

PM10 AND LOW EMISSION ZONES IN GERMANY



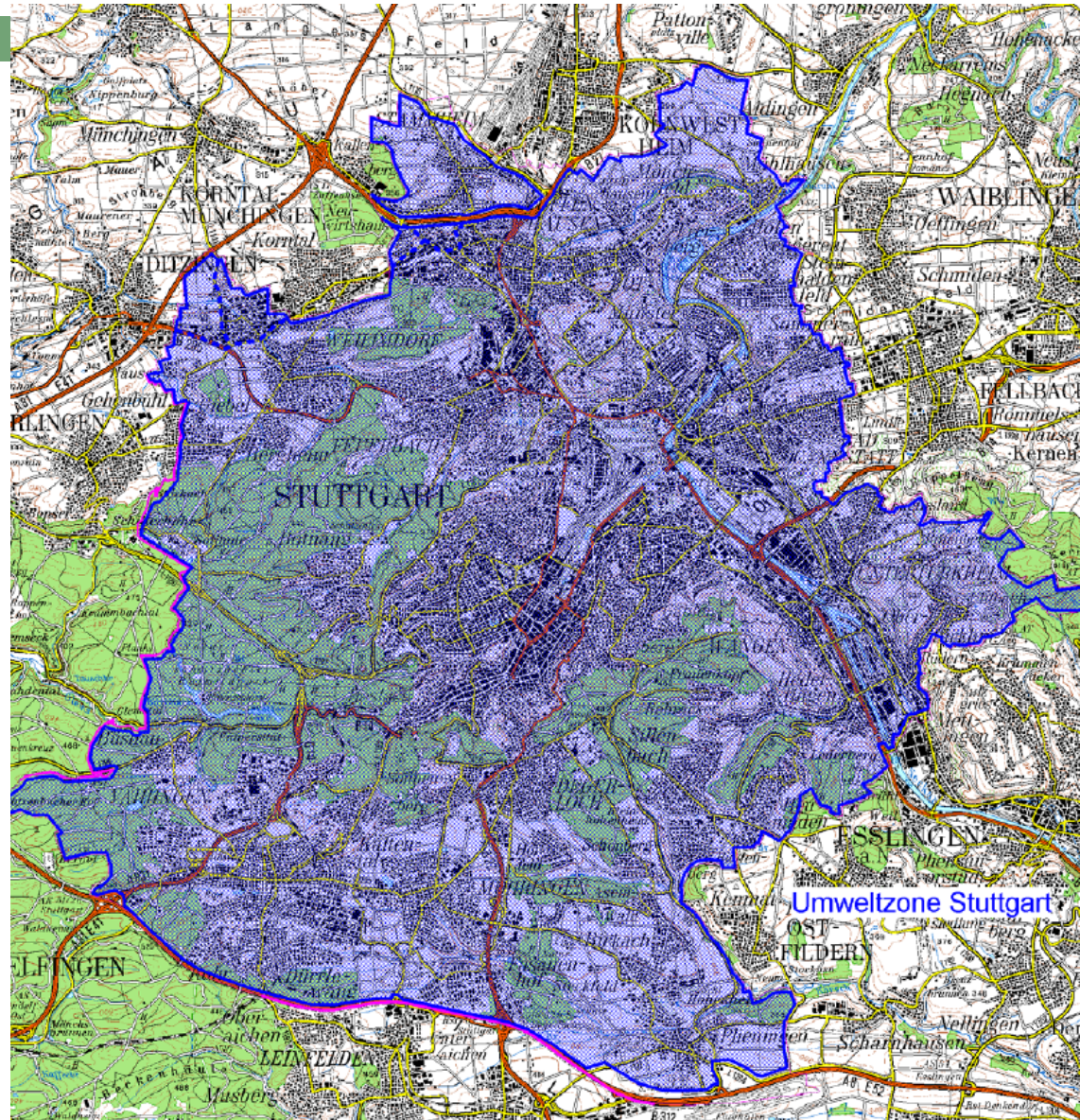
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Particulate Matter (PM10)

- 6.4 million years of healthy life lost²
- causes 348,000 premature deaths/year in EU¹
(Ozone causes 21,000 premature deaths)

1). Cohen et al., 2005 2). Watkiss et al., 2005;

Low Emission Zone of Stuttgart



Low Emission Zone (LEZ)

- Area where driving is restricted based on PM10 emission of vehicle
- In response to EU regulation: 8 EU countries implemented LEZs
- 32 German cities have LEZs

