Low Emission Zones for Better Health: Evidence from German Hospitals

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Online EAERE pre-conference workshop:
The economic impacts of air pollution and the implications for policy

Motivation

Air pollution is detrimental to human well-being

- A wide range of health hazards attributed to poor air quality
  - About 7 million premature deaths per year (WHO, 2018)
  - Major concern not only in developing countries
- Air pollution creates large economic costs
  - Health and human capital formation
  - Labor supply and worker productivity
- Traffic is a major source of air pollution in urban areas
  - Automobile exhaust particularly harmful
  - Great importance for environmental policy-making

What is a Low Emission Zone?

- In Germany key policy measure to reduce air pollution in inner-cities
- Low Emission Zones are signposted areas where access of vehicles is regulated based on the vehicle's emission standard
- Typically high-emitting vehicles are banned from entering the zone altogether

This paper

Do Low Emission Zones benefit population health?

- Staggered policy implementation in Germany since 2007
  - Exploit variation in timing and exact coverage
  - Difference-in-differences framework
- Study pollution and health effects from 2006 to 2016
  - Data from official air pollution monitoring system
  - Rich panel data on the universe of German hospitals
- Main findings
  - Low Emission Zones improve air quality in inner-cities
  - Significant reductions in circulatory and respiratory diseases

Institutional Background and Data

EU Air Quality Standards

- EU Directives to improve ambient air quality ▸ EU Limit Values
  - Measurement procedures, limit values and alert thresholds
  - Violations require member states to adopt action plans
- Particulate Matter (PM10)
  - Concentration of airborne particles in ambient air ($< 10\mu m$)
  - May enter lungs, blood stream, overcome blood-brain barrier
- Nitrogen Dioxide (NO2)
  - Results from burning fossil fuels (in cities mainly from traffic)
  - Nose and throat irritation, inflammation of the lining of lungs
- PM10 and NO2 cause respiratory and cardiovascular diseases

Institutional Background and Data

Low Emission Zones in Germany

- German states responsible for compliance with EU regulation at the local (city) level
- Authorities obliged to develop a bundle of measures to improve air quality (Clean Air Plans)
- Low Emission Zone most tangible measure from the toolbox based on vehicle emission standard

Institutional Background and Data

Clean Air plans (gray) and Low Emission Zones (black)

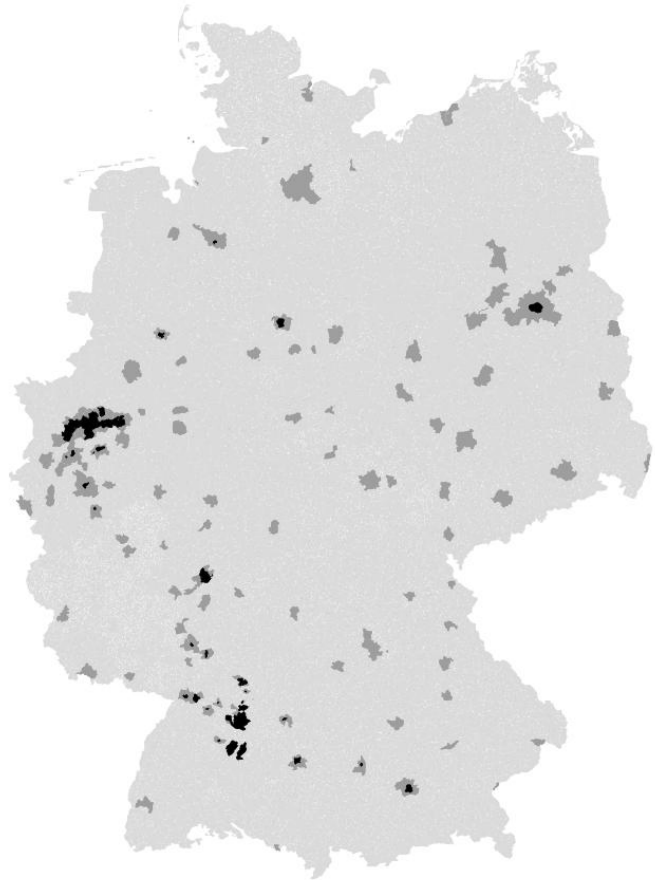
2007

▸ LEZ Evolution

Institutional Background and Data

Clean Air plans (gray) and Low Emission Zones (black)

