Lost in Aggregation: The Local Environmental and Welfare Effects of Large Industrial Shutdowns

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Roadmap

Motivation

Data

The Impact of Large Industrial Shutdowns

The Amenity Effects of Industrial Closures

Conclusion

Structural Transformation in Germany

▸ Industrial Employment

The New York Times

Germany Closes Its Last Black Coal Mine

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The Prosper-Haniel coal mine in Germany was closed with a ceremony last Friday. The black coal it produced helped fuel the country's industry. Christophe Gateau/DPA, via Agence France-Presse — Getty Images

By The Associated Press

Dec. 24, 2018

East Germany's old mines transformed into new lake district

Despite a €2.2bn regeneration programme, the Lusatian Lake District project, on land once occupied by the GDR's industrial heartland, remains relatively unknown to non-east Germans. So we took a tour ...

What a dive ... a floating house on Geierswalder lake, east Germany. Photograph: Alamy

'This was once one of the dirtiest areas in East Germany," says Sören, my tour guide from IBA Tours, as our bikes swoosh through the Lusatian Lake District. "When I was growing up here, before the Wall fell, we never hung our laundry outside, and we never wore white socks, because we knew they wouldn't be white after a few minutes. The coal dust was everywhere, all the time."

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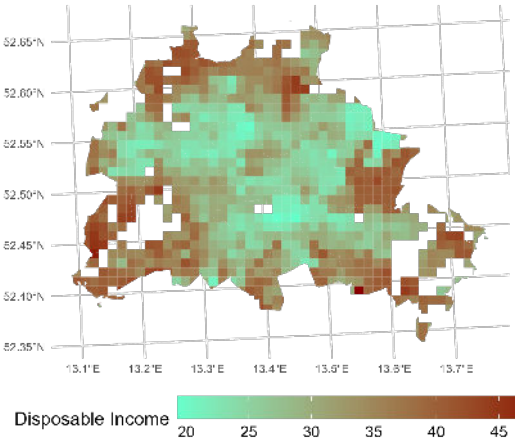
Data: EEA Industrial Reporting Database ▸ Industrial Composition

- Combines previous reporting requirements from E-PRTR and IED
- Two reporting thresholds:
  - **pollutant** specific (e.g. 100t of nitrogen oxides per year)
  - **installation** specific (e.g. heat input $>=$ 50 MW for thermal power stations)
- Covers almost 100,000 facilities in the EU and partner countries since 2007 - 10,400 of which are located in Germany
- New release contains information on the operating status of reporting facilities
- CO2 emissions reported in 2021 account for 47% and 82% of total territorial and combined industry CO2 emissions respectively, reported NOx emissions cover 20% of national total ▸ Emission Breakdown ▸ Distribution across Plants

Data: Socio-Economic and Real Estate Information

- Socio-Economic Data at 1km $\times$ 1km grid cell level from RWI-GEO-GRID for 2005 & 2009-2021 (Breidenbach and Eilers, 2018)
- Real estate data on house/apartment sales and rents at the object level from *Immobilienscout24* (Schaffner and Thiel, 2024)
- $\Rightarrow$ Panel of $\approx$ 2 million grid cell - year observations

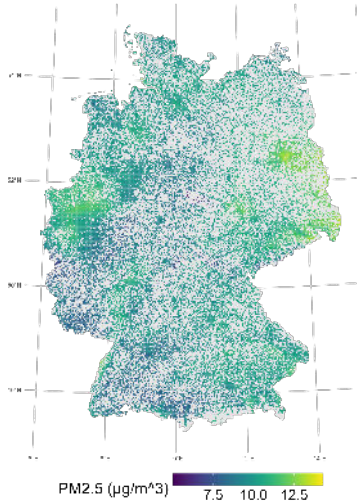


Mean Grid Cell Income Berlin 2021

Data: Air Pollution & Weather

- $PM_{2.5}$ reanalysis raster data from van Donkelaar et al. (2021) at $0.01° \times 0.01°$ resolution
- Weather data from CRU at East Anglia University ($0.5° \times 0.5°$ resolution) (Harris et al., 2020)

- Fowlie et al. (2019) show attrition in remote sensing $PM_{2.5}$ data at high pollution levels ▸ Attrition Plot



Mean Ambient PM2.5 Concentration 2021

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The Role of Industrial Facilities in Pollution Exposure

$$Y_{nt} = \sum_{s \neq -1} \theta_s \times \mathbb{1}[Closure_{nt}] \times \mathbb{1}[t - \tau_n = s] + C_{nt}\beta' + \alpha_n + \omega_{l \times t} + \epsilon_{nt} \quad (1)$$

- Y_{nt}: Outcome of interest (PM2.5, housing prices, etc) in grid cell n in year t
- $Closure_{nt}$: indicator for facility closure affecting grid cell n in year t
- C_{nt}: vector of weather controls
- τ_n year of **first** treatment for grid cell n

Model estimated using the two-stage estimator proposed in Gardner et al. (2024)

▸ Estimation Sample

Effect of Plant Closures on PM2.5 Concentration

Effect of Plant Closures on PM2.5

Dependent Variable:	PM2.5		
Model:	(1)	(2)	(3)
Closure	-0.1856***	-0.1909***	-0.1990***
	(0.0546)	(0.0523)	(0.0525)
Closure × Downwind			
Fixed Effects			
Grid Cell	Yes	Yes	Yes
Bundesland × Year	Yes	Yes	
Year			Yes
Weather Controls		Yes	Yes
Mean (SD) at t-1		11.30 (1.72)	
Observations	223,801	223,801	223,801

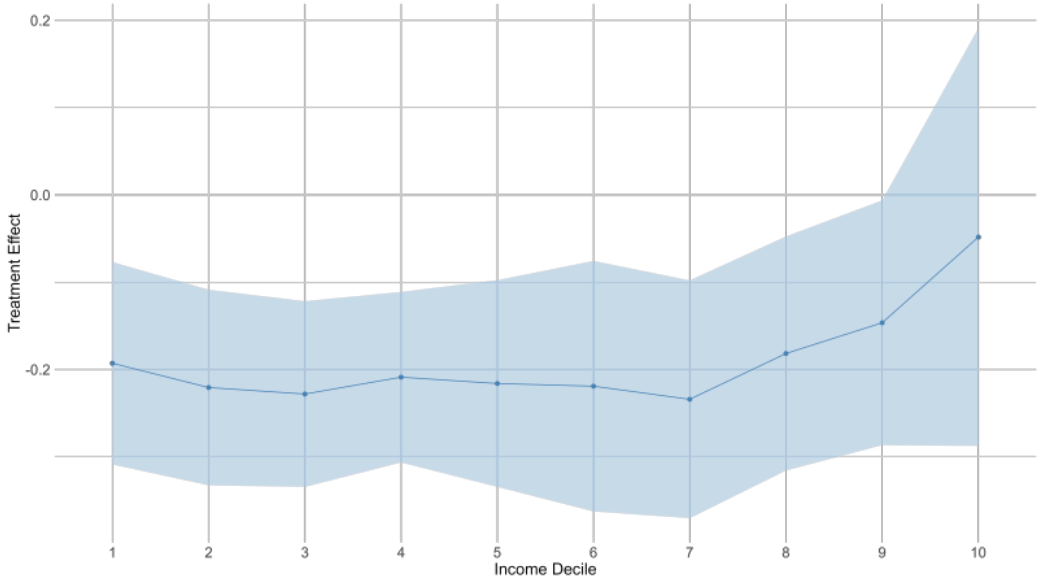
Standard errors clustered by municipality
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Effect of Plant Closures on PM2.5

Dependent Variable:	PM2.5		
Model:	(1)	(2)	(3)
Closure	-0.1856***	-0.1909***	-0.1990***
	(0.0546)	(0.0523)	(0.0525)
Closure × Downwind	-0.2141***	-0.2157***	-0.2221***
	(0.0643)	(0.0600)	(0.0598)
Fixed Effects			
Grid Cell	Yes	Yes	Yes
Bundesland × Year	Yes	Yes	
Year			Yes
Weather Controls		Yes	Yes
Mean (SD) at t-1		11.30 (1.72)	
Observations	223,801	223,801	223,801

Standard errors clustered by municipality
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

