Explaining Regional Differences in Environmental Inequality
A Multi-Level Assessment of German Cities

Tobias Rüttenauer

Department of Social Sciences
TU Kaiserslautern

November 22, 2017
Analytische Soziologie
Venice
Aim of this study

Environmental inequality in Germany

- Foreign-minorities are affected by disproportionately high amount of environmental pollution

![Graph showing the effect of % Foreigners on air pollution](image)
Aim of this study

Environmental inequality in Germany

- Foreign-minorities are affected by disproportionately high amount of environmental pollution

![Graph showing effect of percentage of foreigners on air pollution](attachment:graph.png)

⇒ How can we explain this variation between the cities?
Aim of this study

Environmental inequality in Germany

- Foreign-minorities are affected by disproportionately high amount of environmental pollution

How can we explain this variation between the cities?
Theoretical Mechanisms

Selective siting

- Lower political protest of minorities
- Lower land / housing prices where minorities live
⇒ Facilities are sited close to minorities

Selective migration

- Socio-economic resources
- Housing discrimination
⇒ Minorities move into polluted areas

(Campbell et al., 2015; Crowder and Downey, 2010; Mohai and Saha, 2015)
Theoretical Mechanisms

Selective siting

- Lower political protest of minorities
- Lower land / housing prices where minorities live
  ⇒ Facilities are sited close to minorities

Selective migration

- Socio-economic resources
- Housing discrimination
  ⇒ Minorities move into polluted areas

(Campbell et al., 2015; Crowder and Downey, 2010; Mohai and Saha, 2015)
Between-city variation

Selective siting

- Political efficacy of majority group
- Residential segregation

Selective migration

- Economic inequality (minority vs. majority)
- Residential segregation

But:

- Do a poor job of explaining environmental inequality (Downey, 2007)
- Studies ‘fail to take the spatial distribution of environmental hazards within metropolitan areas into account’ (Downey, 2007, p. 970)

See also Downey (2005); Elliott and Frickel (2015)
Between-city variation

Selective siting

- Political efficacy of majority group
- Residential segregation

Selective migration

- Economic inequality (minority vs. majority)
- Residential segregation

But:

- Do a poor job of explaining environmental inequality (Downey, 2007)
- Studies ‘fail to take the spatial distribution of environmental hazards within metropolitan areas into account’ (Downey, 2007, p. 970)

See also Downey (2005); Elliott and Frickel (2015)
Between-city variation

Selective siting

- Political efficacy of majority group
- Residential segregation

Selective migration

- Economic inequality (minority vs. majority)
- Residential segregation

But:

- Do a poor job of explaining environmental inequality (Downey, 2007)
- Studies ‘fail to take the spatial distribution of environmental hazards within metropolitan areas into account’ (Downey, 2007, p. 970)

See also Downey (2005); Elliott and Frickel (2015)
Low Environmental Inequality

Minorities cluster around the city centre
Pollution occurs far from the city centre
High Environmental Inequality

Chemnitz

% Foreigners

- 0.00
- 0.00 to 0.60
- 0.60 to 1.10
- 1.10 to 2.05
- over 2.05

Indoor Air Pollution

- 0.00
- 0.00 to 5.57
- 5.57 to 16.19
- 16.19 to 18.26
- over 18.26

Erlangen

% Foreigners

- under 4.67
- 4.67 to 6.22
- 6.22 to 9.44
- 9.44 to 13.10
- over 13.10

Indoor Air Pollution

- 0.00
- 0.00 to 14.92
- 14.92 to 15.61
- 15.61 to 16.32
- over 16.32

⇒ Minorities cluster around the city centre
⇒ Pollution occurs close to the centre
Data

German census 2011

- 1 km² grid over 79 German cities (≥100,000 inhabitants)
- Final sample: 9,061 grid cells
- Average number of inhabitants: 2,650 (median: 1,717)
- Predictor variable: % foreigners
- Main controls: Population density, % vacant housing