2010

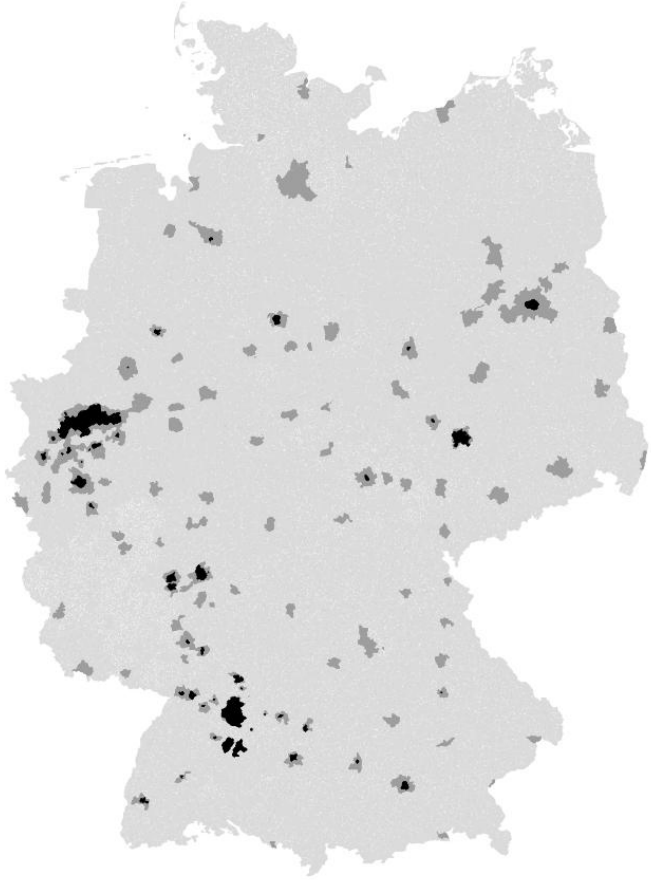


▸ LEZ Evolution

Institutional Background and Data

Clean Air plans (gray) and Low Emission Zones (black)

2013

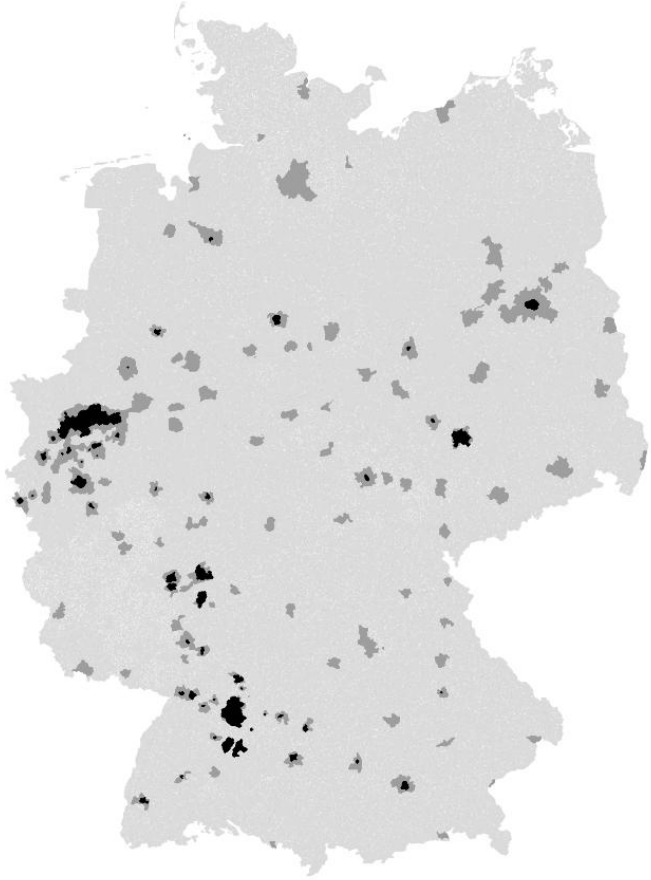


▸ LEZ Evolution

Institutional Background and Data

Clean Air plans (gray) and Low Emission Zones (black)

2016



▸ LEZ Evolution

Institutional Background and Data

Air pollution data

- Monitoring system of the Federal Environment Agency
  - All monitors measuring the concentration of PM10 and NO2
  - Yearly averages and number of limit exceedances

▸ PM10 Descriptives ▸ NO2 Descriptives

Hospital data

- Panel dataset of the universe of hospitals in Germany
  - Annual number diagnoses based on ICD-10 classification
  - Sample hospitals with unit for surgery and internal medicine
- Assignment of hospital catchment areas
  - Based on hospital locations (no info on patient residences)
  - Share covered by Low Emission Zone based on driving time

▸ Bonn Example ▸ Hospital Descriptives

Empirical Strategy

Difference-in-differences

$$y_{ict} = \alpha + \beta\ LEZ_{it} + \boldsymbol{X}'_{\boldsymbol{ict}}\gamma + \delta_i + \delta_t + \varepsilon_{ict},$$

- y_{ict}: Outcome for unit i in city c in year t
- LEZ_{it}: Treatment by Low Emission Zone
- X_{ict}: Controls
  - Weather: temperature, precipitation, wind speed
  - City population: Inhabitants, Employed, Age-gender composition
  - Hospital characteristics: Ownership, capacity
- δ_i, δ_t: Fixed effects for unit i and year t
- ε_{ict}: Standard errors clustered at county level

Overview of Results

Introduction of Low Emission Zone reduces air pollution...