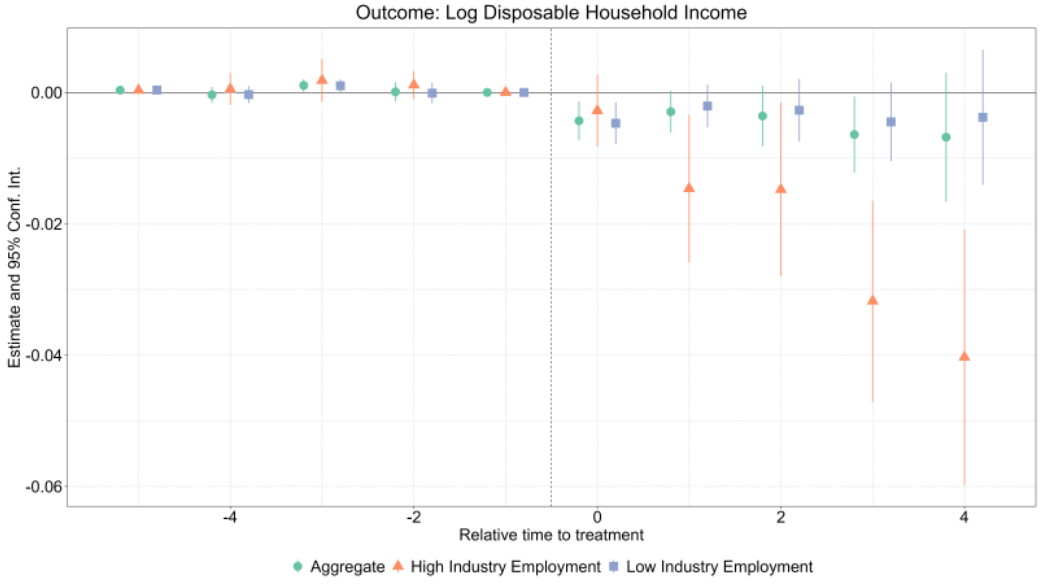
Treatment Effect Heterogeneity by Income Decile



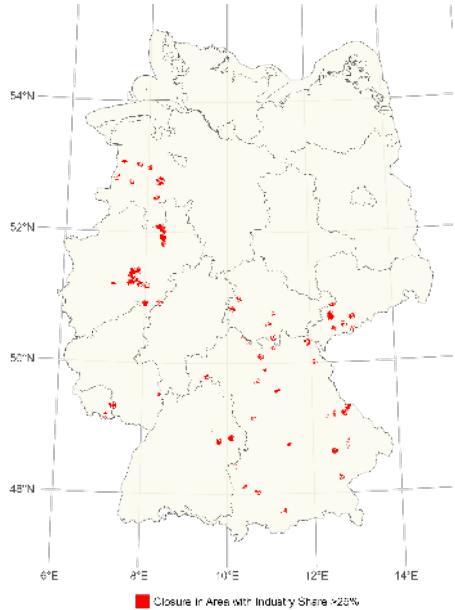
Effect of Plant Closures on Household Income

Effect of Plant Closures on Local Income

▸ Triple Diff ▸ Unemployment Controls ▸ Rud et al (2024)



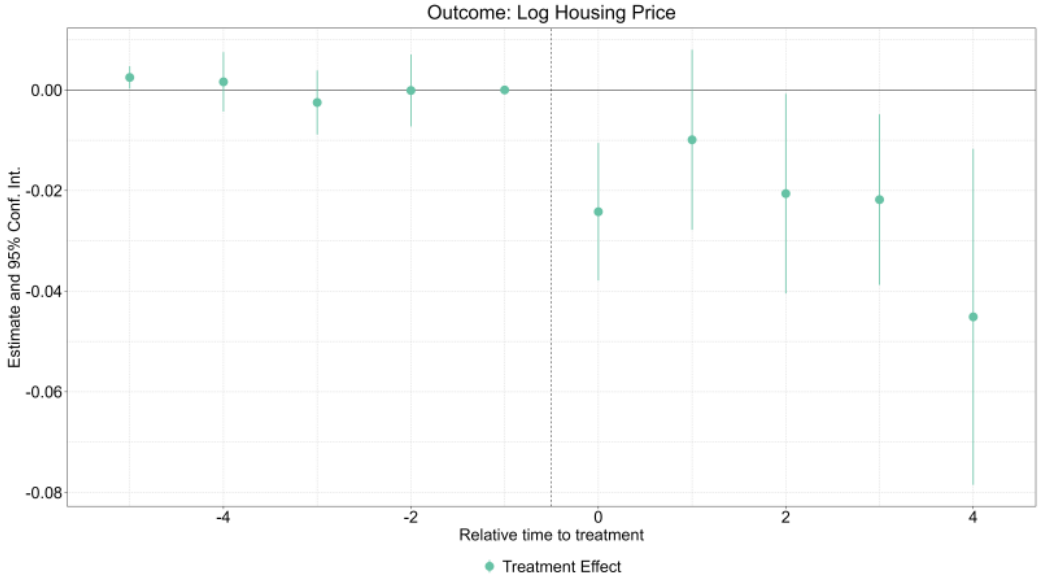
Spatial Distribution of Income Losses



Effect of Plant Closures on Housing Prices

Effect of Plant Closures on Housing Prices

Unemployment Controls | US Estimate



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Model

Consider the most simple version of a Rosen-Roback framework as in Bartik et al. (2019) :

$$\max_{c,h} \; u_{ln} = A_n \cdot h^{\alpha} \cdot c^{1-\alpha} \cdot \theta_{ln}$$

$$s.t. \; h \cdot p_n + c = w_n.$$

Assume that:

- every worker inelastically supplies one unit of labor in the neighborhood they live in (i.e. no commuting to work in a different neighborhood)
- the taste shock θ_{ln} is drawn from a TII EV distribution

Model

Indirect utility of living in neighborhood n is given by

$$U_{ln} = \frac{A_n w_n}{h_n^{\alpha}} \theta_{ln}$$

Hence, the probability that a worker chooses neighborhood n over any neighborhood r is given by

$$P\Big(\frac{A_n w_n}{h_n^{\alpha}} \theta_{nl} \geq \frac{A_r w_r}{h_r^{\alpha}} \theta_{rl} \Big) \qquad \forall\, r \neq n.$$

Model

Using the assumption that $\theta_{ln} \sim F(\theta_n) = exp(-\theta^{-\phi})$, the share of workers living in neighborhood n can be expressed as

$$s_n = \frac{\left(\frac{A_n w_n}{h_n^{\alpha}}\right)^{\phi}}{\sum_{r=1}^{N} \left(\frac{A_r w_r}{h_r^{\alpha}}\right)^{\phi}}.$$

Let $R_n = L \cdot s_n$ the population in neighborhood n

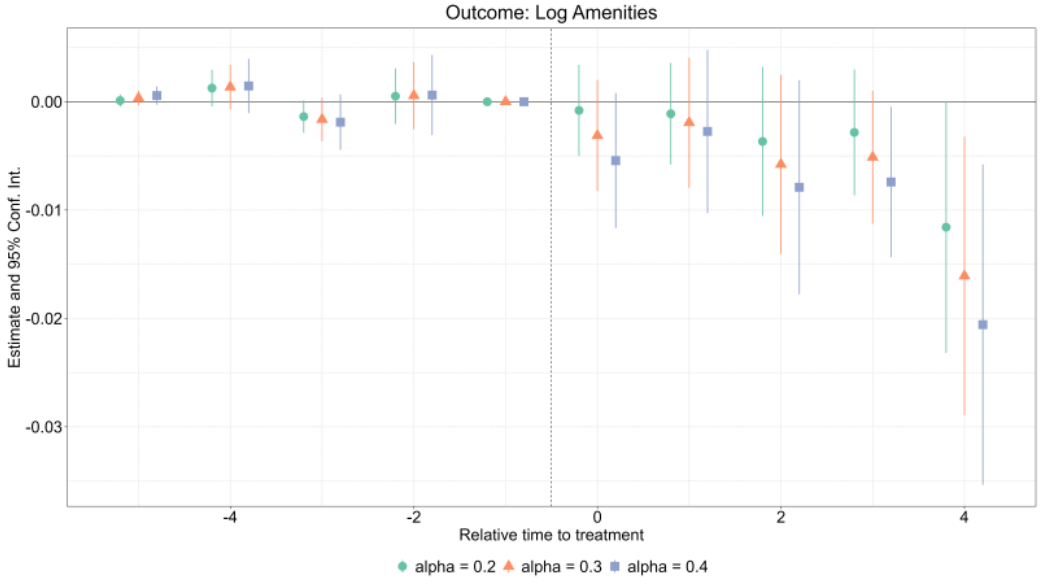
Model

Rearranging the previous expression for s_n gives an expression of amenities in neighborhood n as a function of observables and the parameters ϕ and α

$$ln(A_n) = \frac{1}{\phi} ln(R_n) + \alpha\, ln(h_n) - ln(w_n) - \frac{1}{\phi} ln(L) + \frac{1}{\phi} ln\Big(\sum_{r=1}^{N} \frac{A_r w_r}{h_r^{\alpha}} \Big)^{\phi}$$

