Air Pollution and Migration – exploiting a natural experiment from the Czech Republic

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Environment and Migration

- Climate variability and extreme events seem to trigger migration
  - In Nigeria, the likelihood of migration is found to increase with greater temperature variability (Dillon et al., 2011),
  - Heat stress is responsible for greater migration in Pakistan (Mueller et al., 2014)
  - Drought increases men's labor migration in Ethiopia (Gray and Mueller, 2012).
  - In Burkina Faso increased migration is a consequence of scarce precipitations (Henry et al., 2004).
  - Temperature increases positively related to bilateral migration in particular from countries dependent on agriculture (Cai et al., 2016).
- Not much is known about the role of environmental pollution.

Pollution and Migration

- Air pollution causes many negative health and economic effects:
  - Detrimental effects on a range of health outcomes or on infant and adult mortality (Graff Zivin and Neidell, 2013; Currie and Neidell, QJE2005; Currie, Neidell and Schmeider JHE2009; Newell et al, 2018; Selevan et al. 2000; Currie et al. 2014; Tanaka, JHE2015; Schlenker and Reed Walker, RES2016;...).
  - Impacts economic outcomes such as health expenditures, labor suply, hours worked (Hanna and Oliva, JPE2015;..), labor productivity (Graff Zivin and Neidell, AER2012; Chang et al.,AEJ:AE2019;...), and education outcomes such as reduction in test scores, increased school absences (Currie et al. RESTAT2009; Liu and Salvo, 2017, etc.), and long-term human capital accumulation (Graff Zivin and Neidel JEL 2013; Bharadwaj et al, 2017), cognition (Bishop et al. NBER2018), long-run earnings (Isen, Rosin-Slater and Walker, JPE2017).

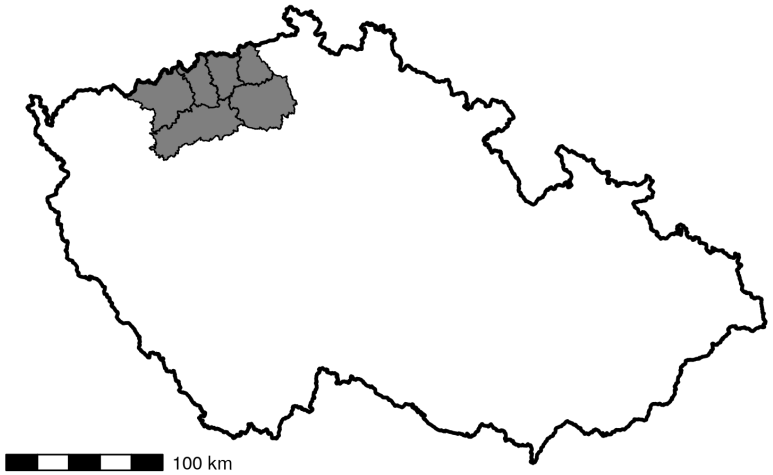
Thus, polluted environments can be seen as negative amenities.

Pollution and Migration

- Recent studies focusing on the effects of air pollution on migration suggest that air pollution acts as a strong push migration factor.
  - Chen, Oliva and Zhang (NBER2017) looks at the effects of air pollution on migration in China using changes in the average strength of thermal inversions over five-year periods as a source of exogenous variation for medium-run air pollution levels. Their results show that air pollution is responsible for large changes in inflows and outflows of migration in China.
  - Xu and Silvester (2016) examined a relationship between air pollution (approximated by PM2.5) and international migration from low and middle-income countries to OECD countries. They showed that pollution is significant, although not dominant, factor as to why people migrate, especially in countries of Sub-Saharan Africa and Eastern Europe.

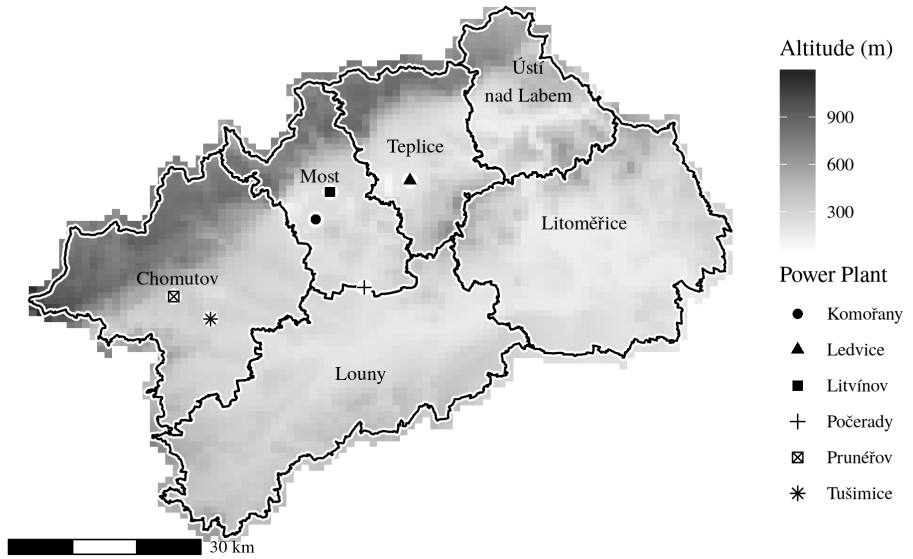
Contribution

In this paper, we look at *extremely polluted areas in Northern Bohemia (NB), Czech Republic.* We exploit *fast introduction of desulfurization technologies (1993–1999)* resulting in dramatic decrease in pollution loads to identify the *effect of air pollution on residential migration.*

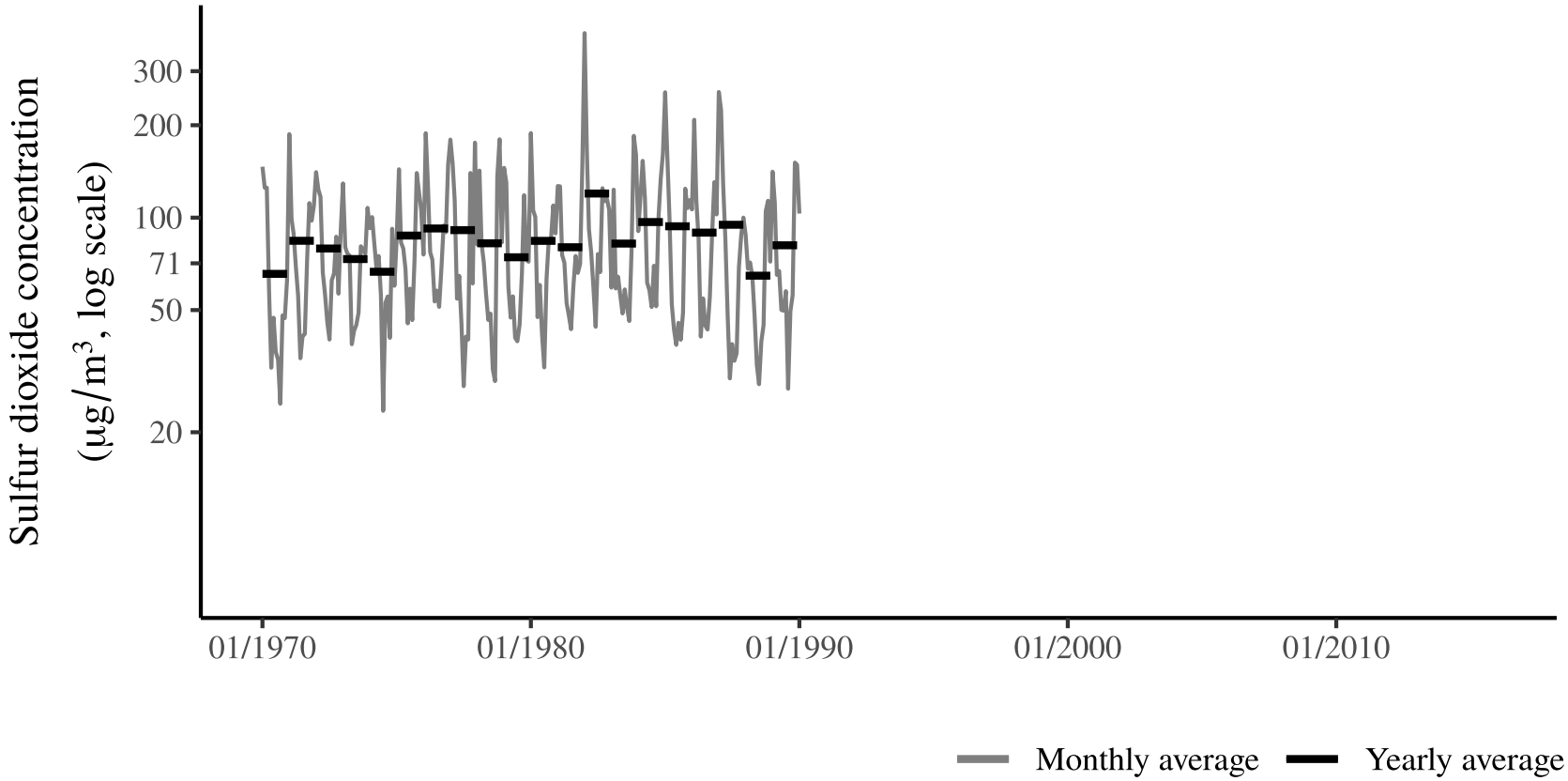


Historical setting

- Industrialization of Czechoslovakia fueled by utilizing sulfur-rich lignite from North Bohemia coal basin.
- New power plants were build in adjacency of open-pit mines.
- No measures were taken to limit air pollution.
- Geographical conditions limited dispersion of emissions.
- **Result: High sulfur dioxide concentrations with high spatial variability.**



What is "high" sulfur dioxide concentration?