- Average concentration of air pollutants decreases
  - PM10 by 1.3 $\mu g/m^3$ (about 6%)
  - NO2 by 1.6 $\mu g/m^3$ (about 5%)
- Incidence of limit exceedances and violations is reduced

...and thereby improves human health

- Reduction in total number of diagnosed diseases
  - mainly diseases of the circulatory and respiratory system
  - mainly chronic and *non*-emergency diagnoses
- Effect size: Reductions of up to 5% for a 20 percentage point increase in hospital catchment area coverage

▸ Detailed Results

Conclusions

Summary of findings

- Low Emission Zones significantly reduce air pollution in cities
- The improvements in air quality translate into health benefits
- Mainly decrease of circulatory and respiratory diseases

Policy implications

- Potential for reducing overall costs of health care system
- Indirect benefits for human capital, productivity and growth
- Controversial debates about further Diesel driving bans

Thank you for your attention!

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IZA Discussion Paper No. 12545
http://ftp.iza.org/dp12545.pdf

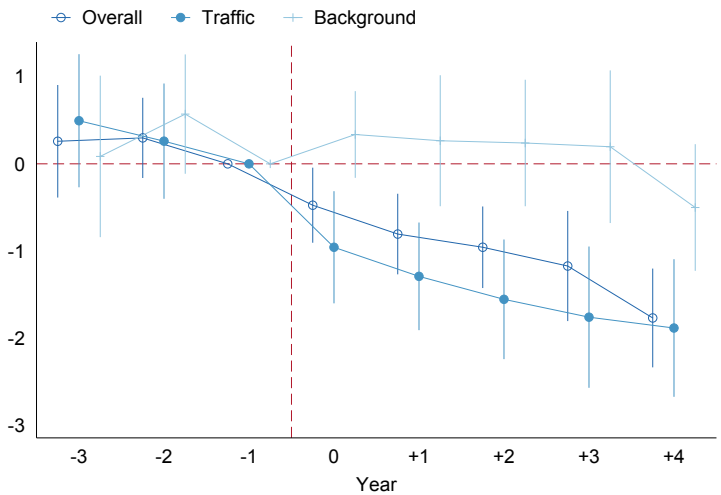
Results – Pollution

	PM10			NO2		
	(1)	(2)	(3)	(4)	(5)	(6)
A. Pollution levels	Yearly mean PM10 ($\mu g/m^3$)			Yearly mean NO2 ($\mu g/m^3$)		
In LEZ	-1.461***	-1.450***	-1.273***	-1.829***	-1.823***	-1.581***
	(0.188)	(0.188)	(0.204)	(0.454)	(0.455)	(0.461)
Adj. R^2	0.93	0.93	0.93	0.74	0.74	0.74
N	4290	4290	4290	5237	5237	5237
B. Limit exceedances	Yearly days PM10 $>$ 50 ($\mu g/m^3$)			Yearly hours NO2 $>$ 200 ($\mu g/m^3$)		
In LEZ	-7.068***	-7.068***	-6.580***	-7.071	-7.061	-5.572
	(0.916)	(0.918)	(0.972)	(4.783)	(4.785)	(3.883)
Adj. R^2	0.81	0.81	0.82	0.48	0.48	0.50
N	4290	4290	4290	4365	4365	4365
C. Violations	Yearly mean PM10 $>$ 40 ($\mu g/m^3$)			Yearly mean NO2 $>$ 40 ($\mu g/m^3$)		
In LEZ	-0.003	-0.003	-0.000	-0.050**	-0.051**	-0.043**
	(0.007)	(0.007)	(0.006)	(0.021)	(0.021)	(0.022)
Adj. R^2	0.16	0.17	0.17	0.86	0.86	0.86
N	4290	4290	4290	5237	5237	5237
Controls:						
Station FE	Yes	Yes	Yes	Yes	Yes	Yes
State $\times$ Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Weather characteristics	No	Yes	Yes	No	Yes	Yes
Municipality characteristics	No	No	Yes	No	No	Yes