- ϕ = 4.56 based on a recent estimate for Germany by Krebs and Pflüger (2023)
- $\alpha \in (0.2; 0.4)$ based on Monte et al. (2018); Quentel (2023)

Effect of Plant Closures on log Amenities



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- Significant PM2.5 exposure gap between richest and poorest neighborhoods in Germany - a result that is masked in more aggregate data
- Industrial Shutdowns lead to improved local air quality and reduce exposure gap locally - avoided mortality cost from local PM2.5 reductions $\sim$ € 1.2 - 3.2 billion
- Total annual household income losses from shutdowns amount to € 0.9 - 1.7 billion (0.2 - 0.4% of public spending)
- No evidence for amenity gains in neighborhoods surrounding closed sites

Thank you for your attention!

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WORKING PAPER

Roadmap

Appendix

Descriptive Results

References I

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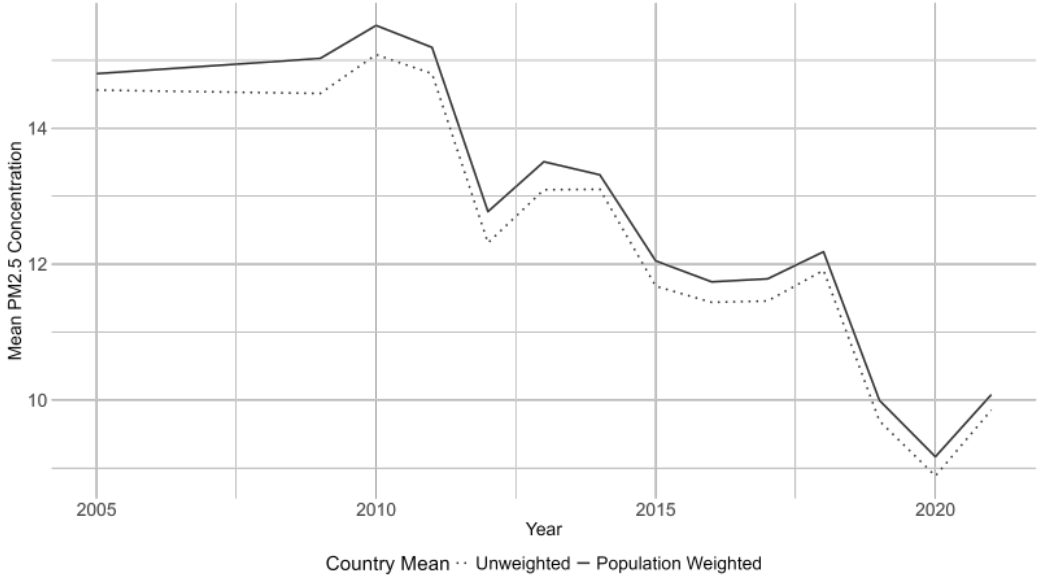
Air Quality in Germany 2005 - 2021



Roadmap

Appendix

Descriptive Results

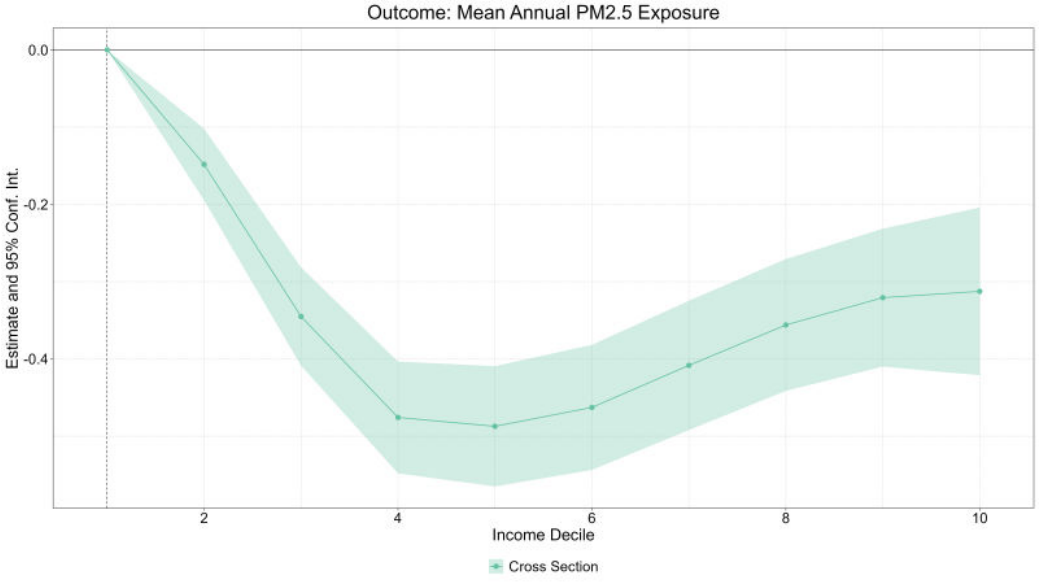
Pollution Exposure Across Income Deciles

$$PM_{2.5,nt} = \omega_{l \times t} + \sum_{k=2}^{10} \theta_k \mathbb{1}(D_{nt} = k) + C_{nt}\beta' + X_{nt}\delta' + \epsilon_{nt} \quad (2)$$

- $PM_{2.5,nt}$: Mean annual PM2.5 concentration in grid cell n in year t
- D_{nt}: Decile of mean annual disposable household income
- C_{nt}: Average Temperature & Precipitation
- X_{nt}: Share of foreign-born residents

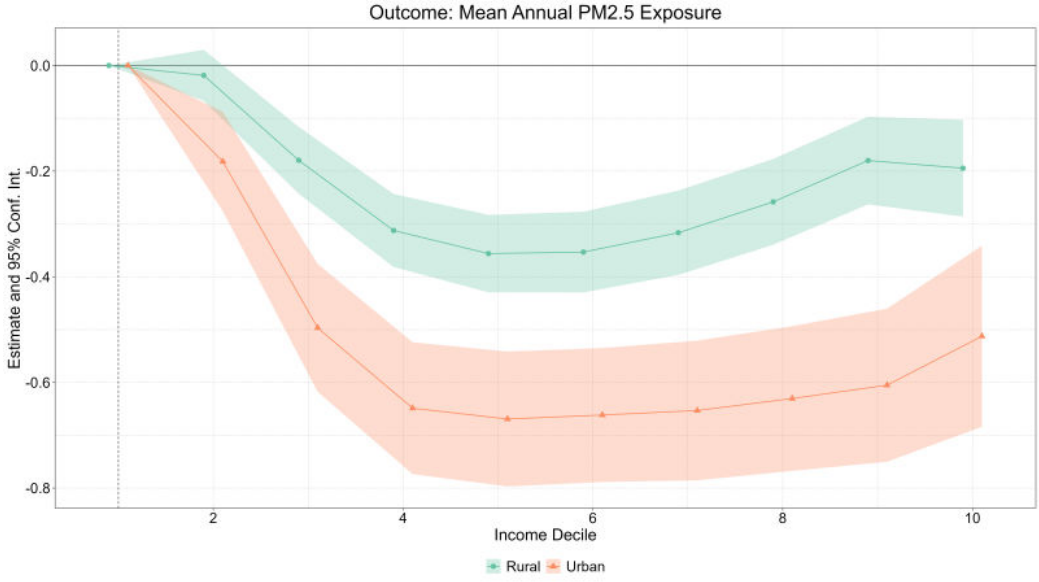
Pollution Exposure across Income Deciles