E-PRTR

- Industrial facilities exceeding a pollutant-specific threshold
- 366 facilities reporting industrial emissions to air within cities
- Response variable: industrial air pollution (ln kg)
Merging Strategy

Proportional Overlap

- 2 km buffer around facility location
- Overlap of buffer and census cell
- Allocation proportionate to overlap

(e.g. Banzhaf and Walsh, 2008)
City level variables

INKAR 2011

- Economic Inequality: Unemployment ratio (non-Germans/Germans)
- Political efficacy: Voter turnout

Segregation

- Spatial information theory index $\tilde{H}_{2000}$ (Reardon and O’Sullivan, 2004)

Facility centrality

$$FC_i = \left( \frac{\frac{1}{M} \sum_{j=1}^{M} d_{ij}}{\max(\tilde{d}_i)} \right)^{-1},$$

where $d_{ij}$ is the distance between each facility $j = 1, ..., M$ in the 2km surrounding of city $i$ and the city’s centre, and $\tilde{d}_i$ a vector of the distances between the city centre and all coordinates of the city’s boundary.
City-fixed effects multi-level model

- First level: within-city correlation
- Random slope: variation of within-effect between cities
- Parameter of interest: cross-level interaction

\[
pollution_{ij} = \beta_0 + \beta_1 \text{for} g_{ij} + \beta_2 \text{for} g_{ij} \text{segr}_j + u_{1j} \text{for} g_{ij} + \varepsilon_{ij},
\]

for all \( i = 1, \ldots, N \) observations and \( j = 1, \ldots, J \) cities. This is achieved by within-group demeaning the data (Enders and Tofighi, 2007) and estimating a multilevel random-slope model.
Dependent variable: In Pollution

Cross-level interaction with % foreigners (in standard deviations)

- Residential Segregation
- Unemployment ratio
- Voter turnout
- Facility centrality

Separate Model M2 M3

Rüttenauer
Explaining Regional Differences in Environmental Inequality
Dependent variable: In Pollution

- Residential Segregation
- Unemployment ratio
- Voter turnout
- Facility centrality

Cross-level interaction with % foreigners (in standard deviations)

- Separate Model
- M2
- M3
Dependent variable: ln Pollution

Cross-level interaction with % foreigners (in standard deviations)

- Residential Segregation
- Unemployment ratio
- Voter turnout
- Facility centrality

Separate Model M2 M3
Dependent variable: ln Pollution

- Residential Segregation
- Unemployment ratio
- Voter turnout
- Facility centrality

Cross-level interaction with % foreigners (in standard deviations)

Separate Model M2 M3
Dependent variable: ln Pollution

Residential Segregation

Unemployment ratio

Voter turnout

Facility centrality

Cross-level interaction with % foreigners (in standard deviations)

Separate Model • M2 • M3
Dependent variable: In Pollution

Cross-level interaction with % foreigners (in standard deviations)

- Residential Segregation
- Unemployment ratio
- Voter turnout
- Facility centrality

Separate Model M2 M3

Rüttener
Explaining Regional Differences in Environmental Inequality
Dependent variable: In Pollution

Facility centrality

Voter turnout

Unemployment ratio

Residential Segregation

Cross-level interaction with % foreigners (in standard deviations)
Dependent variable: In Pollution

- Residential Segregation: 0.47
- Unemployment ratio: -1.88
- Voter turnout: -2.06
- Facility centrality: 31.29

Explained Slope Variance (%)

Cross-level interaction with % foreigners (in standard deviations)

- Separate Model
- M2
- M3
What does it mean?

1) Confounding mechanism
   - Process 1: Minorities cluster in central cities
   - Process 2: High pollution in inner cities
   ⇒ Two independent processes

2) Mediating mechanism
   - Facilities are centrally sited because minority share is high
   - Minorities cluster in inner city because pollution is high
   ⇒ Causal mechanism of selective siting or migration?
What does it mean?