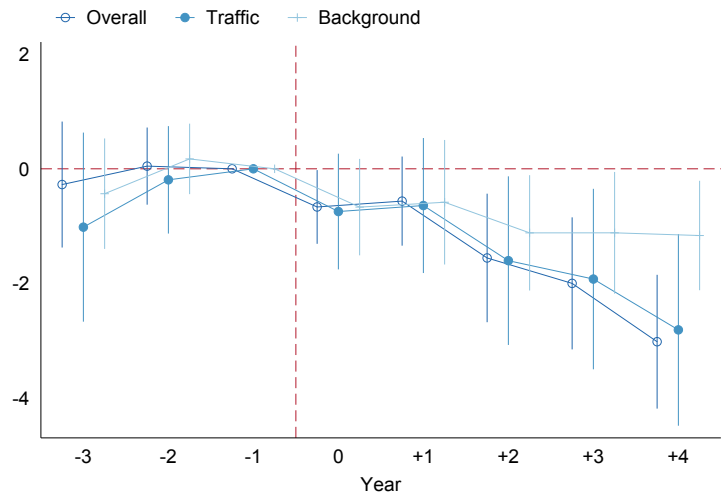
▸ Back to Overview of Results

Results – Pollution II

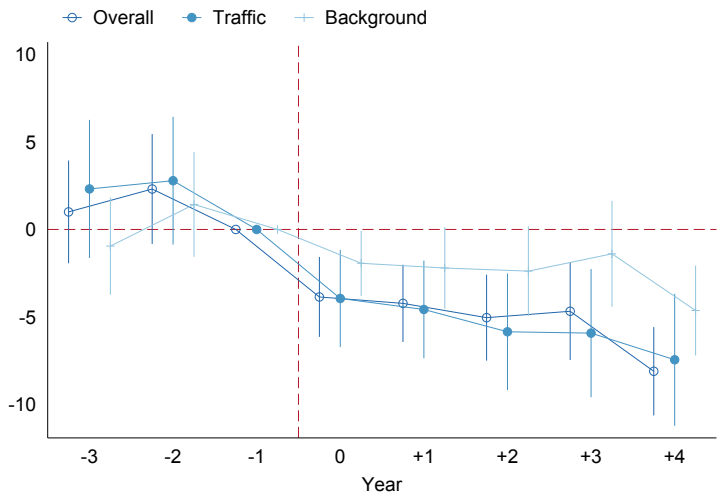
Mean PM10 $\mu g/m^3$



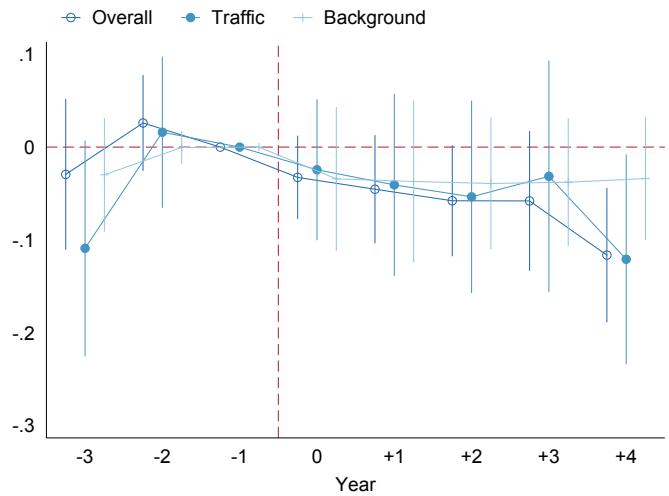
Mean NO2 $\mu g/m^3$



Days PM10>50 $\mu g/m^3$



Mean NO2>40 $\mu g/m^3$



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Results – Health Outcomes

	(1)	(2)	(3)	(4)	(5)
All diseases (A00-N99)	-0.049	-0.050	-0.051	-0.066	-0.072*
	(0.040)	(0.039)	(0.047)	(0.047)	(0.043)
Diseases of the ciculatory system (I00-I99)	-0.105*	-0.105*	-0.109*	-0.144**	-0.145***
	(0.055)	(0.055)	(0.061)	(0.058)	(0.055)
Hypertension (I10-I15)	-0.120*	-0.119*	-0.120	-0.165*	-0.157*
	(0.069)	(0.069)	(0.076)	(0.092)	(0.091)
Ischemic heart diseases (I20-I25)	-0.132	-0.133	-0.174*	-0.258**	-0.263***
	(0.082)	(0.082)	(0.091)	(0.103)	(0.099)
Cerebrovascular disease (I60-I69)	-0.134	-0.133	-0.188*	-0.191*	-0.208**
	(0.099)	(0.099)	(0.103)	(0.106)	(0.102)
Diseases of the respiratory system (J00-J99)	0.009	0.009	-0.007	-0.099	-0.108*
	(0.060)	(0.059)	(0.060)	(0.065)	(0.059)
Acute lower respiratory diseases (J20-J22)	-0.007	-0.006	-0.007	-0.167*	-0.171*
	(0.089)	(0.088)	(0.086)	(0.095)	(0.090)
Chronic lower respiratory diseases (J40-J47)	-0.135**	-0.136**	-0.149**	-0.217***	-0.222***
	(0.063)	(0.063)	(0.067)	(0.079)	(0.077)
Low birth weight (P07) [t+1]	0.027	0.027	0.027	-0.095	-0.091
	(0.077)	(0.077)	(0.082)	(0.111)	(0.112)
N	8828	8828	8828	8828	8828
Controls:					
Hospital FE	Yes	Yes	Yes	Yes	Yes
State × Year FE	Yes	Yes	Yes	Yes	Yes
Weather characteristics	No	Yes	Yes	Yes	Yes
Municipality characteristics	No	No	Yes	Yes	Yes
Linear municipality time trends	No	No	No	Yes	Yes
Hospital characteristics	No	No	No	No	Yes