▸ Raw Distribution



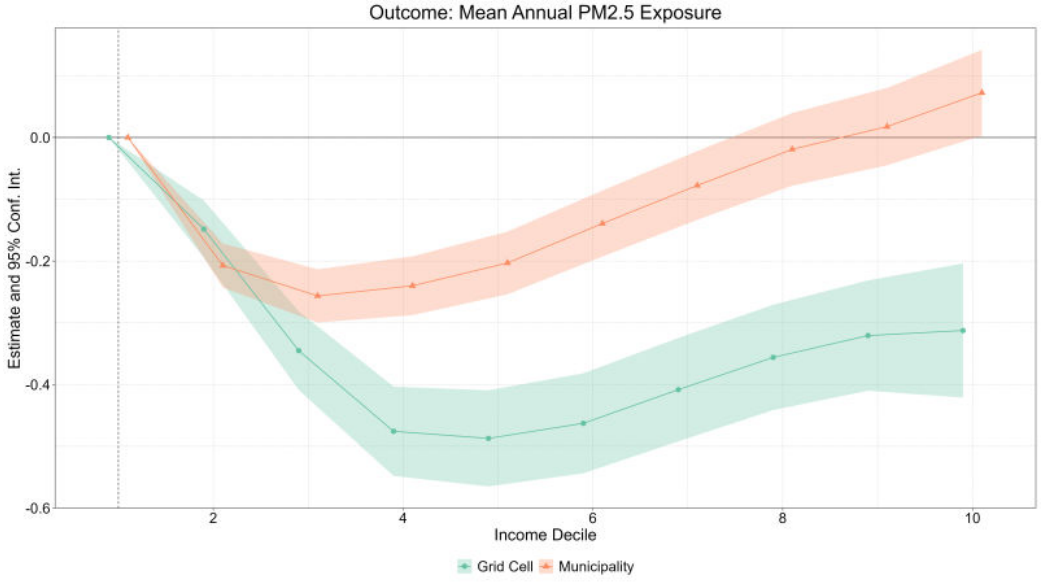
Exposure across Income Deciles

Back



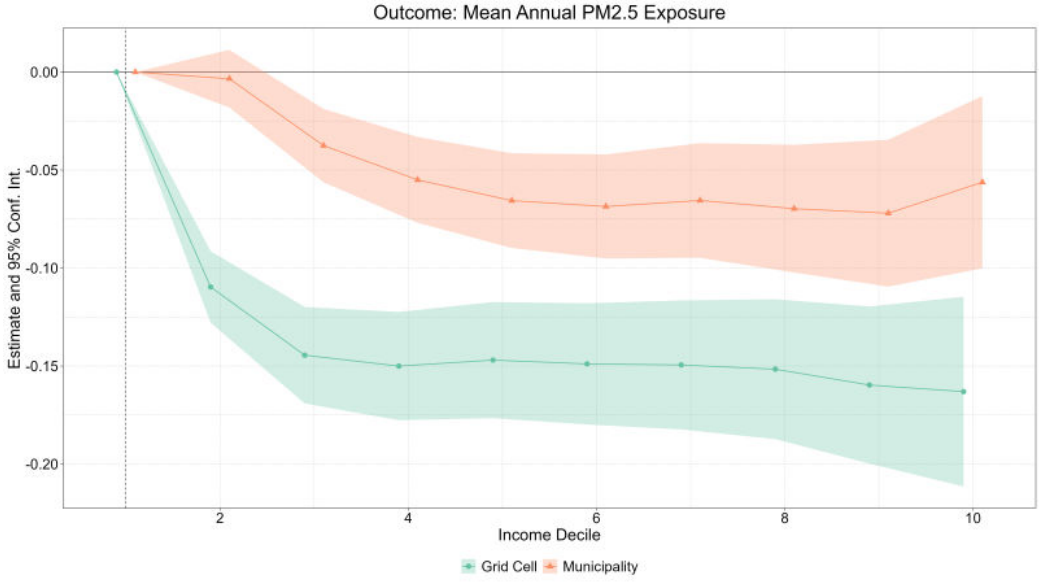
Pollution Exposure Across Income Deciles

