alike; men work fewer days
  - No effect on dependents' health; no extra reduction among women with dependents
- Contribution
  - Rural developing-country setting, where evidence is scarce
  - High-resolution satellite data avoids sparse-monitor bias

Thank you

Rida Hameed · American University
rh4304a@american.edu

Appendix

Appendix: OLS, Reduced Form, First Stage, and 2SLS

	(1) OLS ln(Hours)	(2) Reduced form ln(Hours)	(3) First stage $PM_{2.5}$	(4) 2SLS ln(Hours)
Thermal inversions		-1.296^{***}	86.70^{***}	
		(0.384)	(9.59)	
$PM_{2.5}$	0.0005			-0.0149^{***}
	(0.0004)			(0.0049)
Controls	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
Season $\times$ Year FE	Yes	Yes	Yes	Yes
Observations	32,940	32,940	32,940	32,940
N clusters	179	179	179	179
First-stage F			81.7	

Notes. Column (1) is OLS of log monthly hours on $PM_{2.5}$ (one-month lag, *not* instrumented); column (2) is the reduced form (log hours on the instrument); column (3) is the first stage ($PM_{2.5}$ on the instrument); column (4) is the 2SLS estimate. All columns include individual and one-month-lag weather controls, household and season-by-year fixed effects, and SEs clustered at the thermal-inversion grid (179 cells). OLS is small and statistically insignificant; instrumenting for measurement error and endogeneity yields a substantially larger negative estimate. The 2SLS estimate equals the reduced-form/first-stage ratio ($-1.296/86.70 = -0.0149$). $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Appendix: First Stage and Reduced Form

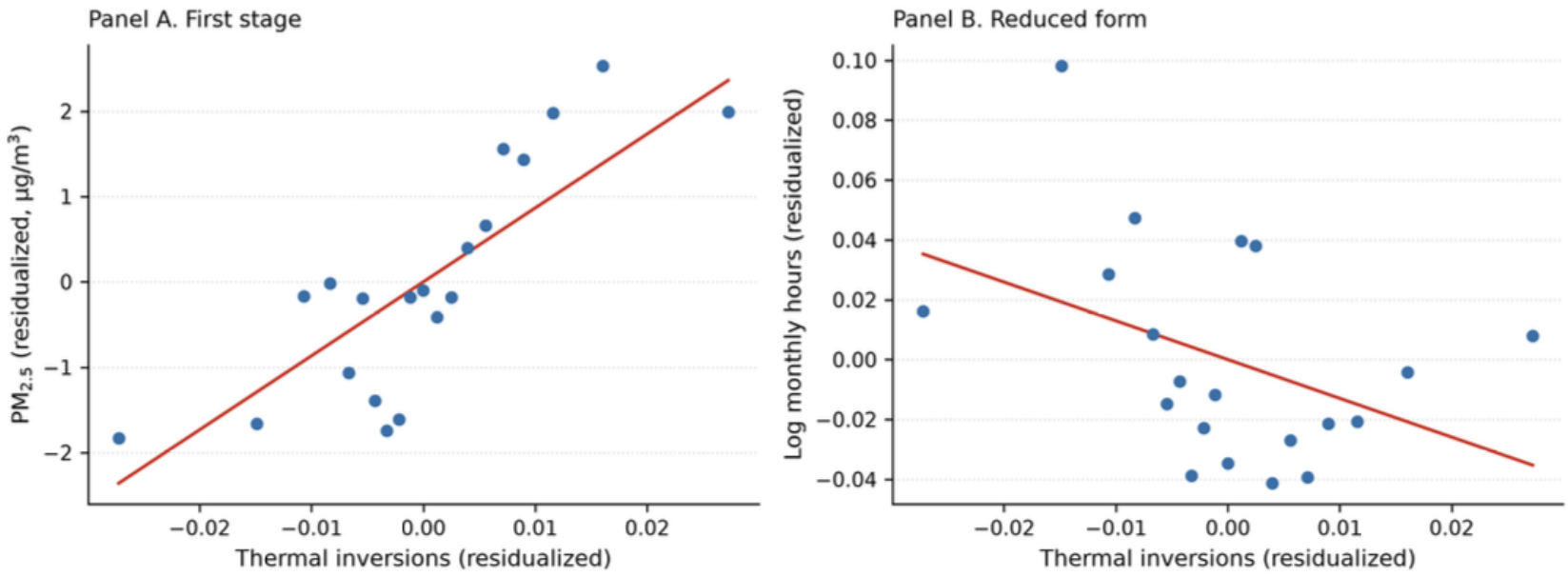


Figure A2: First Stage and Reduced Form

Note: Panel (a) plots $PM_{2.5}$ against the thermal-inversion instrument; panel (b) plots log monthly hours against the same instrument. Both are residualized on household and season-by-year fixed effects and baseline controls (age, education, household size, marital status, weather); points are means within 20 equal-sized bins, red lines are regression fits ($N = 32{,}940$). Inversions raise pollution (panel a; slope 86.7, Kleibergen–Paap $F = 81.7$) and reduce hours (panel b; slope -1.30). The ratio $-1.296/86.7 = -0.0149$ equals the 2SLS estimate.