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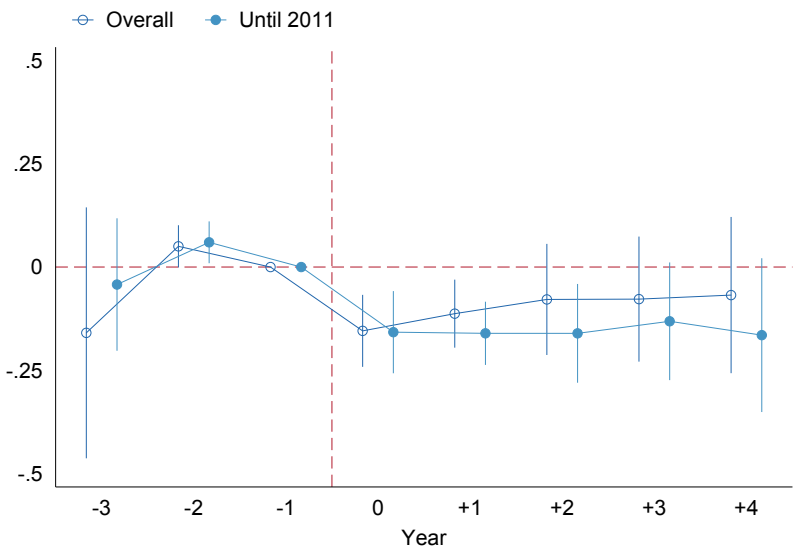
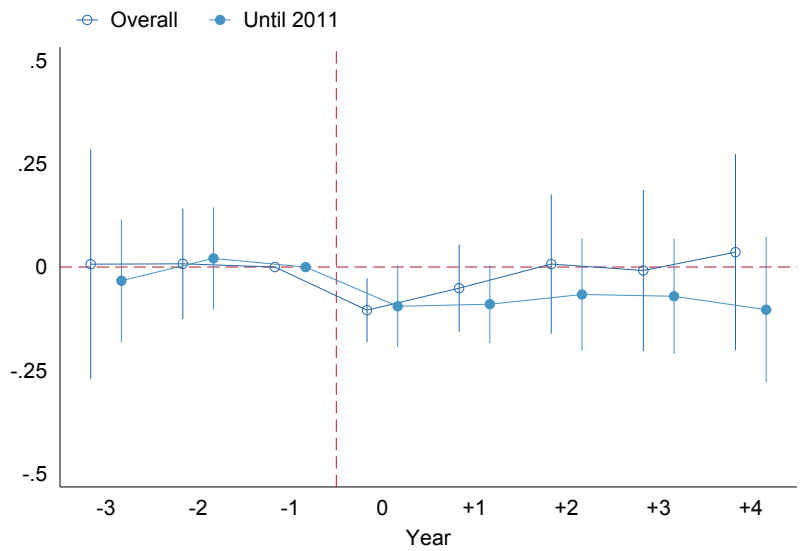
Results – Health Outcomes II

Circulatory diseases



Respiratory diseases



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Results – Additional Results and Robustness

Pollution

- Effects stem from Low Emission Zones, not Clean Air Plans
- Very little evidence for "pollution shifting"

Health

- Treatment: main findings robust to other treatment definition
- "Placebo": no effects for special hospitals
- Outcomes: no effects on dementia, neoplasm, stress, injuries

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Appendix – Hospital Data Descriptives