LEZ and Vehicles



LEZ and Vehicles



LEZ and Vehicles



German LEZs



Summary

- Empirical Evaluation of LEZs in Germany
 - Analyze PM10
 - Spatial substitution effects of clean/dirty vehicles

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- Preliminary results:
 - PM10 decreases at traffic stations within LEZs
 - “Donut effects” of air pollution
 - Drivers close to a LEZ go “green” at faster rate

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- Empirical Evaluation of LEZs in Germany
 - Analyze PM10
 - Spatial substitution effects of clean/dirty vehicles
- Preliminary results:
 - PM10 decreases at traffic stations within LEZs
 - “Donut effects” of air pollution
 - Drivers close to a LEZ go “green” at faster rate
 - Used car market data in preparation

Driving Restrictions Worldwide

- ▣ Total/Partial Bans

- Mexico City, Bogota, Santiago, Sao Paulo, La Paz, Honduras, Beijing, Milan, Athens, Amsterdam, Barcelona, Tokyo

- ▣ Congestion Charging and LEZ: London

Literature - Empirical evidence scarce:

- Davis (2008, JPE) studies Mexico's license plate program
 - Increase of air pollution
 - Increase in second car with higher-emission

- Rosen, Small (1998); Small, Kazimi (1995): target high pollution vehicles

EU PM10 regulation

	Phase 1 from 1 January 2005
Yearly average	40 $\mu\text{g}/\text{m}^3$

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Daily average	50 $\mu\text{g}/\text{m}^3$
Maximum number of exceedance days per year	35

EU PM10 regulation

	Phase 1 from 1 January 2005	<u>Phase 2</u> <u>from 1</u> <u>January</u> <u>2010</u>
Yearly average	40 $\mu\text{g}/\text{m}^3$	20 $\mu\text{g}/\text{m}^3$
Daily average	50 $\mu\text{g}/\text{m}^3$	50 $\mu\text{g}/\text{m}^3$
Maximum number of exceedance days per year	35	7

EU PM10 regulation

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Daily average	50 $\mu\text{g}/\text{m}^3$	50 $\mu\text{g}/\text{m}^3$
Maximum number of exceedance days per year	35	7
German cities violation	81	285

EU air pollution regulation

- 81 cities in nonattainment of PM10 limit
 - must design “action plan”

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- Action plans can include instruments:
 - Improving public transportation
 - Ring roads
 - Improving traffic flow

EU air pollution regulation

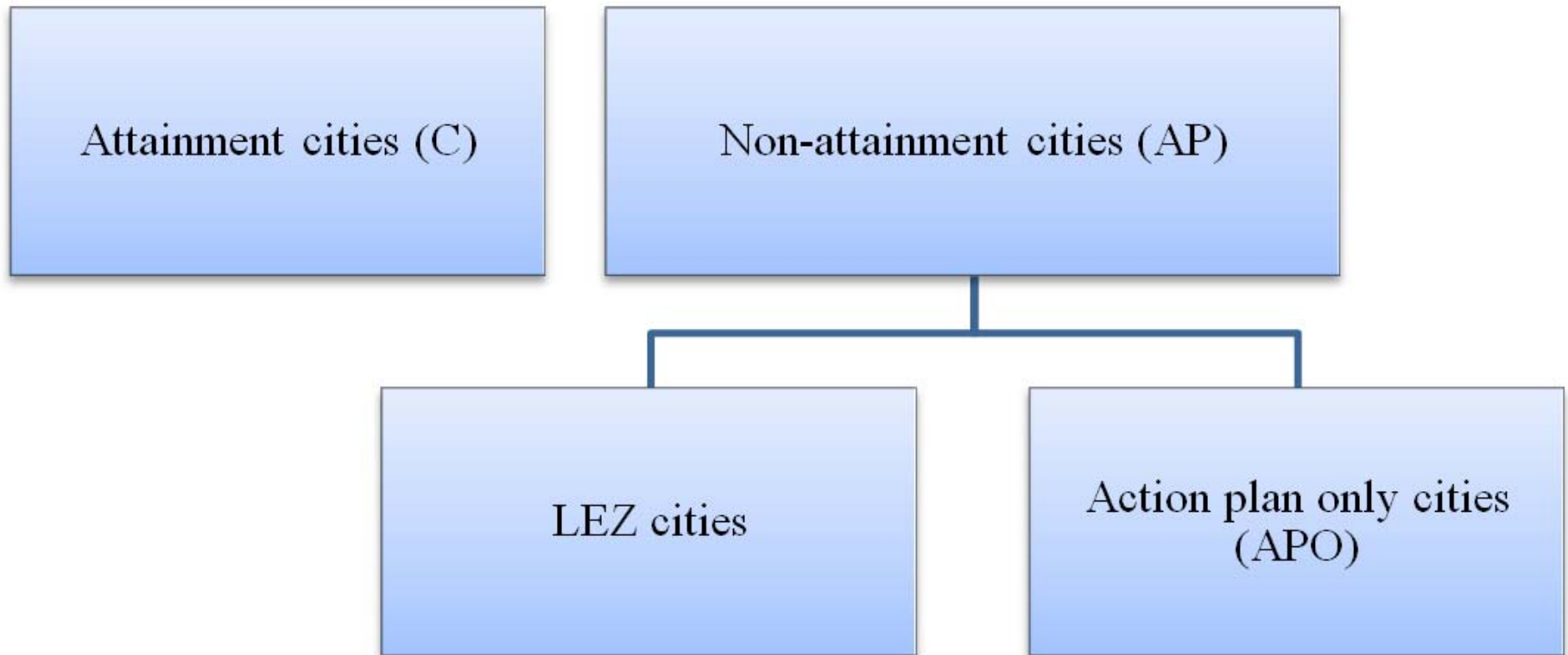
- 81 cities in nonattainment of PM10 limit
 - must design “Action Plan”
- Action plans can include instruments:
 - Improving public transportation
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 - Improving traffic flow
 - **LEZs (32 cities)**