Unit FE | Urban v Rural | Within Unit Variation



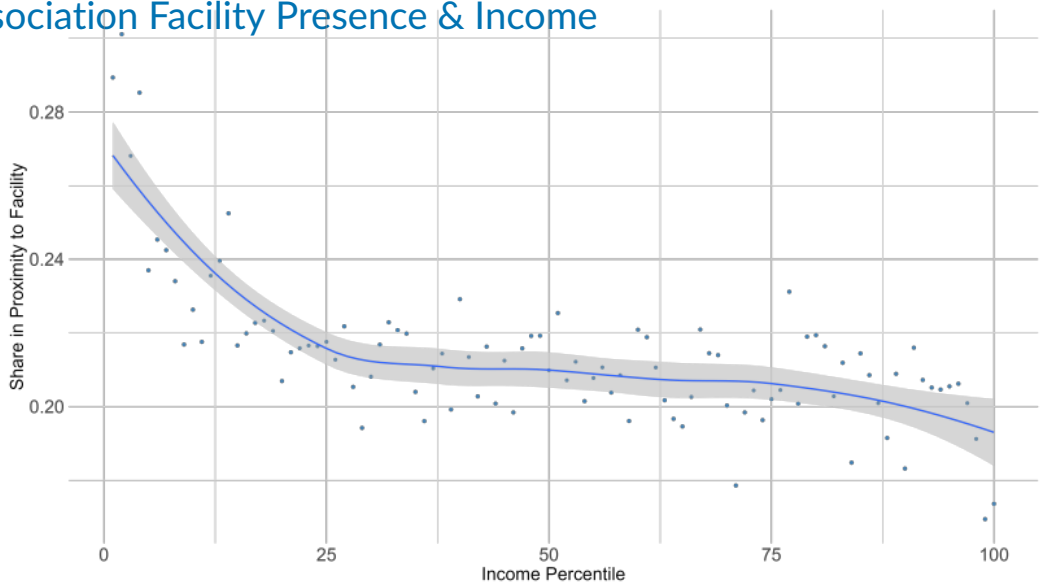
Exposure across Income Deciles

Back

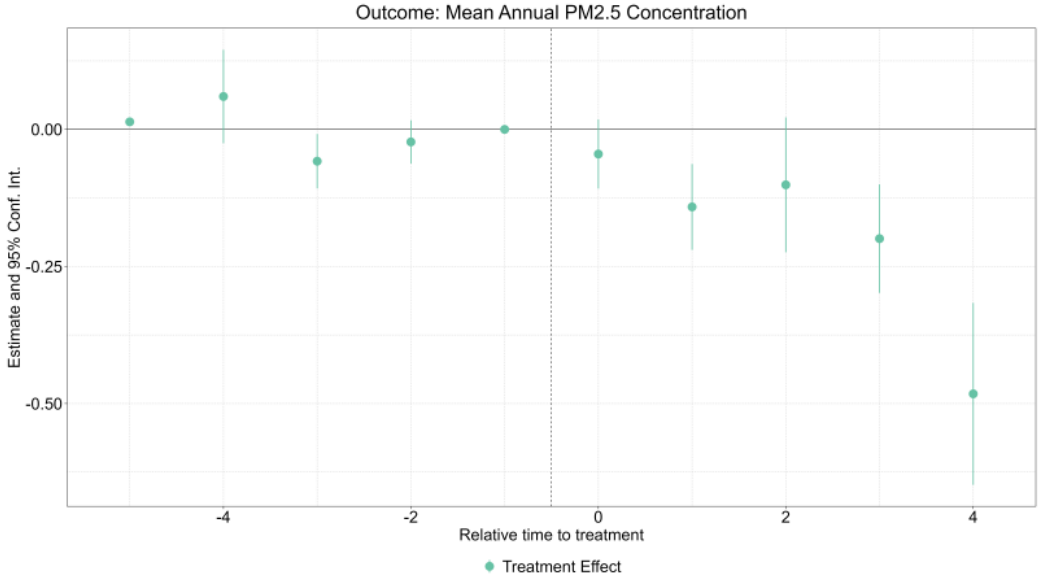


Location of Plant Closures in Germany

Association Facility Presence & Income

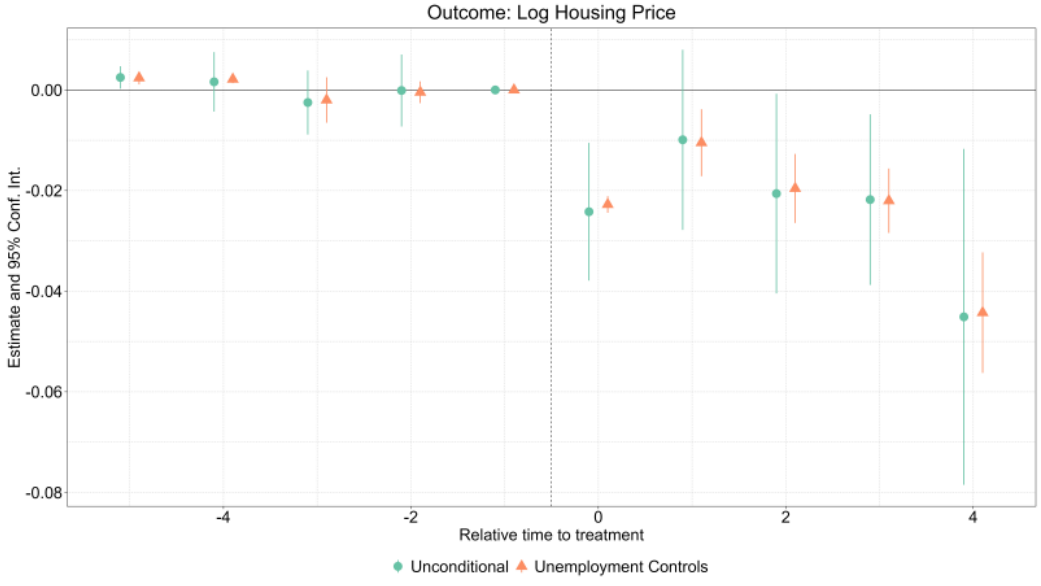


Effect of Plant Closures on PM2.5



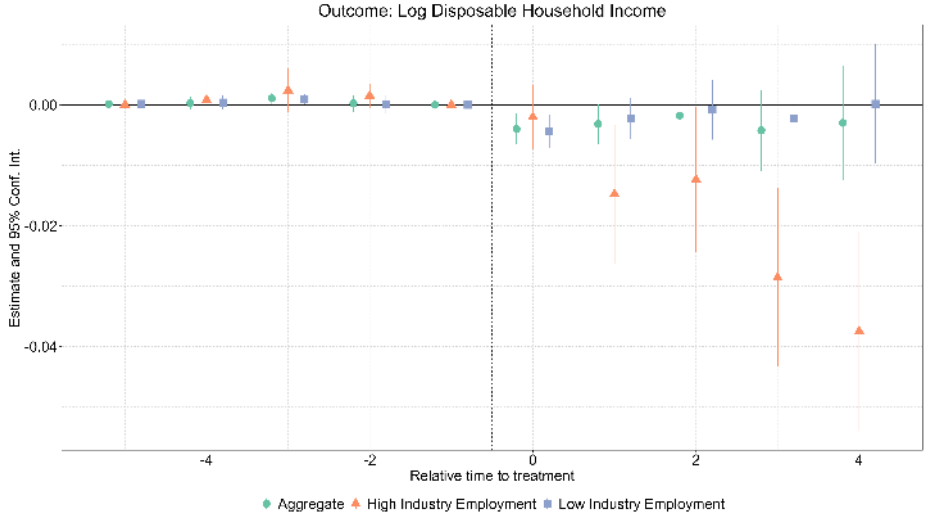
Effect of Plant Closures on Housing Prices

Back



Effect of Plant Closures on Local Income (with Unemployment Controls)

Back



Within Municipality Variation - Berlin

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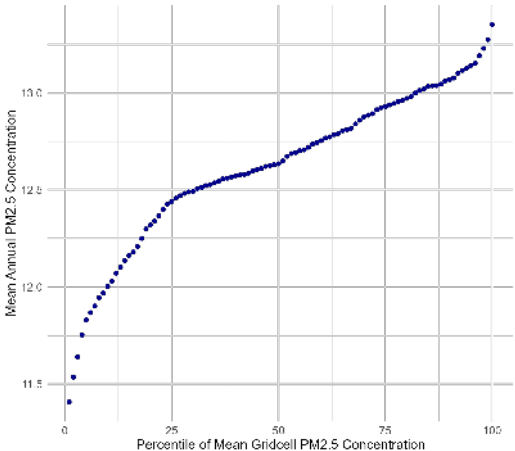
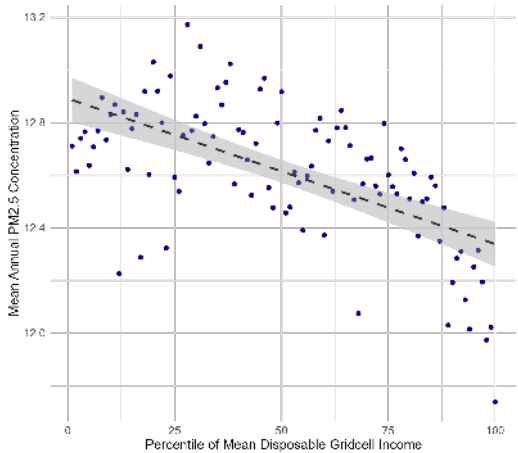
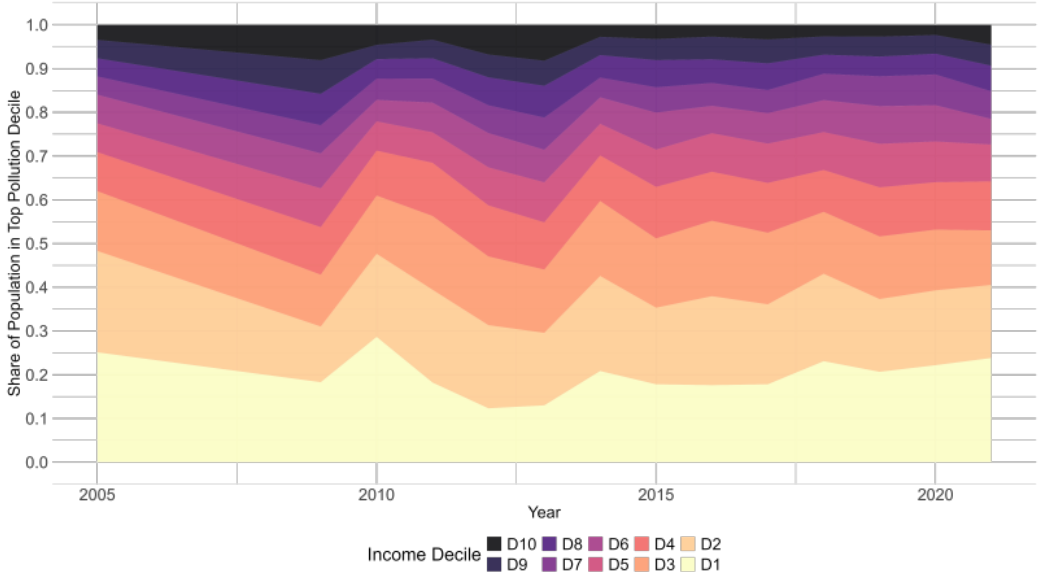