Means from measuring stations located in worst-polluted districts (Teplice, Chomutov, Most).

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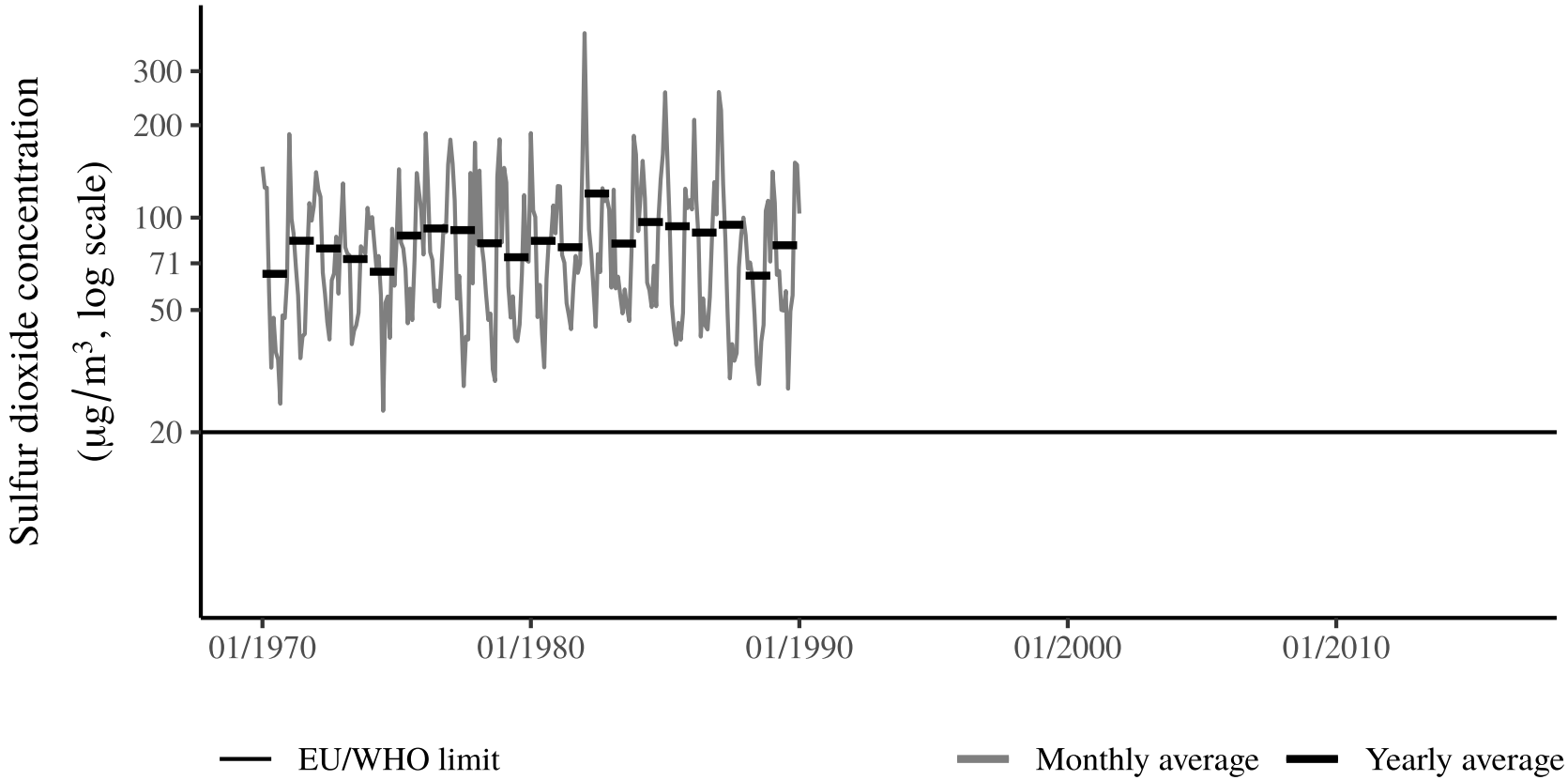