	Mean	(SD)	min	max	N
A. Hospital characteristics					
Non-profit	0.43	0.50	0	1	8828
Public	0.40	0.49	0	1	8828
Private	0.17	0.38	0	1	8828
Number of Beds	375.49	312.82	4	2917	8828
Base rate in €	2990.23	260.91	871	14238	8828
Inpatients	15669.04	14263.88	77	198452	8828
Catchment area in km^2	503.51	559.65	0	4671	8828
Population in catchment area	75859.64	54525.85	282	447094	8820
B. Diagnoses					
All diseases (A00-N99)	10506.28	10257.91	32	155406	8828
Diseases of the circulatory system (I00-I99)	2294.15	2579.06	0	55735	8828
Hypertension (I10-I15)	258.84	398.95	0	18855	8828
Ischemic heart diseases (I20-I25)	565.18	867.48	0	17668	8828
Cerebrovascular disease (I60-I69)	277.00	420.80	0	6118	8828
Diseases of the respiratory system (J00-J99)	944.61	989.36	0	15512	8828
Chronic lower respiratory diseases (J40-J47)	203.95	221.67	0	3812	8828
Acute lower respiratory diseases (J20-J22)	103.91	122.82	0	1392	8828
Low birth Weight (P07) [t+1]	46.09	104.92	0	1840	7507
Stress (F40-F48)	74.71	141.68	0	2614	8828
Injuries (S00-S99)	1185.00	1119.20	0	19174	8828
C. Treatment characteristics					
In active Clean Air Plan	0.34	0.47	0.00	1.00	8828
In LEZ ban on Euro 1	0.10	0.30	0.00	1.00	8828
In LEZ ban on Euro 1-2	0.07	0.26	0.00	1.00	8828
In LEZ ban on Euro 1-3	0.06	0.23	0.00	1.00	8828
Catchment areas covered by LEZ	0.16	0.37	0.00	1.00	8828
Overall share of catchment area covered by LEZ	0.06	0.20	0.00	1.00	8828
Overall share of population covered by LEZ	0.07	0.22	0.00	1.00	8828
D. Weather characteristics					
Mean temperature in $^\circ$ C	9.63	1.43	-5.27	12.64	8828
Mean precipitation in mm/m^2	2.05	0.58	0.80	5.89	8828
Mean Wind speed (m/ss)	3.42	0.98	1.18	11.19	8828
E. Municipality characteristics					
Inhabitants/1000	263.36	634.02	0.40	3574.83	8828
Employed/1000	113.82	249.37	0.00	1367.68	8828
Share male $<$ 30 years	0.32	0.03	0.23	0.41	8828
Share male 30 - 64 years	0.50	0.02	0.43	0.55	8828
Share male $>$ 64 years	0.18	0.02	0.13	0.27	8828
Share female $<$ 30 years	0.29	0.03	0.20	0.39	8828
Share female 30 - 64 years	0.47	0.02	0.41	0.53	8828
Share female $>$ 64 years	0.23	0.03	0.16	0.34	8828

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Appendix – PM10 Monitor Descriptives

	Mean	(SD)	min	max	N
A. Pollution outcomes					
Yearly mean PM10 ($\mu g/m^3$)	21.94	5.68	7.00	55.00	4290
Yearly days PM10 $>$ 50 $\mu g/m^3$	15.41	14.18	0.00	175.00	4290
Violation (Yearly mean PM10 $>$ 40 $\mu g/m^3$)	0.00	0.06	0	1	4290
Violation (Days PM10 $>$ 50 $\mu g/m^3$)	0.08	0.28	0	1	4290
B. Treatment characteristics					
In active Clean Air Plan	0.54	0.49	0	1	4290
In LEZ ban on Euro 1	0.14	0.33	0	1	4290
In LEZ ban on Euro 1-2	0.09	0.28	0	1	4290
In LEZ ban on Euro 1-3	0.07	0.25	0	1	4290
C. Weather characteristics					
Mean temperature ($^\circ$ C)	9.70	1.44	2.75	12.78	4290
Mean precipitation (mm/m^2)	2.05	0.61	0.54	5.82	4290
Mean Wind speed (m/ss)	3.46	0.98	1.66	11.19	4290
D. Municipality characteristics					
Inhabitants/1000	151.06	453.30	0.04	3574.83	4290
Employed/1000	65.76	182.65	0.00	1367.68	4290
Share male $<$ 30 years	0.32	0.03	0.23	0.41	4290
Share male 30 - 64 years	0.50	0.02	0.43	0.55	4290
Share male $>$ 64 years	0.18	0.02	0.13	0.27	4290
Share female $<$ 30 years	0.29	0.03	0.20	0.39	4290
Share female 30 - 64 years	0.47	0.02	0.41	0.52	4290
Share female $>$ 64 years	0.24	0.03	0.17	0.34	4290

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Appendix – NO2 Monitor Descriptives