(a) PM2.5 Percentile

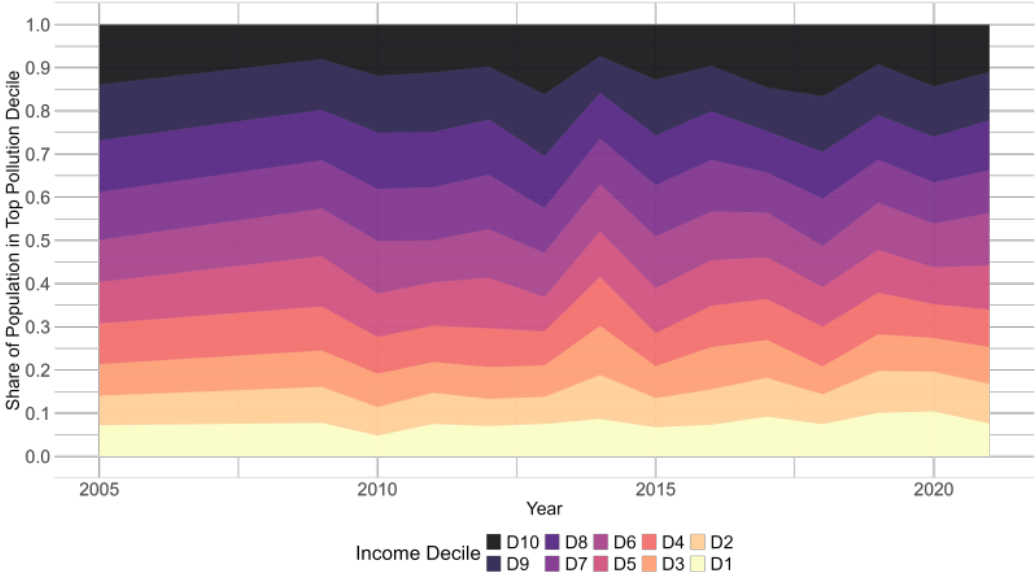


(b) Household Income Percentile

Share of Income Deciles Within Top Pollution Decile



Share of Income Deciles Within p45p55 of Pollution Distribution



Absolute Income Effects

	t - 5	t - 4	t - 3	t - 2	t	t + 1	t + 2	t + 3	t + 4
Industrial Employment Share $<= 25\%$									
Coefficient	0.0115*	-0.0032	0.0447***	-0.0097	-0.1409***	-0.0672	-0.0663	-0.1168	-0.0731
(SE)	(0.0065)	(0.0176)	(0.0157)	(0.0252)	(0.0482)	(0.0452)	(0.0652)	(0.0998)	(0.1539)
Industrial Employment Share $> 25\%$									
Coefficient	0.0049	0.0107	0.0577	0.0304	-0.0277	-0.3811**	-0.3641**	-0.8009***	-0.9308***
(SE)	(0.0071)	(0.0367)	(0.0563)	(0.0287)	(0.0588)	(0.1650)	(0.1691)	(0.2139)	(0.2161)

	Observations	Within R^2	Adjusted R^2	Baseline Income (Full)	Baseline Income (Estimation)
Industr Empl $<= 25\%$	187,882	0.00154	0.00150	27.57	27.42
Industr Empl $> 25\%$	34,801	0.07952	0.07931	28.13	27.48

Standard errors clustered by Municipality
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Total Income Losses

- Total population in neighborhoods with closures and industrial employment share $> 25\% \approx$ 1.4 million adults
- Based on the 95% CI of the estimate in t+4, the total annual income loss amounts to **€ 0.9 - 1.7 billion** (0.2 - 0.4% of federal public spending in Germany in 2023)
- Avoided mortality cost from local PM2.5 reductions € 1.2 - 3.2 billion (€110 - 280 million of which in high industry areas)

Industry Composition

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Sector	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Animal and vegetable products	53	47	36	37	27	25	32	31	30	29	26	27	26
Chemical industry	232	227	209	210	206	206	198	181	177	178	161	171	170
Energy sector	832	840	815	821	803	750	743	748	678	688	621	539	566
Intensive livestock production	516	558	569	652	678	651	632	641	614	619	587	615	580
Mineral industry	368	368	375	375	369	368	359	358	359	359	341	324	317
Other activities	78	76	75	73	71	72	54	61	55	57	56	49	49
Paper and wood production	116	128	124	133	123	114	114	120	107	99	84	83	88
Production and processing of metals	319	340	323	339	327	300	308	318	309	316	317	295	288
Waste and wastewater management	406	410	395	402	389	382	377	384	361	317	290	293	285
Sum	**2920**	**2994**	**2920**	**3042**	**2993**	**2868**	**2817**	**2842**	**2690**	**2662**	**2483**	**2396**	**2369**

Composition of CO2 Emissions

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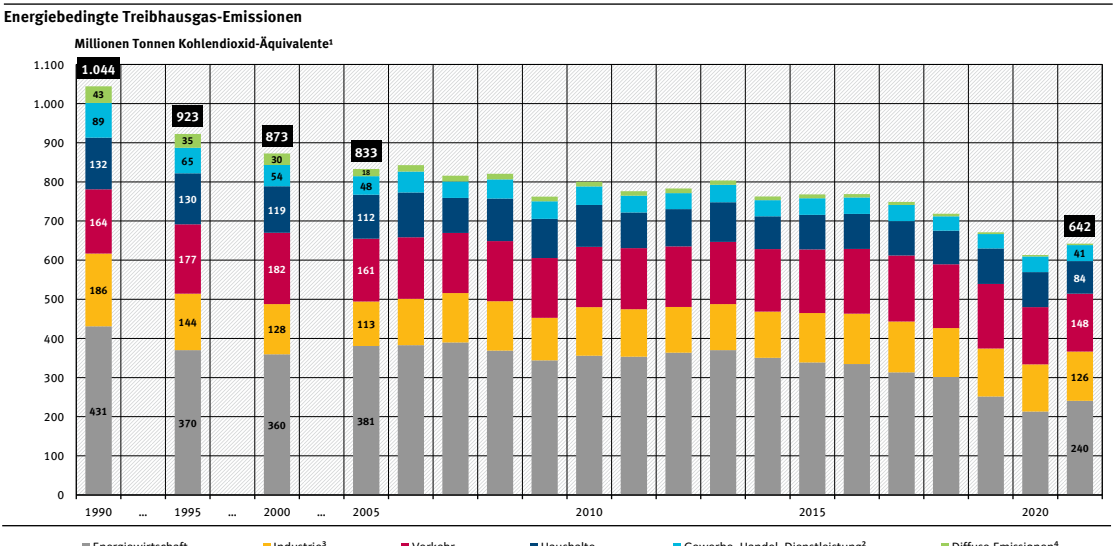

¹ in Kohlendioxid-Äquivalenten, berücksichtigt sind Kohlendioxid (CO_2), Methan (CH_4) und Lachgas (N_2O)
² einschließlich Militär und Landwirtschaft (energiebedingt)
³ enthält nur Emissionen aus Industriefeuerungen, keine Prozessemissionen
⁴ durch Gewinnung, Umwandlung und Verteilung von Brennstoffen

Quelle: Umweltbundesamt, Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen 1990-2021 (Treibhausgase), Stand 04/2022