Structure of Cities

Attainment cities (C)

Non-attainment cities (AP)

Structure of Cities



Low Emission Zones



- Foreigners also need sticker
- Sticker cost €5-10
- Fine: €40 & 1 point in Flensburg
- Upgrading costs
 - €500 - €5000 for cars
 - €4000 - 15,000 for trucks

Staggered nature of LEZs



Stage 1 from 1.1. 2008:

Vehicles (lorries and passenger cars) must at least meet the requirements of Pollutant Class 2 of the recently adopted national vehicle marking scheme. Therefore, vehicles with red, yellow and green stickers are allowed.



Stage 2 from 1.1.2010:

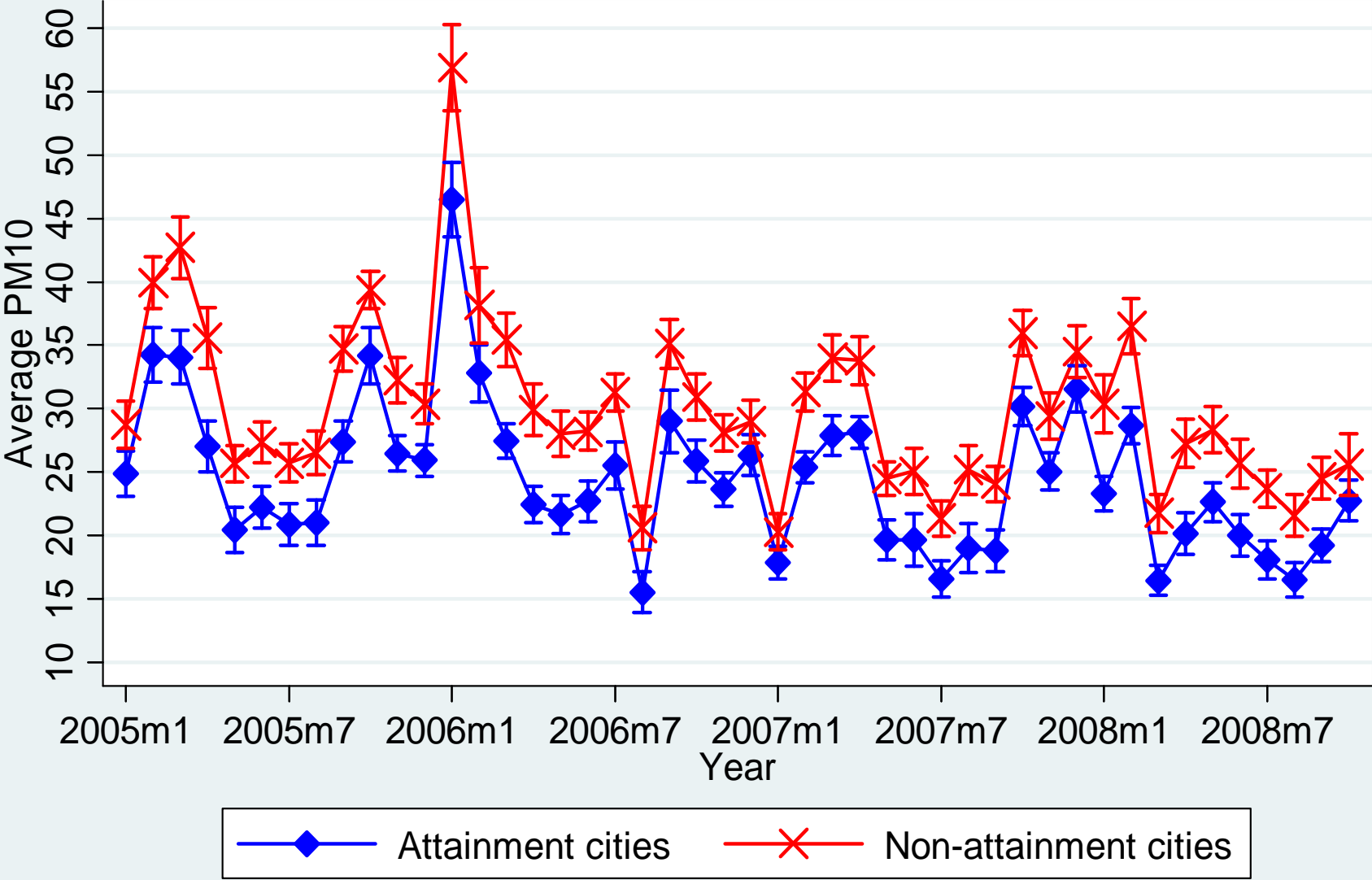
Only vehicles in Pollutant Class 4—thus, only vehicles with green stickers—can drive in the zone.