1) Confounding mechanism
   - Process 1: Minorities cluster in central cities
   - Process 2: High pollution in inner cities
   ⇒ Two independent processes

2) Mediating mechanism
   - Facilities are centrally sited *because* minority share is high
   - Minorities cluster in inner city *because* pollution is high
   ⇒ Causal mechanism of selective siting or migration?
Dependent variable: facility centrality

<table>
<thead>
<tr>
<th></th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centralization index(^a)</td>
<td>0.021</td>
<td></td>
<td>0.215</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.114)</td>
<td></td>
<td>(0.158)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\tilde{H}_{2000})</td>
<td></td>
<td>−0.103</td>
<td></td>
<td>−0.178</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.113)</td>
<td></td>
<td>(0.148)</td>
<td></td>
</tr>
<tr>
<td>Unemployment ratio</td>
<td>0.295(^*)</td>
<td>0.208(^\dagger)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.109)</td>
<td>(0.122)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voter turnout</td>
<td>0.243(^*)</td>
<td>0.190</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.111)</td>
<td>(0.136)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R^2</td>
<td>0.000</td>
<td>0.011</td>
<td>0.087</td>
<td>0.059</td>
<td>0.130</td>
</tr>
<tr>
<td>Adj. R^2</td>
<td>−0.013</td>
<td>−0.002</td>
<td>0.075</td>
<td>0.047</td>
<td>0.083</td>
</tr>
<tr>
<td>Num. obs.</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
</tbody>
</table>

\(^{***}p < 0.001, \,**p < 0.01, \,*p < 0.05, \,\dagger p < 0.1\). All variables are centered around their mean and scaled by their standard deviation. Standard errors in parentheses.

\(^a\) Relative Centralization Index (RCE) as described in Massey and Denton (1988): proximity of the foreign population to the city centre relative to the proximity of the German population to the city centre.
Conclusion

Causal mechanisms of environmental inequality

- Challenges the importance of selective siting and migration
- Magnitude driven by centrality of minorities and pollution
- Independence of facility centrality and minority centrality?

Campbell et al. (2015)

- Simulations don’t reach a realistic level of environmental inequality when just assuming selective siting and migration

Limitations

⇒ Only industrial air pollution
⇒ Only ‘proxies’ of selective siting & migration
⇒ Results are only descriptive
⇒ (Social) mechanism?
Conclusion

Causal mechanisms of environmental inequality

- Challenges the importance of selective siting and migration
- Magnitude driven by centrality of minorities and pollution
- Independence of facility centrality and minority centrality?

Campbell et al. (2015)

- Simulations don’t reach a realistic level of environmental inequality when just assuming selective siting and migration

Limitations

⇒ Only industrial air pollution
⇒ Only ‘proxies’ of selective siting & migration
⇒ Results are only descriptive
⇒ (Social) mechanism?
Conclusion

Causal mechanisms of environmental inequality

- Challenges the importance of selective siting and migration
- Magnitude driven by centrality of minorities and pollution
- Independence of facility centrality and minority centrality?

Campbell et al. (2015)

- Simulations don’t reach a realistic level of environmental inequality when just assuming selective siting and migration

Limitations

- Only industrial air pollution
- Only ‘proxies’ of selective siting & migration
- Results are only descriptive
- (Social) mechanism?
Thank you very much!