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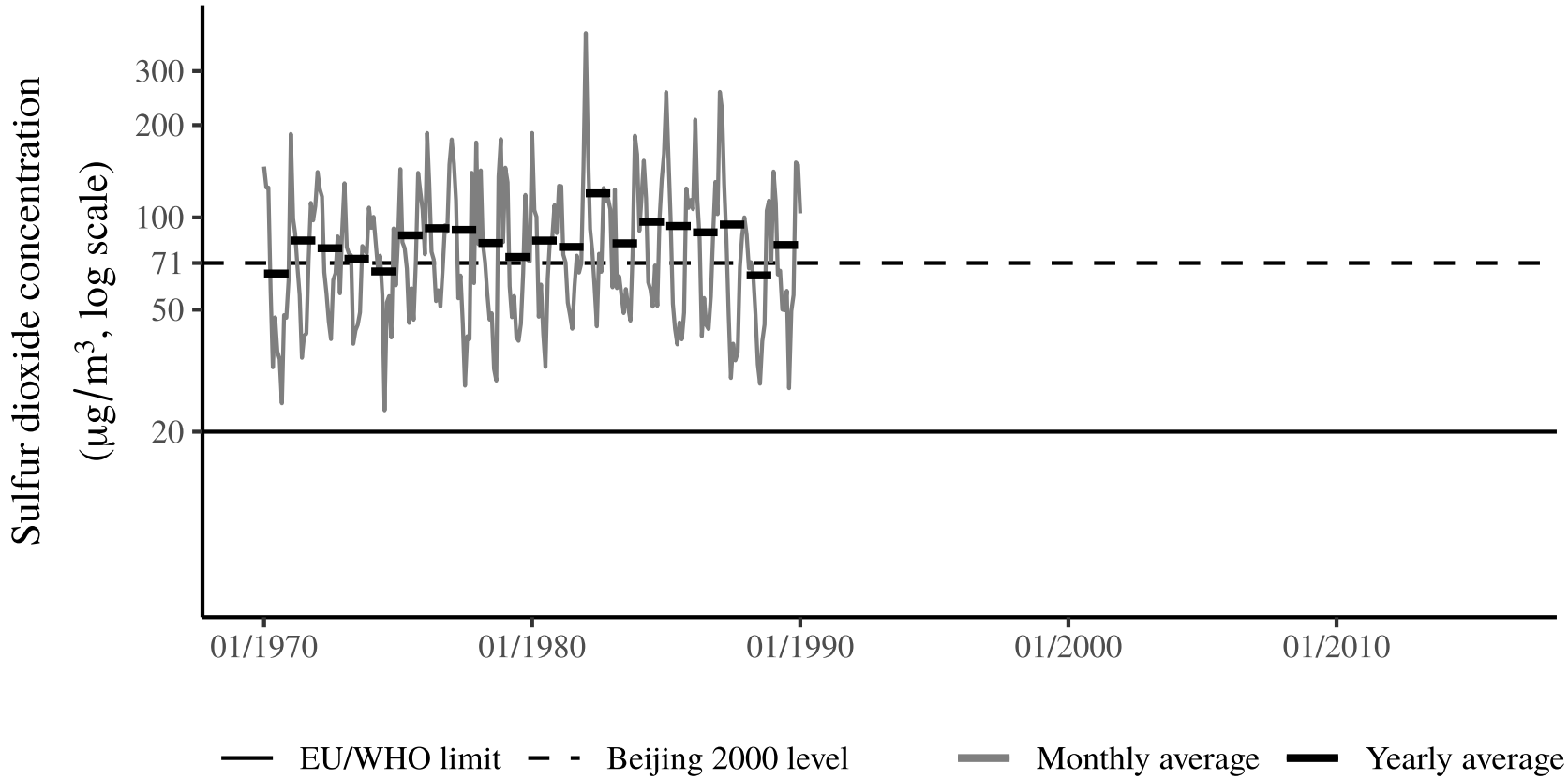
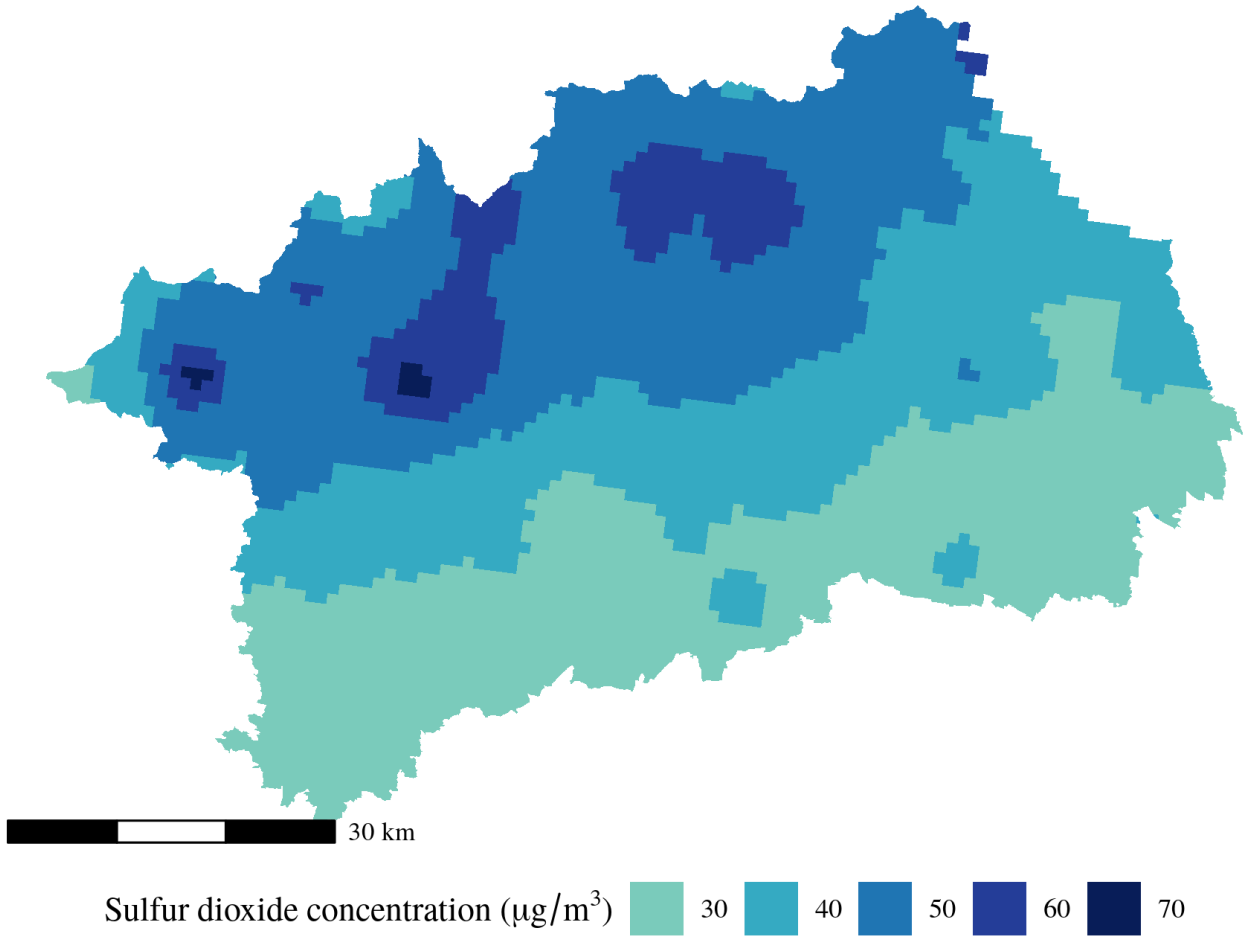


Means from measuring stations located in worst-polluted districts (Teplice, Chomutov, Most).

What is "high" spatial variability?

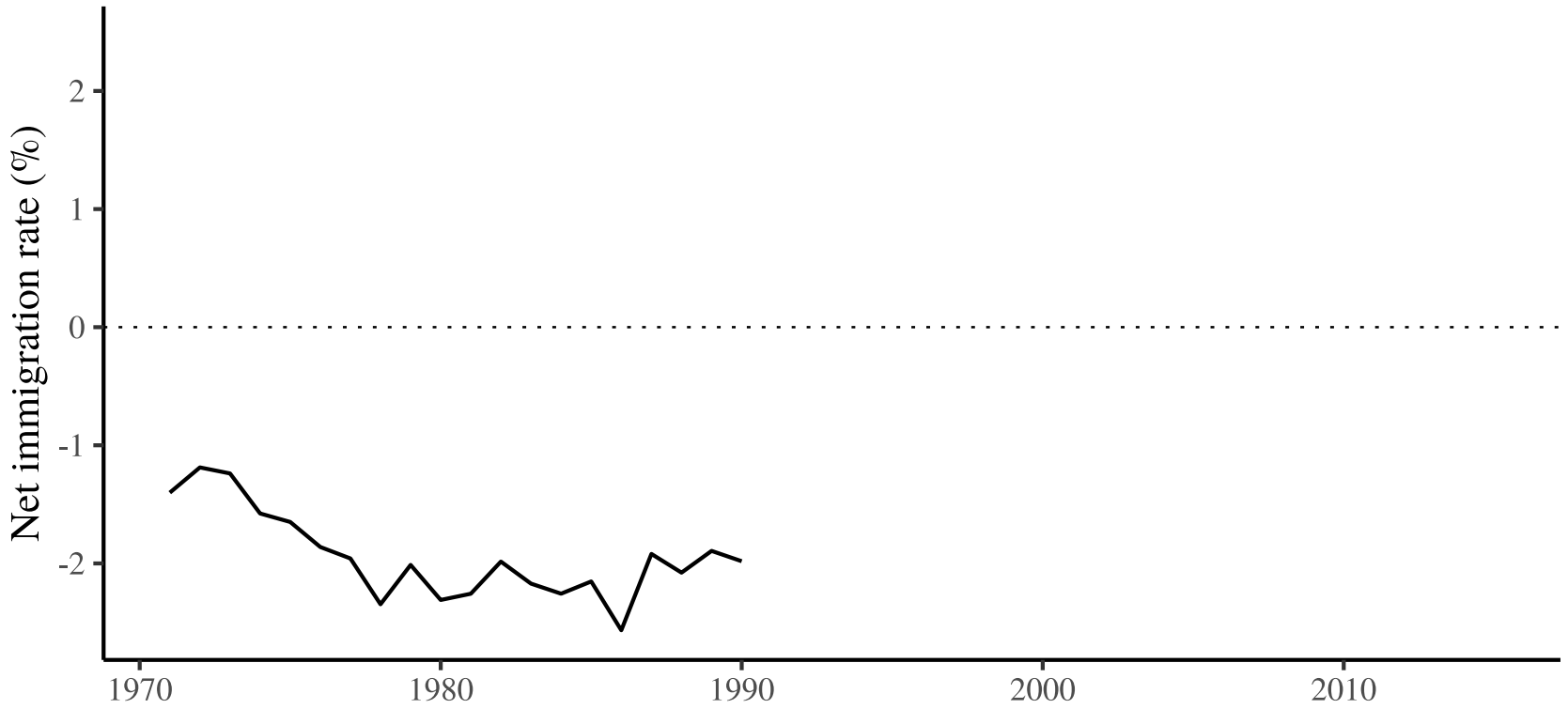


Results of CHMI dispersion model for 1994 (oldest iteration available).

"As I walked on the street, I walked through some kind of a cotton cloud, I could see down to my knees only."

(A local librarian describing situation during 1982 inversions.)

- Rapid deterioration of the environment (acid rains,. . .)
- The Communist government never implemented any measure to decrease the air pollution.
- Population was not informed about the health risks. There was no warning system implemented until late 1980s.


Net immigration rate (%)
2
1
0
-1
-2
1970
1980
1990
2000
2010

System of benefits

The government implemented a program to attract people in the area and to decrease outmigration.

1. Annual bonuses for long-term stayers (5.7% of average yearly income):
   - Municipality of residence/work
   - Length of stay (10 years)
2. Bonuses for newcomers (e.g. up to 186% of average yearly income on housing subsidies):
   - Municipality of residence/work
   - **Individual characteristics** of newcomers (qualification, etc.)

List of benefits

System of benefits was abolished in early 1992.