	Mean	(SD)	min	max	N
A. Pollution outcomes					
Yearly mean NO2 ($\mu g/m^3$)	30.86	21.98	0.00	121.35	5237
Yearly hours NO2 $>$ 200 $\mu g/m^3$	2.07	24.73	0.00	853.00	4365
Violation (Yearly mean NO2 $>$ 40) $\mu g/m^3$)	0.30	0.46	0	1	5237
Violation (Hours NO2 $>$ 200 $\mu g/m^3$)	0.02	0.13	0	1	4365
B. Treatment characteristics					
In active Clean Air Plan	0.59	0.49	0	1	5237
In LEZ ban on Euro 1	0.18	0.37	0	1	5237
In LEZ ban on Euro 1-2	0.12	0.31	0	1	5237
In LEZ ban on Euro 1-3	0.10	0.29	0	1	5237
C. Weather characteristics					
Mean temperature ($^\circ$ C)	9.71	1.47	0.48	12.78	5237
Mean precipitation (mm/m^2)	2.09	0.63	0.54	7.52	5237
Mean Wind speed (m/ss)	3.47	1.01	1.44	11.25	5237
D. Municipality characteristics					
Inhabitants/1000	158.24	443.57	0.04	3574.83	5237
Employed/1000	69.09	179.61	0.00	1367.68	5237
Share male $<$ 30 years	0.32	0.03	0.23	0.41	5237
Share male 30 - 64 years	0.50	0.02	0.43	0.55	5237
Share male $>$ 64 years	0.18	0.02	0.13	0.27	5237
Share female $<$ 30 years	0.29	0.03	0.20	0.39	5237
Share female 30 - 64 years	0.47	0.02	0.41	0.52	5237
Share female $>$ 64 years	0.24	0.03	0.17	0.34	5237

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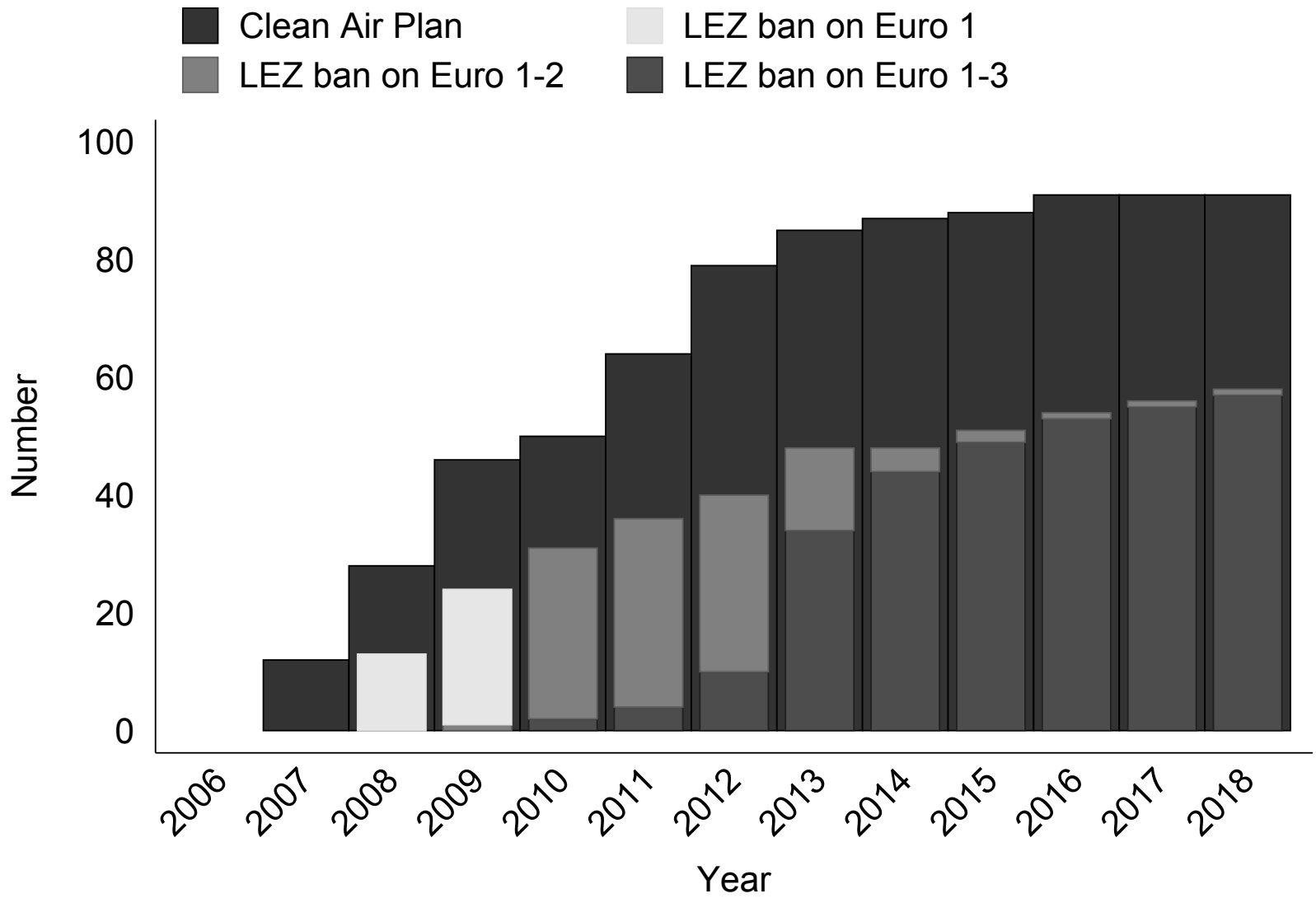
Appendix – Low Emission Zone Evolution