Summary Statistics

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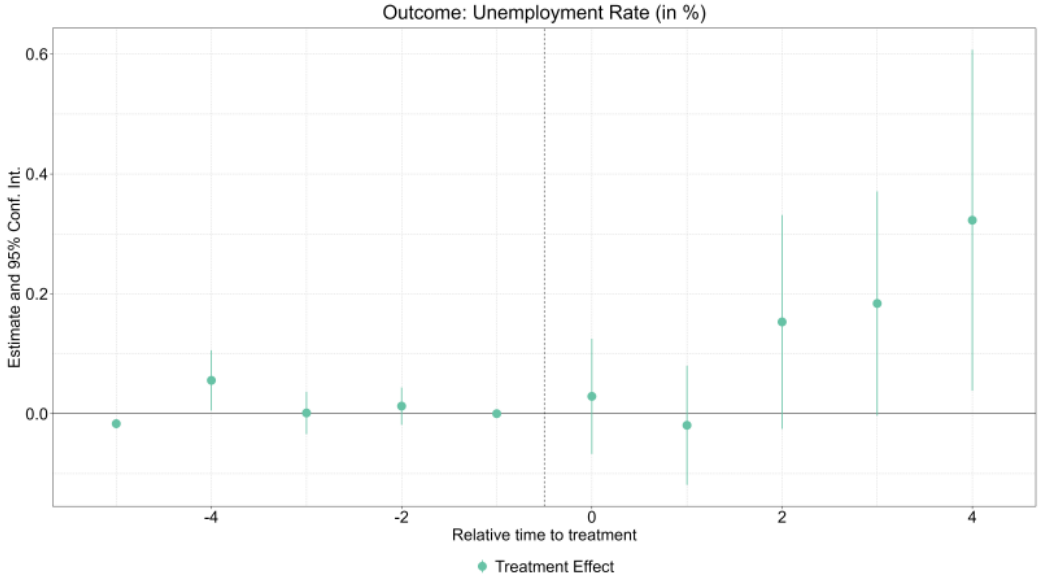
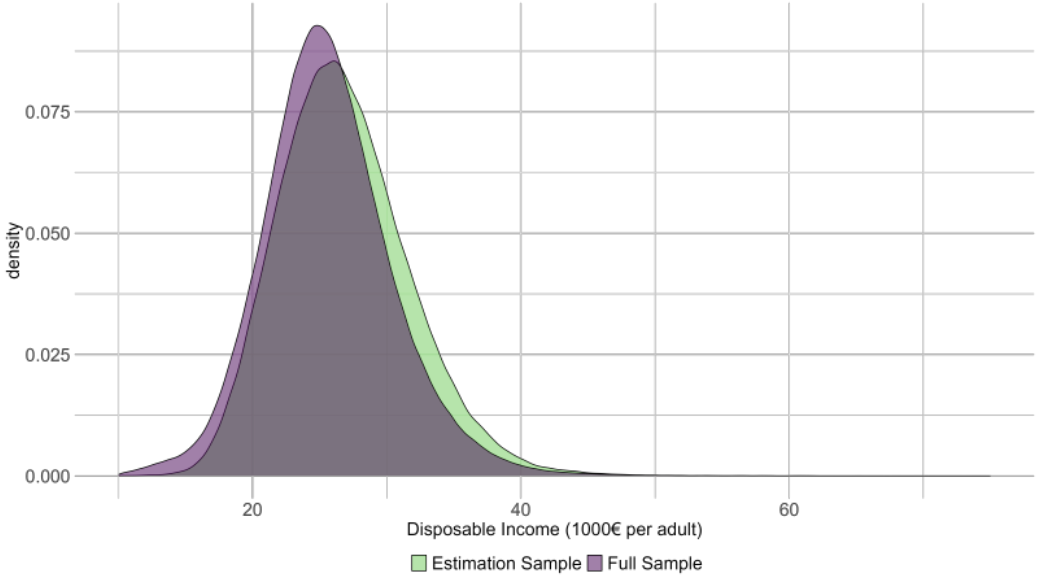
Variable	Mean	SD	P25	Median	P75
			Full Sample		
PM2.5	12.29	2.316	10.61	12.16	13.97
Income pa	25.63	4.923	22.49	25.34	28.45
Unempl Rate	5.021	3.611	2.53	4.12	6.56
Foreign Share	5.178	6.152	0.67	3.44	7.42
Population	546.8	1188	52	145	478
Housing Price (sqm)	1735	1417	996.8	1474	2124
N			2083373		
			Estimation Sample		
PM2.5	12.67	2.317	11.02	12.52	14.33
Income pa	26.85	4.927	23.41	26.46	29.83
Unempl Rate	5.614	3.876	2.79	4.75	7.58
Foreign Share	7.265	7.345	1.88	5.36	10.34
Population	1167	1952	93	335	1367
Housing Price (sqm)	2019	1445	1205	1701	2427
N			224152		

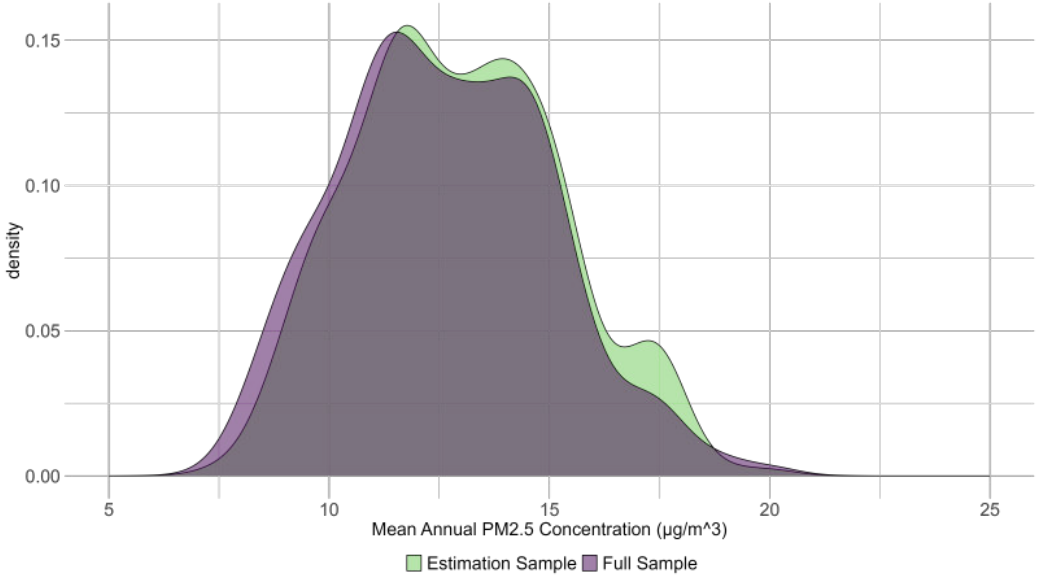
Effect of Plant Closures on Unemployment