Environmental deterioration, decrease in benefits real value and lack of any environmental action from the government resulted in political unrest:

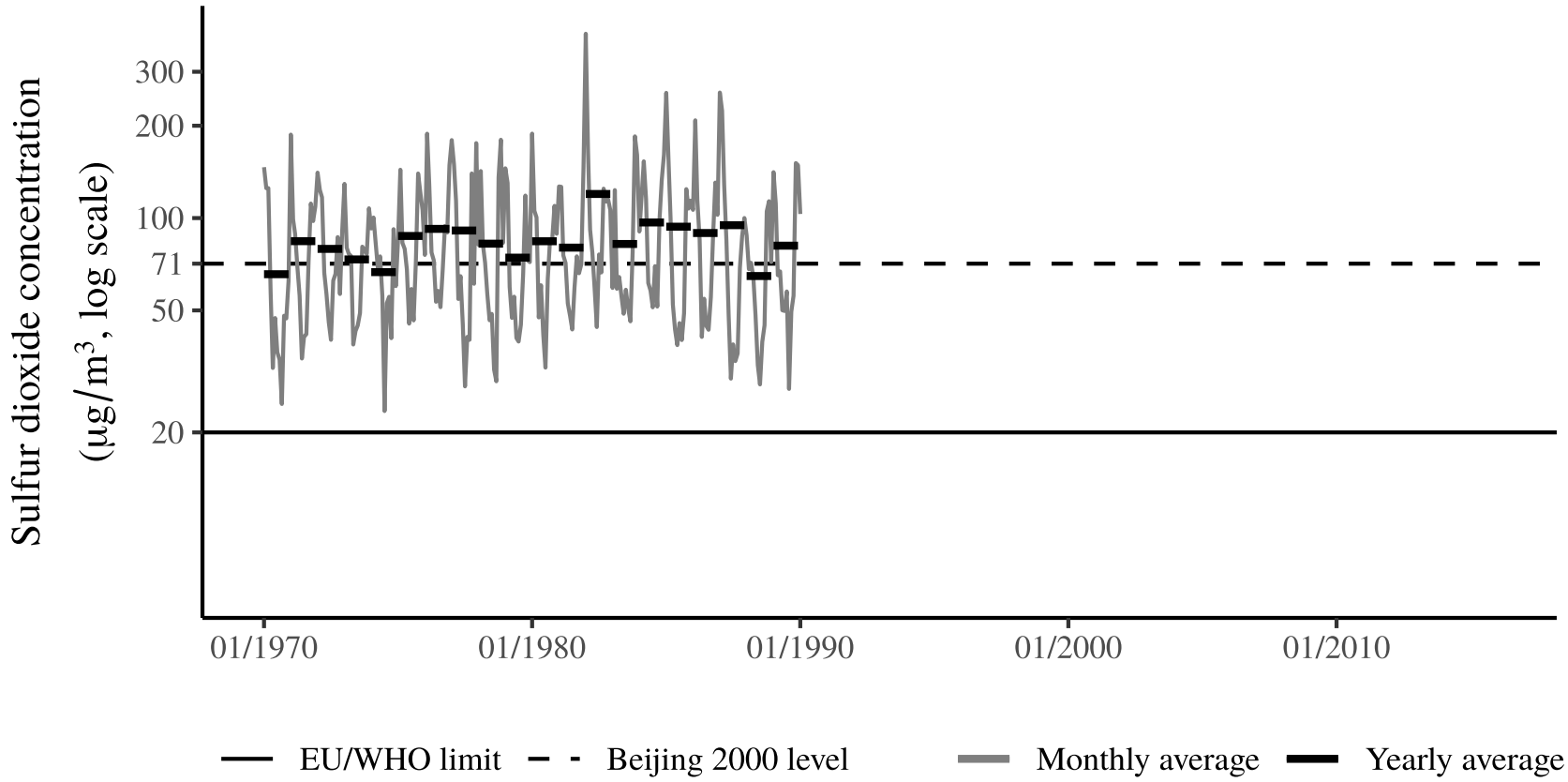
- Over a thousand of locals attended a series of demonstrations, which took place in Teplice (Northern Bohemia) between 11^{th} and 13^{th} November 1989.
- They demanded an action in air pollution reduction under slogans *"We want healthy children!"* or *"We want clean air!"*.
- The other cities in the North Bohemia coal basin followed. Demonstrations took place in Litvínov, Most, and Děčín in the following days.

The first non-communist government swore in on 10^{th} December 1989.

Reforms after the Velvet revolution (1989)

- The new government introduced environmental protection measures and laws in 1991.
  - **All coal-burning power plants were obliged to reduce emissions to the level of state-of-art technology by the 31st December 1998 (i.e. within 7 years).**
  - **Limits for lignite mines were introduced.**
- The last power plant in North Bohemia was desulfurized in Q1 1999.
- System of migration incentives/inhibitors was abolished in early 1992.

Reduction in sulfur dioxide concentrations



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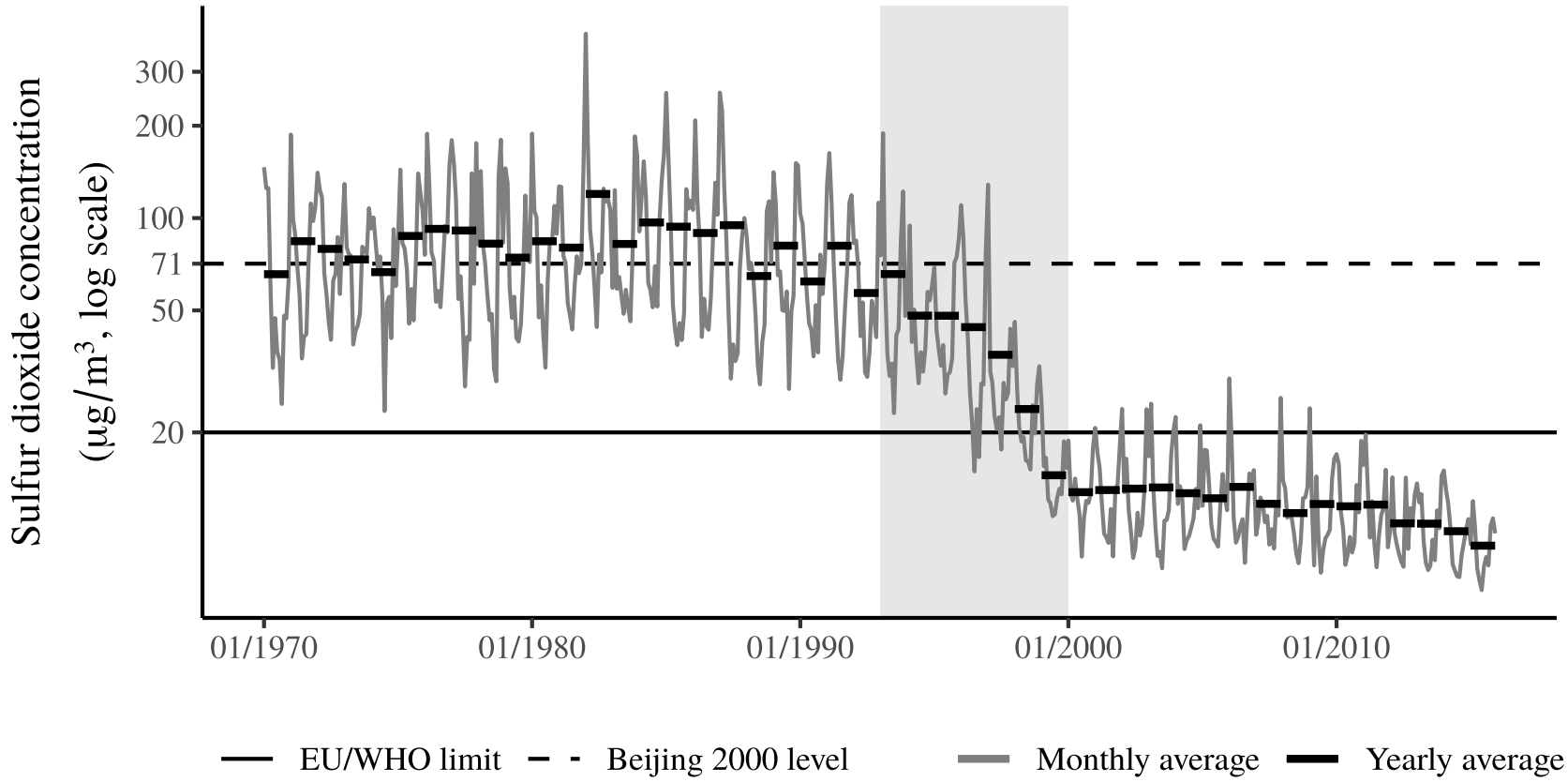
Reduction in sulfur dioxide concentrations