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Appendix – EU Air Quality Standards

Pollutant	Thresholds	Deadline
PM10	Yearly average limit $40\mu g/m^3$ Daily average limit $50\mu g/m^3$ Allowed number of transgression: 35	1 January 2005
NO2	Yearly average limit $40\mu g/m^3$ Hourly average limit $200\mu g/m^3$ Allowed number of transgression: 18	1 January 2010

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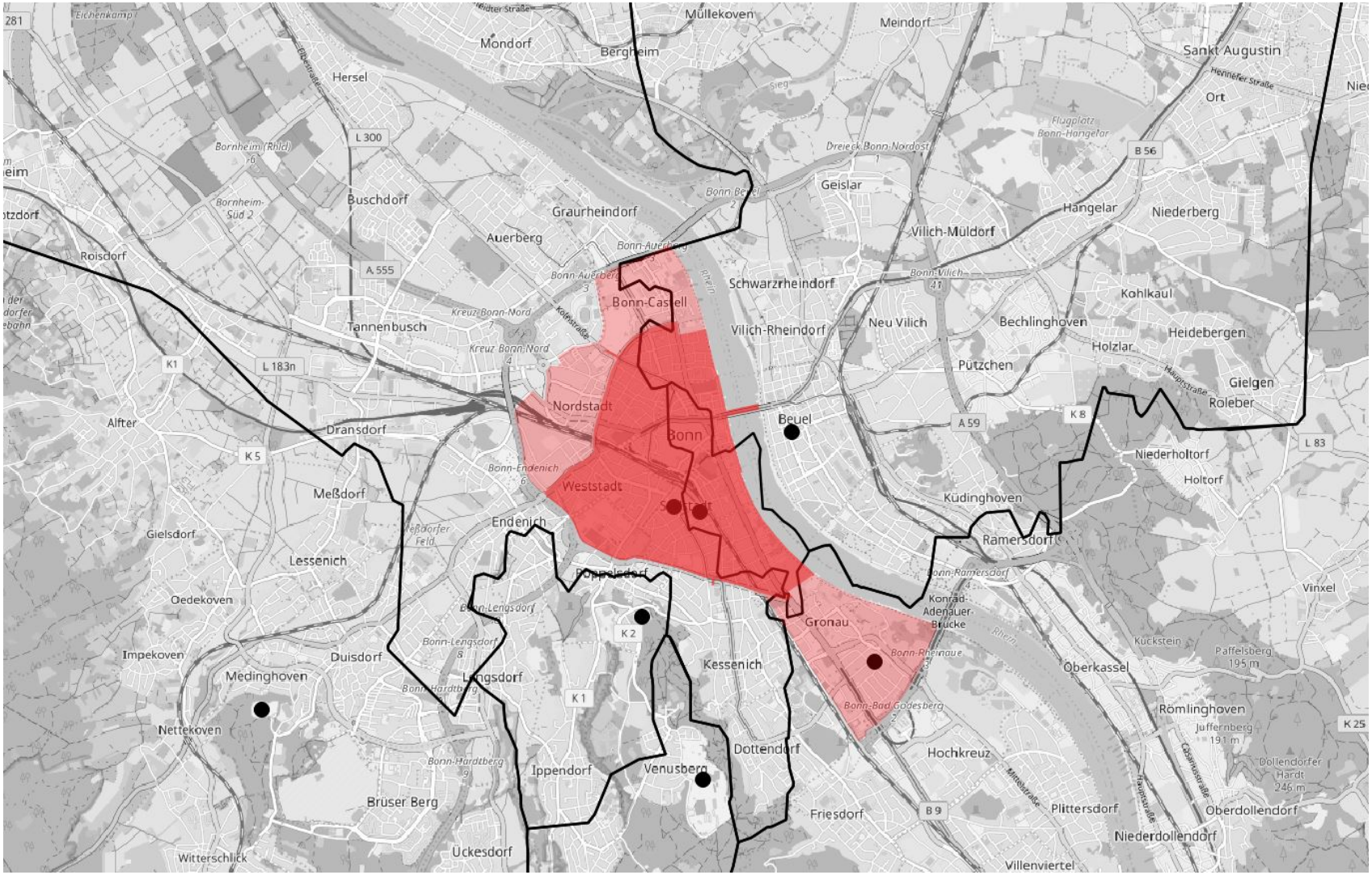
Appendix – Hospitals Bonn Example



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