PM10 data



- Umweltbundesamt Germany
- 1 285 stations in 388 cities
- daily readings from 2005 through October 2008

Monthly PM10 -- 2005 to 2008



Data

- Weather for 108 stations from Deutscher Wetterdienst
- Holiday data
 - School holidays -- differ by state
 - Federal holidays

Methodology

- Matching of cities based on 2005 attributes
 - Differences-in-Differences based on staggered introduction

$$\ln(y_{i,t}) = \alpha + \beta_1 postLEZ_t + \beta_2 LEZstation_i + \beta_3 LEZtreat_{i,t} + \Psi X_{i,t} + u_{i,t}$$

- DD variables:
 - $postLEZ$ = Indicator for time (t) period after LEZ introduction
 - $LEZstation$ = Indicator for station (i) in LEZ area over all time
 - $LEZtreat$ = Treatment effect = $postLEZ * LEZstation$
- Control variables $X_{i,r,k}$:
 - Month, day of week and station fixed effects
 - Extensive weather model
 - Holiday dummies, School vacation

Difference in Differences Model

City	Station
LEZ city	1
LEZ city	1
LEZ city	1
LEZ city	2
LEZ city	2
LEZ city	2
Control city	3
Control city	3
Control city	3
Control city	4
Control city	4
Control city	4

Difference in Differences Model

City	Station	Day
LEZ city	1	1
LEZ city	1	2
LEZ city	1	3
LEZ city	2	1
LEZ city	2	2
LEZ city	2	3
Control city	3	1
Control city	3	2
Control city	3	3
Control city	4	1
Control city	4	2
Control city	4	3

Difference in Differences Model

City	Station	Day	LEZ
LEZ city	1	1	1
LEZ city	1	2	1
LEZ city	1	3	1
LEZ city	2	1	1
LEZ city	2	2	1
LEZ city	2	3	1
Control city	3	1	0
Control city	3	2	0
Control city	3	3	0
Control city	4	1	0
Control city	4	2	0
Control city	4	3	0

Difference in Differences Model

City	Station	Day	LEZ	Post LEZ
LEZ city	1	1	1	0
LEZ city	1	2	1	1
LEZ city	1	3	1	1
LEZ city	2	1	1	0
LEZ city	2	2	1	1
LEZ city	2	3	1	1
Control city	3	1	0	0
Control city	3	2	0	1
Control city	3	3	0	1
Control city	4	1	0	0
Control city	4	2	0	1
Control city	4	3	0	1

Difference in Differences Model

City	Station	Day	LEZ	Post LEZ	PostLEZ*LEZ
LEZ city	1	1	1	0	0
LEZ city	1	2	1	1	1
LEZ city	1	3	1	1	1
LEZ city	2	1	1	0	0
LEZ city	2	2	1	1	1
LEZ city	2	3	1	1	1
Control city	3	1	0	0	0
Control city	3	2	0	1	0
Control city	3	3	0	1	0
Control city	4	1	0	0	0
Control city	4	2	0	1	0
Control city	4	3	0	1	0

Effect of Action Plan Only on logPM10

	All station types
	(1)
Treatment effect	0.000459 [0.0123]
Observations	35097
Adjusted R-squared	0.599