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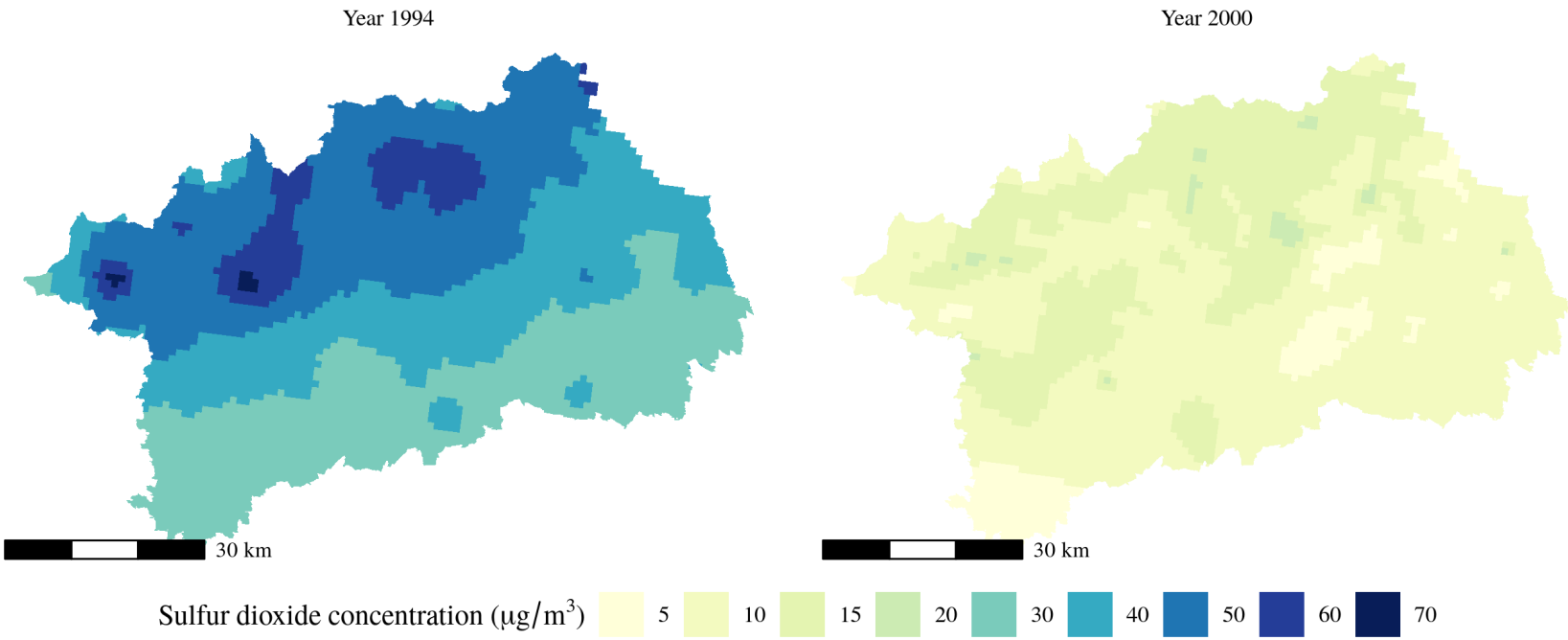
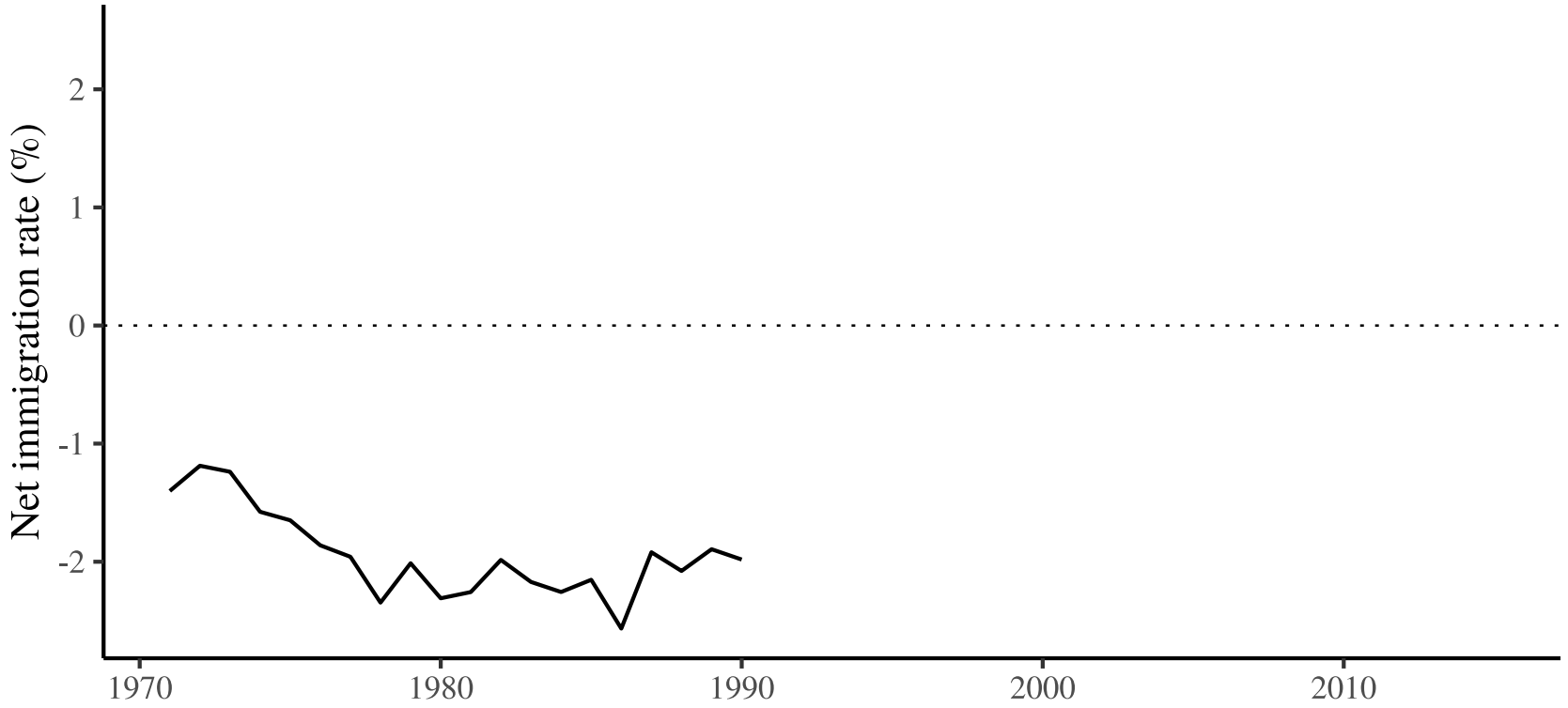
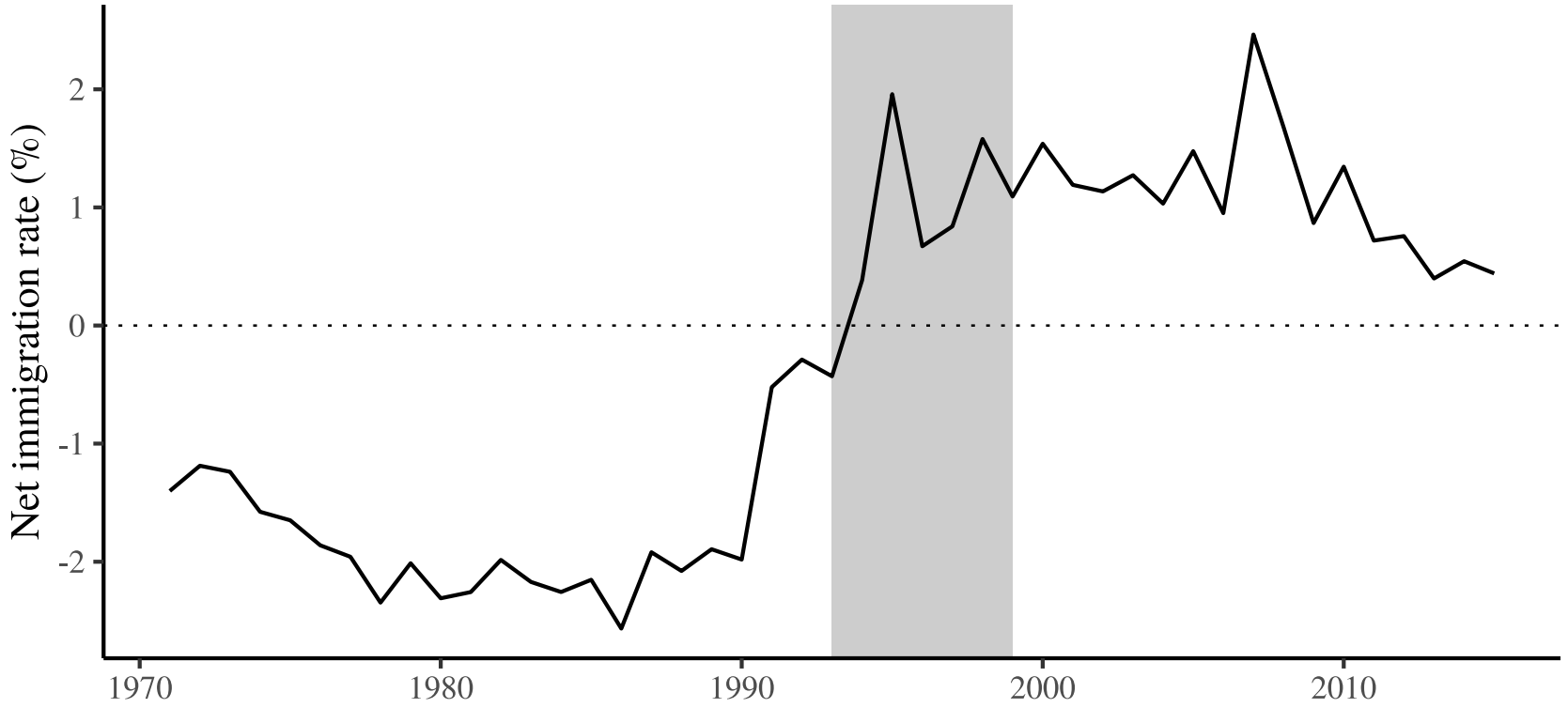
Reduction in sulfur dioxide concentrations