Appendix: Heterogeneity in the Effect of $PM_{2.5}$

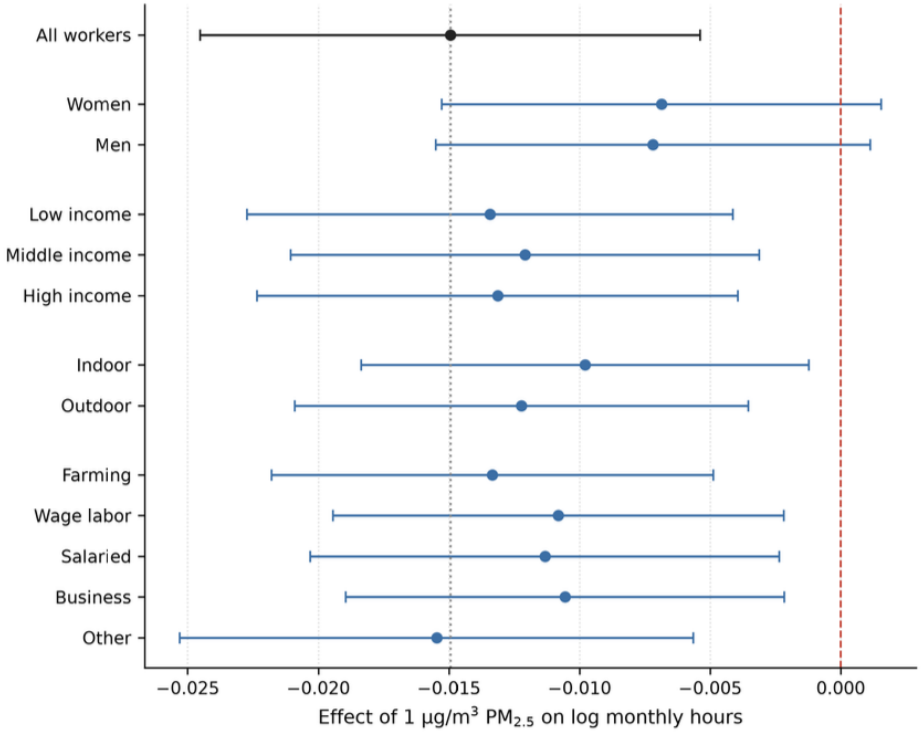


Figure A3: Heterogeneity in the Effect of PM2.5 on Labor Supply

Note: Implied 2SLS effect of 1 μg/m^3 $PM_{2.5}$ on log monthly hours by group (95% CIs); omitted-group coefficient plus the relevant interaction. Red dashed line: zero; grey dotted line: baseline (-0.0149). SEs clustered at the thermal-inversion grid.

Appendix: Descriptive Statistics

	2011–12		2015		2018–19	
Variable	Mean	SD	Mean	SD	Mean	SD
Panel A: Working Hours						
Monthly Hours	116.20	92.95	109.44	94.72	103.29	94.24
Log Monthly Hours	4.324	1.040	4.219	1.081	4.111	1.138
Panel B: Demographics and Work						
Age	36.26	12.22	37.34	12.74	37.15	13.05
Education (years)	3.77	3.89	4.11	3.98	4.61	4.15
Household Size	4.53	1.62	4.83	1.84	4.90	1.95
Married	0.83	0.38	0.81	0.39	0.79	0.41
Male	0.53	0.50	0.50	0.50	0.49	0.50
Farming	0.60	0.49	0.60	0.49	0.61	0.49
Outdoor work	0.80	0.40	0.79	0.41	0.79	0.41
Panel C: Pollution, Inversions & Weather						
$PM_{2.5}$ ($\mu g/m^3$)	68.56	28.44	103.13	29.85	112.16	31.51
Thermal Inversions (hours/month)	5.14	10.10	22.47	17.89	13.35	16.73
Precipitation (mm)	94.84	154.90	29.67	67.51	37.65	62.07
Temperature ($^\circ$C)	24.30	4.01	20.62	2.63	20.78	3.30
Wind Speed (m/s)	1.87	0.69	1.97	0.33	1.90	0.41
Air Pressure (hPa)	1007.39	7.02	1011.89	6.14	1011.58	7.31
Relative Humidity (%)	80.93	3.75	77.13	5.46	75.36	4.40
Observations	11,114		11,880		9,946	

Working sample: individuals aged 15–64 with a primary work activity and complete controls, in households observed in at least two waves. $N = 32{,}940$ across 5,877 households.