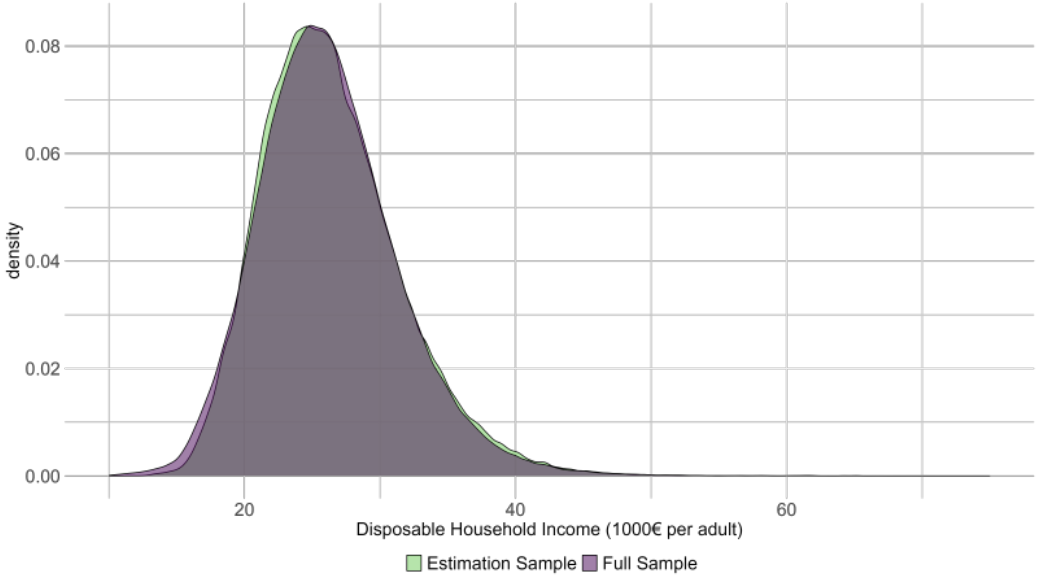
Income Estimation Sample vs Full Sample



Pollution Estimation Sample vs Full Sample



Unemployment Estimation Sample vs Full Sample



Housing Prices Estimation Sample vs Full Sample

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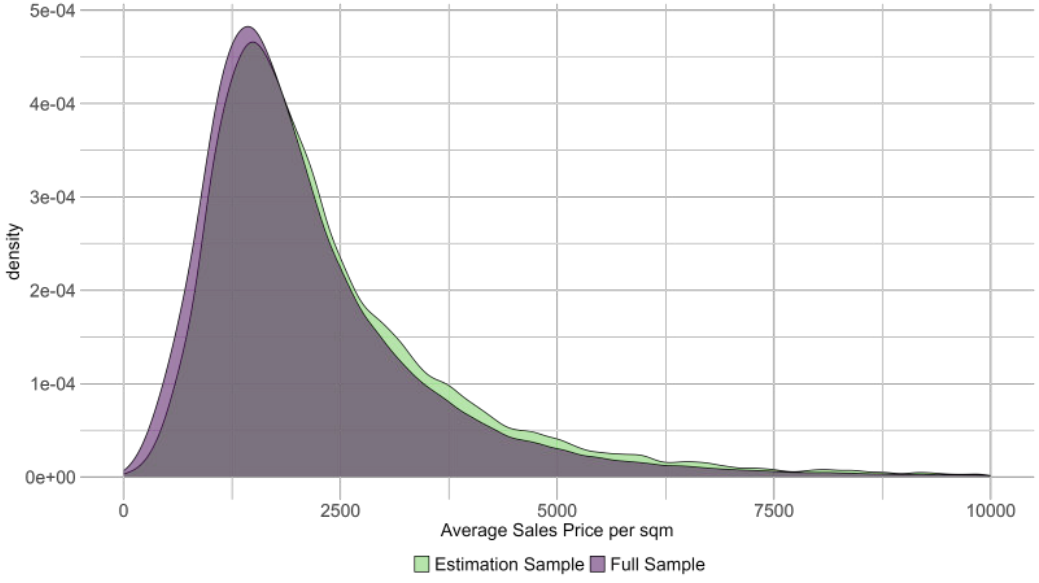
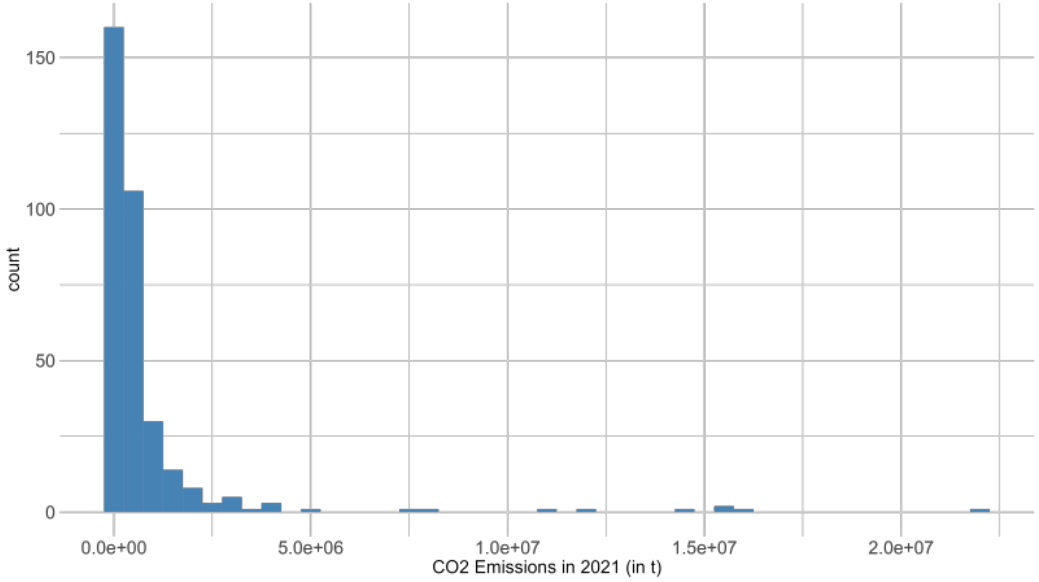


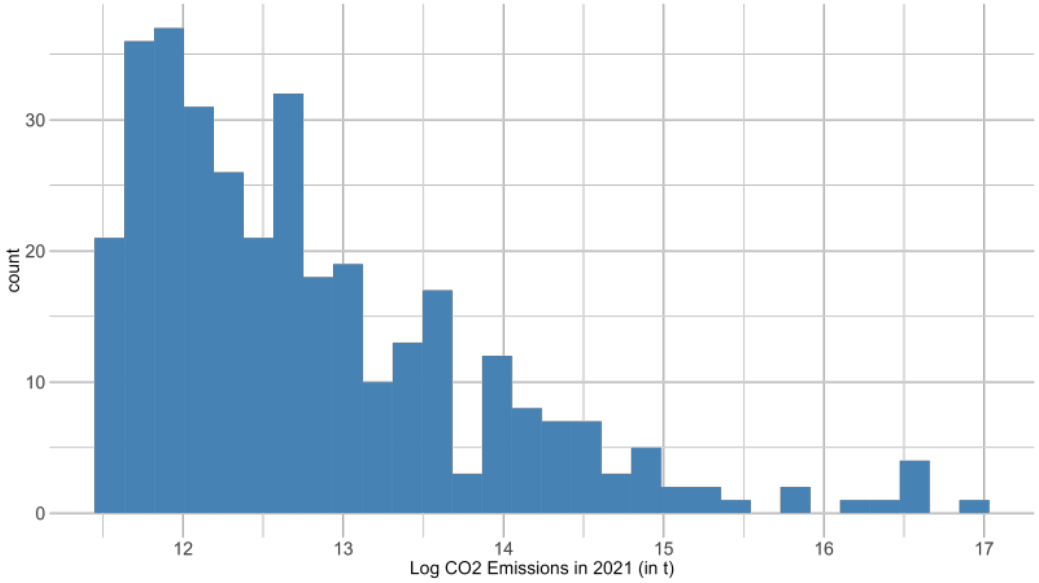
Distribution of CO2 Emissions from IED Plants

Back



Distribution of CO2 Emissions from IED Plants

Back



PM2.5 Concentration across Income Deciles

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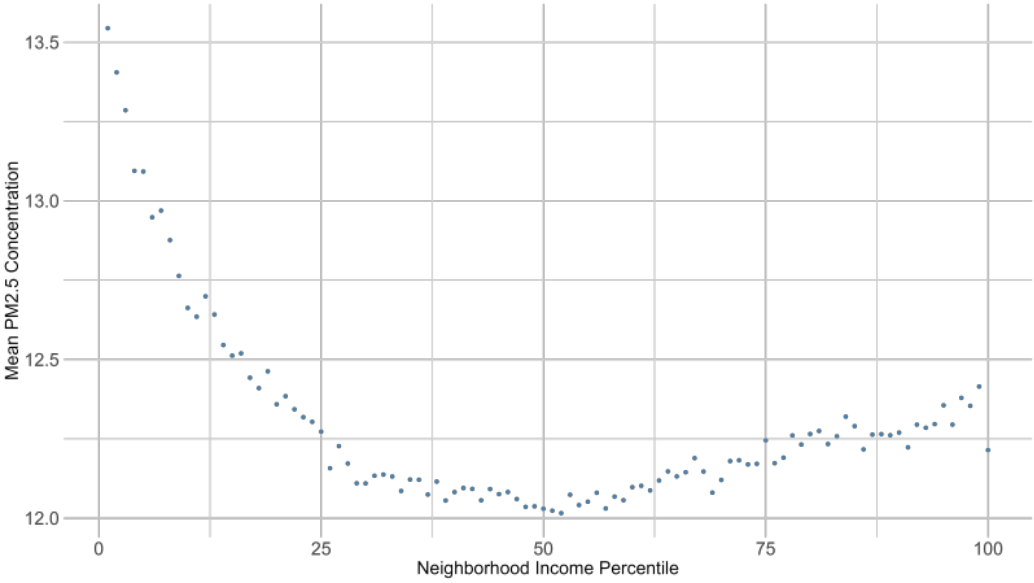

Earnings Loss Coal Mines UK

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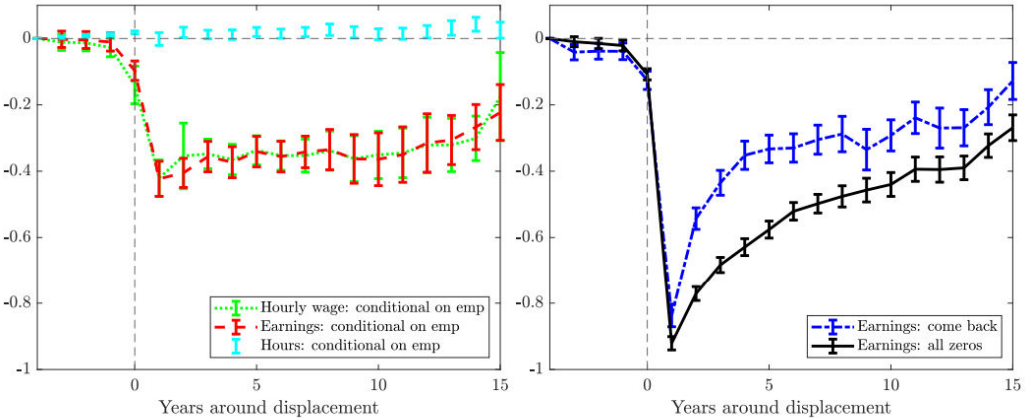

(a) Wages and earnings conditional on employment

(b) Earnings including zeros

Source: Rud et al. (2024)