Net immigration rate



Net immigration rate



Identification

For identification of the causal effect we use the variation in:

- **TIME:** Installation of technology led to a drop in the sulfur dioxide concentrations from extreme high values to values below EU/WHO limit within 5 years.
- **SPACE:** In some areas the pre-desulfurization concentrations were not at the extreme.

We use a difference-in-differences (DiD) estimator to capture the causal effect.
The use of DiD estimator ensures that we account for changes that affected all municipalities alike – such as the change of political regime, etc.

Data

Data availability in the Czech Republic:

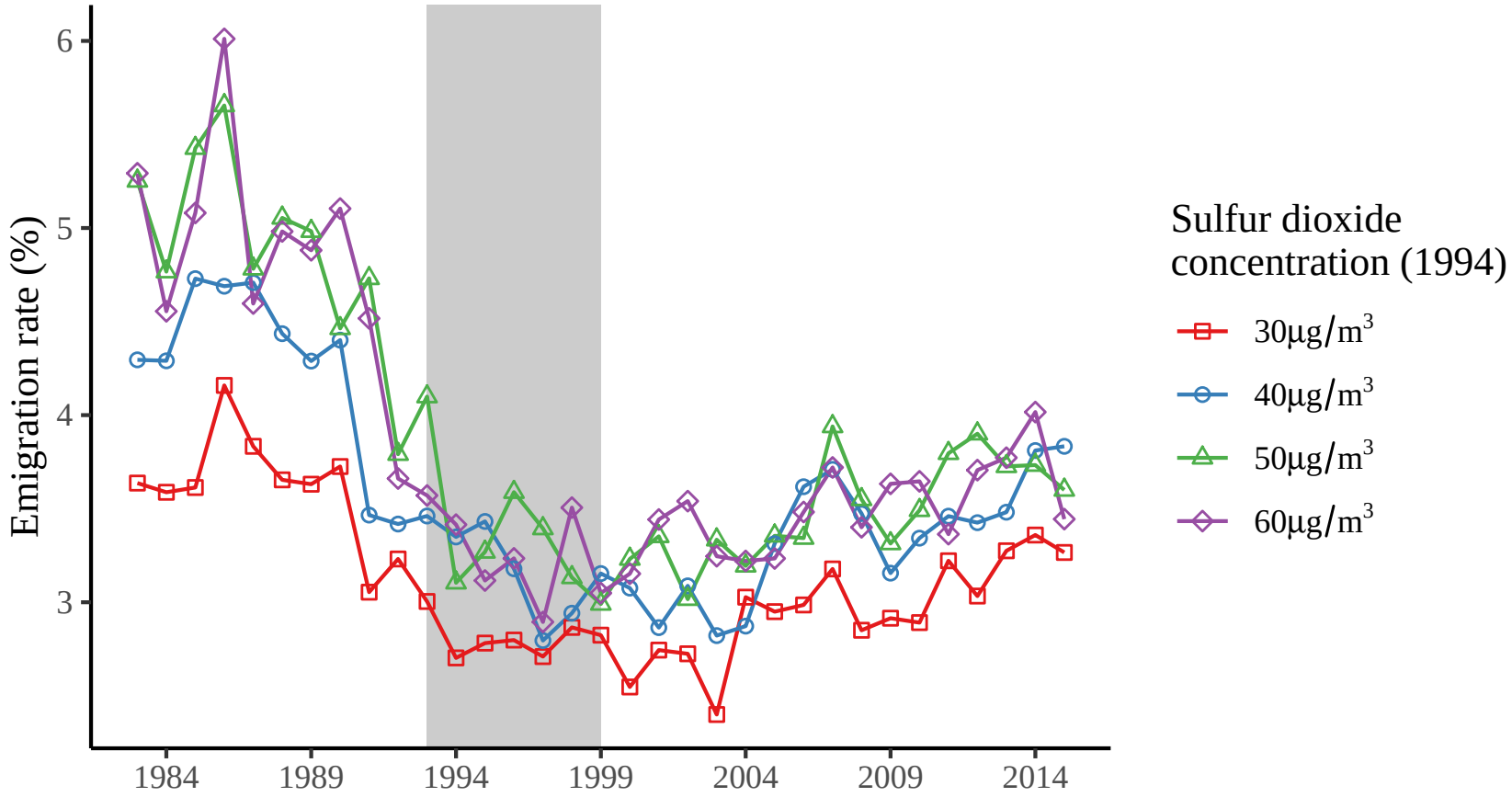
1. Individual data
   - Census data (?, 1980, 1991, 2001, 2011) – no individual IDs
   - Administrative data are in general not accessible (there are exceptions).
   - We cannot match individual records from various databases.
2. Region-level data
   - Census data on the level of "census blocks".
   - Rich municipality-level data.

Data

- Residential migration:
  - Dataset compiled by the Czech Statistical Office from administrative records on permanent residence changes.
  - Municipality-level yearly data, coverage: 1971—2015
  - Population as of January the 1st, number of people who moved in/out
  - Migration rates defined as: $mig_{it} = 100 \frac{\text{movers}_{it}}{\text{population}_{it}}$
- Air pollution:
  - Data from CHMI dispersion model – predicted sulfur dioxide concentrations (annual average) at municipality reference point (church, town hall,. . .)
  - CHMI dispersion model available only for 1994 (pre-desulfurization) and 2000 (post-desulfurization)
  - Data from dispersion model are very expensive: over €300 per year, pollutant and statistic

Descriptive evidence

Emigration rate by sulfur dioxide concentration in 1994



Empirical specification

$$mig_{it} = \beta + \gamma period_t SO_{it} + \theta_i + \theta_t + \theta_d \times \theta_t + \varepsilon_{it} \quad (1)$$

Where:

- mig_{it} is outcome variable (emigration rate) in municipality i in year t.
- $period_t = \begin{cases} 0 \text{ for years 1983–1989 (pre-desulfurization period)} \\ 1 \text{ for years 2000–2015 (post-desulfurization period)} \end{cases}$
- SO_{it} is vector of dummy variables for pre-desulfurization levels of sulfur dioxide concentration: 40, 50, and 60 $\mu g/m^3$. (The 30 $\mu g/m^3$ level is the baseline.)
- θ_i are municipality FE, θ_t year FE, and $\theta_d \times \theta_t$ are FE for interaction of districts and year

Empirical specification: Note 1

1. Due to the lack of individual level data we cannot disentangle the effect of (substantial) benefits and air pollution on immigration – we focus only on **emigration rate.**
2. Using dummies for sulfur dioxide concentration levels **accounts for potential non-linearity.**
3. The baseline sulfur dioxide concentration level is above EU/WHO limit: We estimate **lower bound** of the true effect.

See Note 2

Baseline results

Effect of air pollution on emigration rate (%)

	(1)
Pre-desulfurization SO_2 concentration $= 40\,\mu g/m^3$	-0.465^{*}
$\times$ Post-desulfurization period	(0.274)
Pre-desulfurization SO_2 concentration $= 50\,\mu g/m^3$	-1.458^{***}
$\times$ Post-desulfurization period	(0.551)
Pre-desulfurization SO_2 concentration $= 60\,\mu g/m^3$	-1.290^{**}
$\times$ Post-desulfurization period	(0.593)
Adjusted R2	0.360
Observations	$6,077$

Notes: Table reports coefficients γ from Equation (1). Robust standard errors clustered by municipality are reported in parentheses: *, ** and *** denote statistical significance at 10%, 5% and 1%. The reference category for sulfur dioxide concentration is $30\,\mu g/m^3$.