## Summary Statistics

**Table: Summary Statistics**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>N</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Air pollution</td>
<td>9,061</td>
<td>4.02</td>
<td>6.65</td>
<td>0.00</td>
<td>20.93</td>
</tr>
<tr>
<td>% Foreigners</td>
<td>9,061</td>
<td>9.00</td>
<td>8.43</td>
<td>0.00</td>
<td>87.10</td>
</tr>
<tr>
<td>Population</td>
<td>9,061</td>
<td>2,649.91</td>
<td>2,887.97</td>
<td>3.00</td>
<td>23,379.00</td>
</tr>
<tr>
<td>% 65 and older</td>
<td>9,061</td>
<td>20.57</td>
<td>7.44</td>
<td>0.00</td>
<td>99.60</td>
</tr>
<tr>
<td>% Vacant housing</td>
<td>9,061</td>
<td>3.50</td>
<td>3.54</td>
<td>0.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Living space (m²)</td>
<td>9,061</td>
<td>41.74</td>
<td>5.95</td>
<td>11.00</td>
<td>95.90</td>
</tr>
<tr>
<td>$\tilde{H}_{2000}$</td>
<td>79</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>$\tilde{D}_{2000}$</td>
<td>79</td>
<td>0.17</td>
<td>0.05</td>
<td>0.08</td>
<td>0.30</td>
</tr>
<tr>
<td>Unemployment ratio</td>
<td>79</td>
<td>2.34</td>
<td>0.37</td>
<td>1.28</td>
<td>3.43</td>
</tr>
<tr>
<td>Voter turnout</td>
<td>79</td>
<td>69.18</td>
<td>3.75</td>
<td>60.10</td>
<td>77.10</td>
</tr>
<tr>
<td>Facility centrality</td>
<td>79</td>
<td>2.78</td>
<td>2.18</td>
<td>0.00</td>
<td>17.78</td>
</tr>
</tbody>
</table>
Berlin

Air pollution (ln kg)
- 0
- >0 to 7.20
- 7.20 to 10.12
- 10.12 to 16.79
- 16.79 to 18.10
- over 18.10

% Foreigners
- under 1.70
- 1.70 to 3.09
- 3.09 to 5.00
- 5.00 to 8.10
- 8.10 to 13.58
- over 13.58
### Multilevel-Models

<table>
<thead>
<tr>
<th></th>
<th>M4</th>
<th>M5</th>
<th>M6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Census cell level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Foreigners</td>
<td>0.232***</td>
<td>0.254***</td>
<td>0.245***</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.037)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>Cross-level interactions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Foreigners × (\tilde{H}_{2000})</td>
<td>0.079†</td>
<td>0.086*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.040)</td>
<td></td>
</tr>
<tr>
<td>% Foreigners × Unemployment ratio</td>
<td>-0.010</td>
<td>-0.046</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.032)</td>
<td>(0.028)</td>
<td></td>
</tr>
<tr>
<td>% Foreigners × Voter turnout</td>
<td>0.044</td>
<td>0.024</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.037)</td>
<td>(0.032)</td>
<td></td>
</tr>
<tr>
<td>% Foreigners × Facility centrality</td>
<td></td>
<td></td>
<td>0.139***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.026)</td>
</tr>
<tr>
<td>Fixed effects</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Random slope</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>AIC</td>
<td>23635.200</td>
<td>23680.777</td>
<td>23672.149</td>
</tr>
<tr>
<td>N</td>
<td>9061</td>
<td>9061</td>
<td>9061</td>
</tr>
<tr>
<td>N cluster</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>(\sigma^2) % Foreigners</td>
<td>0.066</td>
<td>0.068</td>
<td>0.044</td>
</tr>
<tr>
<td>(\sigma^2) Residual</td>
<td>0.780</td>
<td>0.780</td>
<td>0.780</td>
</tr>
</tbody>
</table>

*** \(p < 0.001\), ** \(p < 0.01\), * \(p < 0.05\), † \(p < 0.1\). Multilevel models with group centered first level variables. All variables are scaled by their standard deviation. Standard errors in parentheses. Controls: Population, % 65 and older, % Vacant housing, Living space.
Dependent variable: In Pollution (tox-weighted)

Explained Slope Variance (%)

- Residential Segregation: -0.43
- Unemployment ratio: 0.27
- Voter turnout: -1.55
- Facility centrality: 43.38

Cross-level interaction with % foreigners

- Separate Model
- M2
- M3
Spatial Model

![Graph showing the effect of percentage of foreigners on pollution (in standard deviations) with facility centrality (in standard deviations). The graph includes two lines representing direct and indirect effects, with shaded areas indicating the range of variation.]