Baseline results

Overview:

- Substantial and negative effect of air pollution reduction on emigration rate (3.4% in reference municipalities in post-desulfurization period).
- Effect on emigration rate is highly non-linear.

Robustness and falsification

Robustness tests:

- Controlling for unemployment rate
- Controlling for sulfur dioxide concentrations in post-desulfurization period
- Controlling for education and age structure

See Results

Placebo tests:

- Placebo test in pre- and post-desulfurization periods

See Results

Mechanisms

What shapes the migratory response to air pollution?

1. Benefits introduced to compensate for pollution in pre-desulfurization period
2. Stock of local social capital
3. Man-made amenities availability

Benefits

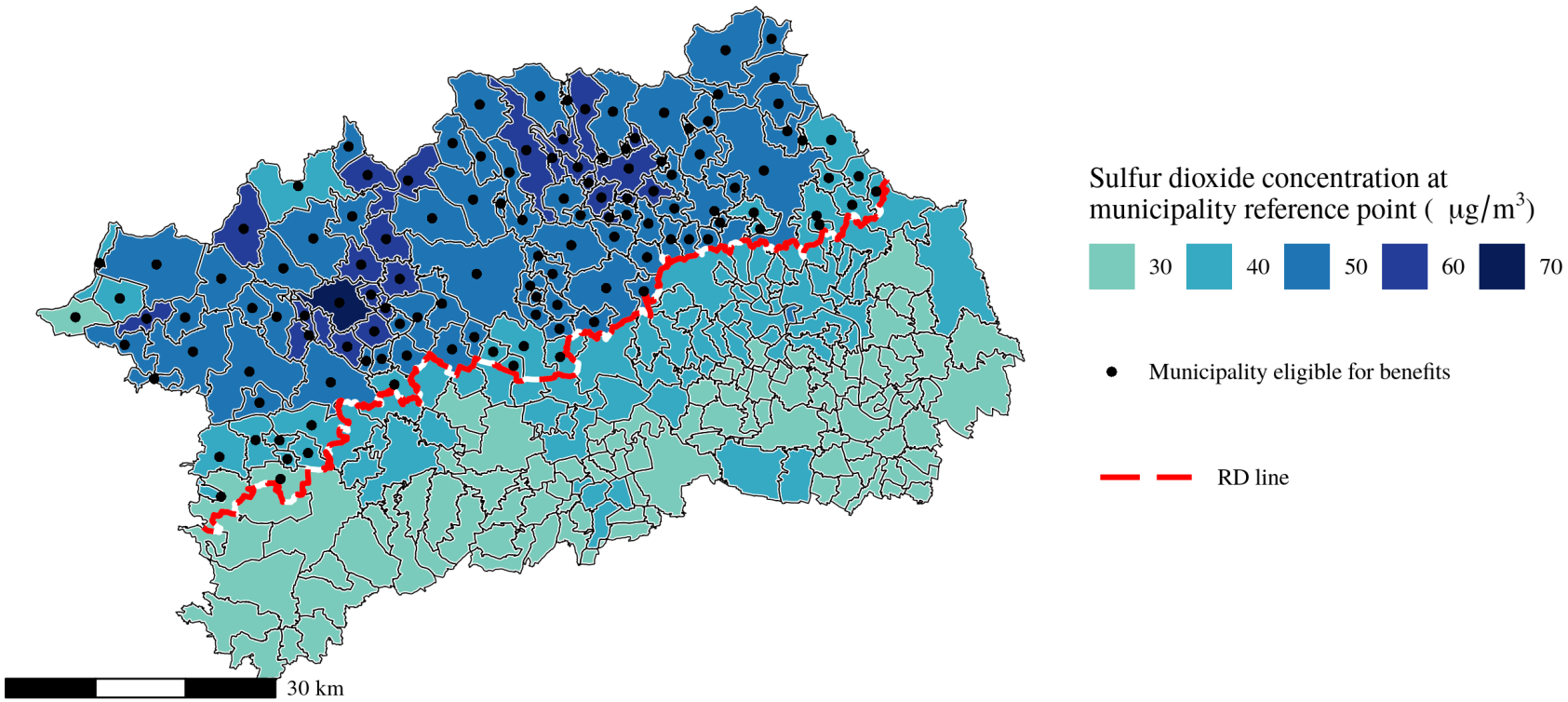
Overview:

- Benefits for long-term stayers (e.g., eligibility for monetary benefits of 5.7% of average yearly income after 10 years)

To be eligible for benefits one had to live/work in (among other things) the region (one of listed municipalities).

Benefits

Eligibility for benefits



Benefits

Eligibility for benefits:

- Variation in eligibility in municipalities with 30 and 40 $\mu g/m^3$.
- Clearly delimited block of municipalities eligible for benefits.

To identify the effect of eligibility for benefits we use two strategies:

- Triple DiD strategy
- RD strategy

Benefits: Triple DiD

Empirical specification (modified Eq. (1)):

$$mig_{it} = \gamma_1 period_t SO_{it} + \gamma_2 period_t SO_{it} benefits_i + \\ + \gamma_3 period_t benefits_i + \theta_t + \theta_i + \theta_s \times \theta_t + \varepsilon_{it} \quad (2)$$

Only municipalities with pre-desulfurization sulfur disoxide concentrations of 30 and 40 $\mu g/m^3$ were not eligible for benefits. Therefore we limit our baseline estimation sample to this group.

Benefits: Triple DiD

Impact of eligibility for benefits on emigration rate (triple DiD strategy)

	(1)
Pre-desulfurization SO_2 concentration $= 40\,\mu g/m^3$	0.008
$\times$ Eligibility for benefits $\times$ Post-desulfurization period	(1.011)
Pre-desulfurization SO_2 concentration $= 40\,\mu g/m^3$	−0.431
$\times$ Post-desulfurization period	(0.276)
Eligibility for benefits $\times$ Post-desulfurization period	−0.335
	(0.847)
Adjusted R2	0.262
Observations	3,936

Notes: Table reports coefficients γ from Equation (2). Robust standard errors clustered by municipality are reported in parentheses: *, ** and *** denote statistical significance at 10%, 5% and 1%. The reference category for sulfur dioxide concentration is $30\,\mu g/m^3$.

Benefits: RD strategy

Empirical specification:

$$mig_{it} = \gamma benefits_i + f(d_i) + \boldsymbol{\beta Z_i} + \boldsymbol{\delta SO_{it}} + \theta_t + \theta_p + \theta_s + \theta_s \times \theta_t + \varepsilon_{it} \quad (3)$$

Estimation sample is limited to municipalities within 20 km from the RD line.

θ_p. . . population size FE
θ_s. . . RD line segment FE

Benefits: RD strategy

	Dependent variable		
	Emigration rate (%)		
	RD Polynomial		
	1st order	2nd order	3rd order
	(1)	(2)	(3)
Eligible for benefits (=1)	−0.042	−0.415	0.267
	(0.671)	(0.788)	(0.957)
Adjusted R2	0.227	0.228	0.228
Observations	1,157	1,157	1,157

Notes: The estimation sample is limit to municipalities within the region and within 20 km from the RD line. Table reports coefficient γ from Equation (3). Robust standard errors clustered by municipality are reported in parentheses: *, ** and *** denote statistical significance at 10%, 5% and 1%.

- No impact of eligibility for benefits on emigration rate

Local social capital

The local social capital is shown to be linked with mobility (David et al. 2010; Bräuninger and Tolciu 2011):

High local social capital and low mobility.

vs.

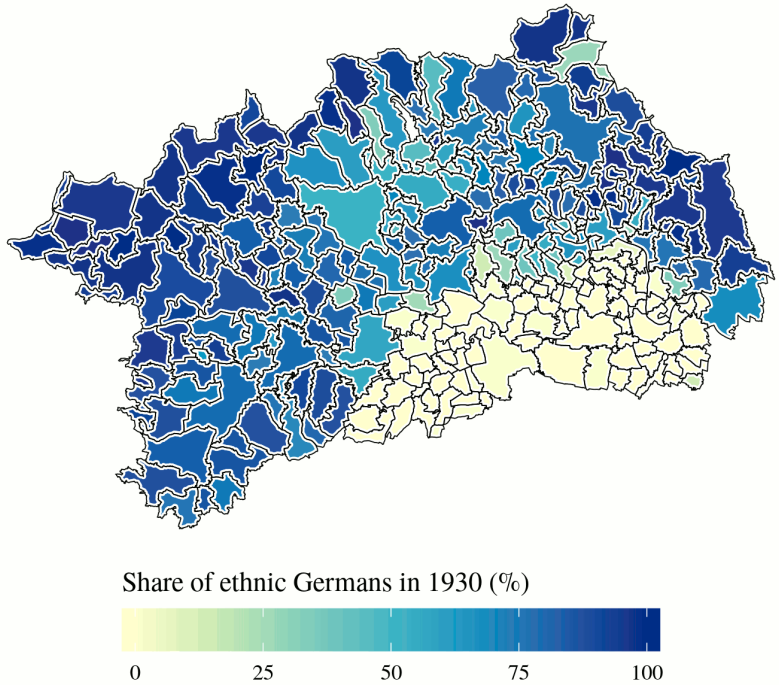
Low local social capital and high mobility.

Can (high) local social capital mitigate the migratory response to air pollution?

Local social capital

- There was a German minority living in segregated municipalities in pre-WWII period.
- After their expulsion in the aftermath of the WWII these municipalities were resettled by ethnic Czechs.
- *Expulsion of the ethnic Germans destroyed local social capital.*

Spatial distribution of ethnic Germans in 1930



Local social capital

Guzi et al. (2019) show:

- Resettled municipalities experience higher emigration and immigration rates even 70 years after the resettlement.
- They document **lower local social capital in resettled municipalities**.

Guzi et al. (2019)

Guzi, Martin, Peter Huber, and Štěpán Mikula (2019): *Old sins cast long shadows: The Long-term impact of the resettlement of the Sudetenland on residential migration.* IZA Discussion Paper No. 12536. `http://ftp.iza.org/dp12536.pdf`

Local social capital

We split the sample by median share of ethnic Germans (70.2%) and re-estimate regression (1):

	Sample split by share of ethnic Germans in 1930	
	Below median	Above median
	Dependent variable: Emigration rate (%)	
	(1)	(2)
Pre-desulfurization SO_2 concentration $= 40\,\mu g/m^3$	-0.260	-0.472
$\times$ Post-desulfurization period	(0.320)	(0.636)
Pre-desulfurization SO_2 concentration $= 50\,\mu g/m^3$	0.639	-1.790^{**}
$\times$ Post-desulfurization period	(0.747)	(0.761)
Pre-desulfurization SO_2 concentration $= 60\,\mu g/m^3$	0.594	-1.283^{*}
$\times$ Post-desulfurization period	(0.986)	(0.766)
Adjusted R2	0.305	0.362
Observations	$3,036$	$3,018$

Notes: Table reports coefficients γ from Equation (1). Robust standard errors clustered by municipality are reported in parentheses: *, ** and *** denote statistical significance at 10%, 5% and 1%. The reference category for sulfur dioxide concentration is $30\,\mu g/m^3$.

See Robustness analysis

Local social capital

- Divergence of effects on migration rates.
- Negative and significant effect on emigration rate in municipalities lower in social capital.

$\Rightarrow$ Tentative evidence that *local social capital can mitigate migratory response to air pollution.*

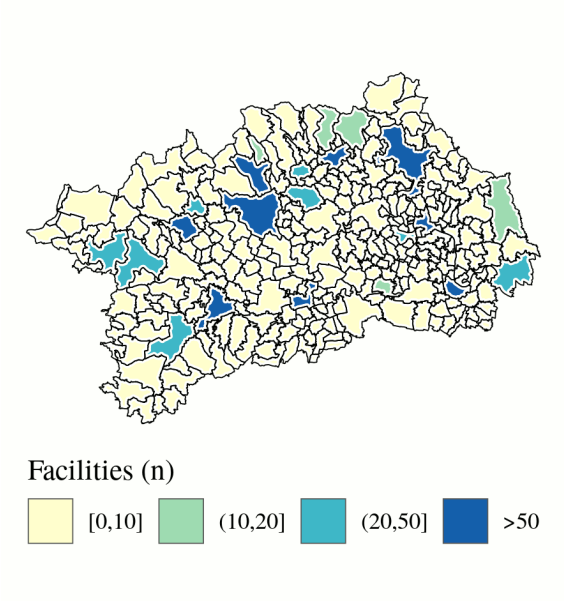
Man-made amenities availability

Man-made amenities availability could shape the migratory response to air pollution.

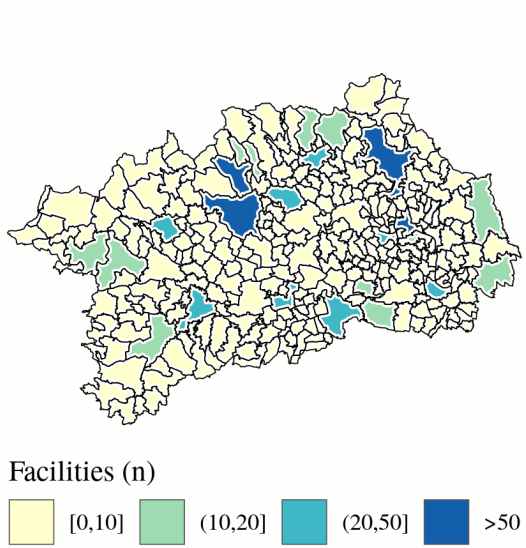
Categories of amenities:

- Education, health and social care facilities (number of schools, hospitals, retirement houses, etc.)
- Culture and sports facilities (number of libraries, cinemas, football fields, etc.)
- Public administration facilities and public utilities (number of job centers, courts, etc., and presence of water supply system, etc.)

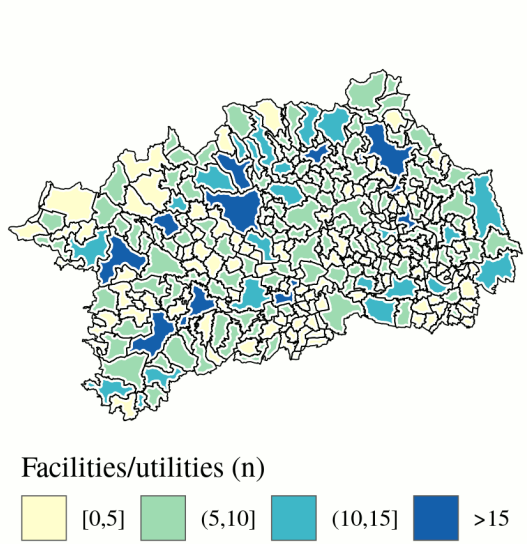
Man-made amenities availability



Education, health, and social care facilities



Culture and sports facilities



Public administration facilities and public utilities

Man-made amenities availability is correlated with population (Spearman's ρ between 0.72 and 0.85) and between amenities groups (Spearman's ρ between 0.67 and 0.75).

BUT it is **not correlated** with **sulfur dioxide concentration** in pre-desulfurization period (Spearman's ρ between 0.06 and 0.24) AND with **pre-war share of ethnic Germans** (Spearman's ρ between 0.06 and 0.12).

Man-made amenities availability

Impact of man-made amenities availability on shaping migratory response to air pollution

	Sample split by median of man-man amenities availability					
	Education, health, and social care facilities		Culture and sports facilities		Public administration facilities and public utilities	
	Below	Above	Below	Above	Below	Above
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Dependent variable: Emigration rate (%)					
Pre-desulfurization SO_2 concentration $= 40\,\mu g/m^3$	-1.028^{*}	-0.149	-0.771	-0.347	-0.457	-0.651^{*}
$\times$ Post-desulfurization period	(0.574)	(0.281)	(0.503)	(0.352)	(0.635)	(0.345)
Pre-desulfurization SO_2 concentration $= 50\,\mu g/m^3$	-2.728^{***}	-0.568	-2.485^{***}	-0.888^{*}	-2.464^{***}	-1.302^{**}
$\times$ Post-desulfurization period	(1.031)	(0.537)	(0.855)	(0.515)	(0.930)	(0.569)
Pre-desulfurization SO_2 concentration $= 60\,\mu g/m^3$	-1.792	-1.219^{*}	-2.026^{**}	-0.953	-1.742^{*}	-1.539^{**}
$\times$ Post-desulfurization period	(1.133)	(0.639)	(0.827)	(0.601)	(1.025)	(0.638)
Adjusted R2	0.352	0.446	0.353	0.383	0.367	0.402
Observations	3,039	3,038	2,932	3,145	3,189	2,888

Notes: Table reports coefficients γ from Equation (1). Robust standard errors clustered by municipality are reported in parentheses: *, ** and *** denote statistical significance at 10%, 5% and 1%. The reference category for sulfur dioxide concentration is $30\,\mu g/m^3$. Alternative specification

Man-made amenities availability

- Substantially larger, negative and significant effect on emigration rate in municipalities lower in man-made amenities availability.

$\Rightarrow$ Tentative evidence that *man-made amenities availability can mitigate migratory response to air pollution.*

Conclusions

- Air pollution is a significant push factor.
- Effect of air pollution is non-linear.

We also find that effect of air pollution on residential migration could be mitigated by:

- Local social capital,
- Man-made amenities availability

Thank you for your attention!

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