All regressions include year-month fixed effects, weather, holiday, station type and population covariates

Robust standard errors clustered by city-week in brackets

Effect of Action Plan Only on logPM10

	All station types	Traffic stations
	(1)	(2)
Treatment effect	0.000459 [0.0123]	0.00336 [0.0147]
Observations	35097	18710
Adjusted R-squared	0.599	0.624

All regressions include year-month fixed effects, weather, holiday, station type and population covariates

Robust standard errors clustered by city-week in brackets

Effect of Action Plan Only on logPM10

	All station types	Traffic stations	Background stations
	(1)	(2)	(3)
Treatment effect	0.000459 [0.0123]	0.00336 [0.0147]	-0.0229 [0.0180]
Observations	35097	18710	16387
Adjusted R-squared	0.599	0.624	0.564

All regressions include year-month fixed effects, weather, holiday, station type and population covariates

Robust standard errors clustered by city-week in brackets

Effect of LEZ vs. Attainment city 2008 vs. 2007

Table 8: LEZ vs. Attainment cities, April-October 2007

	(1)	(2)	(3)
	All station types	All cities Traffic stations	Background stations
Treatment effect	-0.0169 [0.0182]	-0.0647*** [0.0193]	0.0197 [0.0236]
Observations	16,240	7,252	8,988
Adjusted R-squared	0.595	0.636	0.543

All regressions include year-month fixed effects, weather, holiday, sta
 *** p<0.01, ** p<0.05, * p<0.1; Robust standard errors clustered by c:

Effect of LEZ vs. Attainment city 2008 vs. 2007

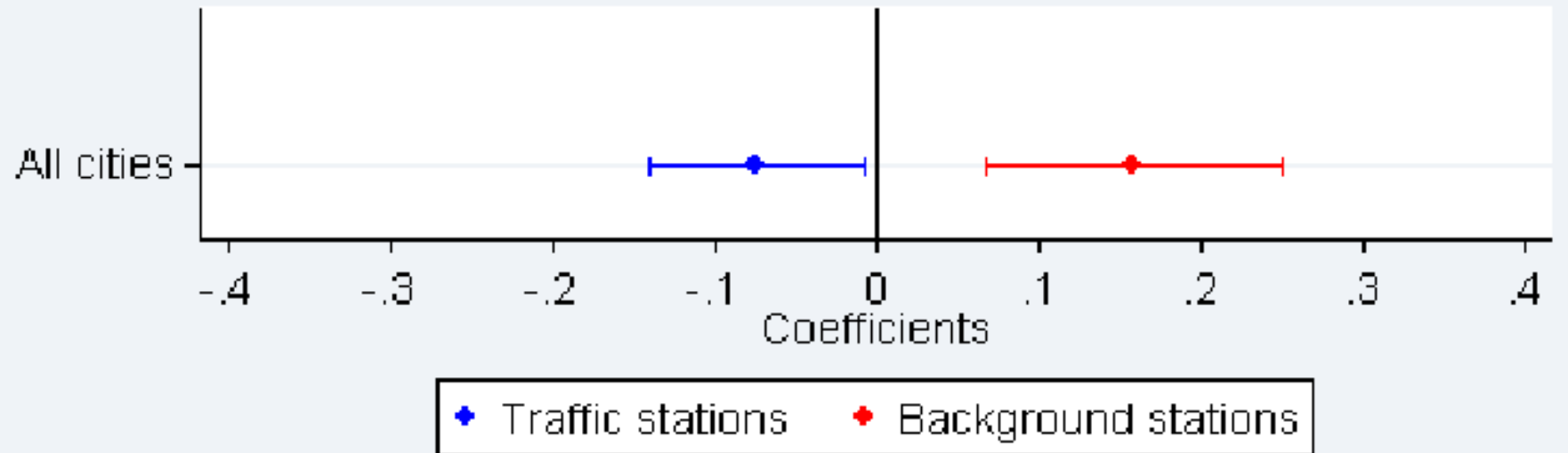
Table 8: LEZ vs. Attainment cities, April-October 2007 vs. 2008

	(1)	(2)	(3)	(4)	(5)	(6)
		All cities			Cities >100,000	
	All station types	Traffic stations	Background stations	All station types	Traffic stations	Background stations
Treatment effect	-0.0169	-0.0647***	0.0197	0.0184	-0.0482*	0.0611**
	[0.0182]	[0.0193]	[0.0236]	[0.0215]	[0.0249]	[0.0251]
Observations	16,240	7,252	8,988	8,561	3,425	5,136
Adjusted R-squared	0.595	0.636	0.543	0.621	0.617	0.581

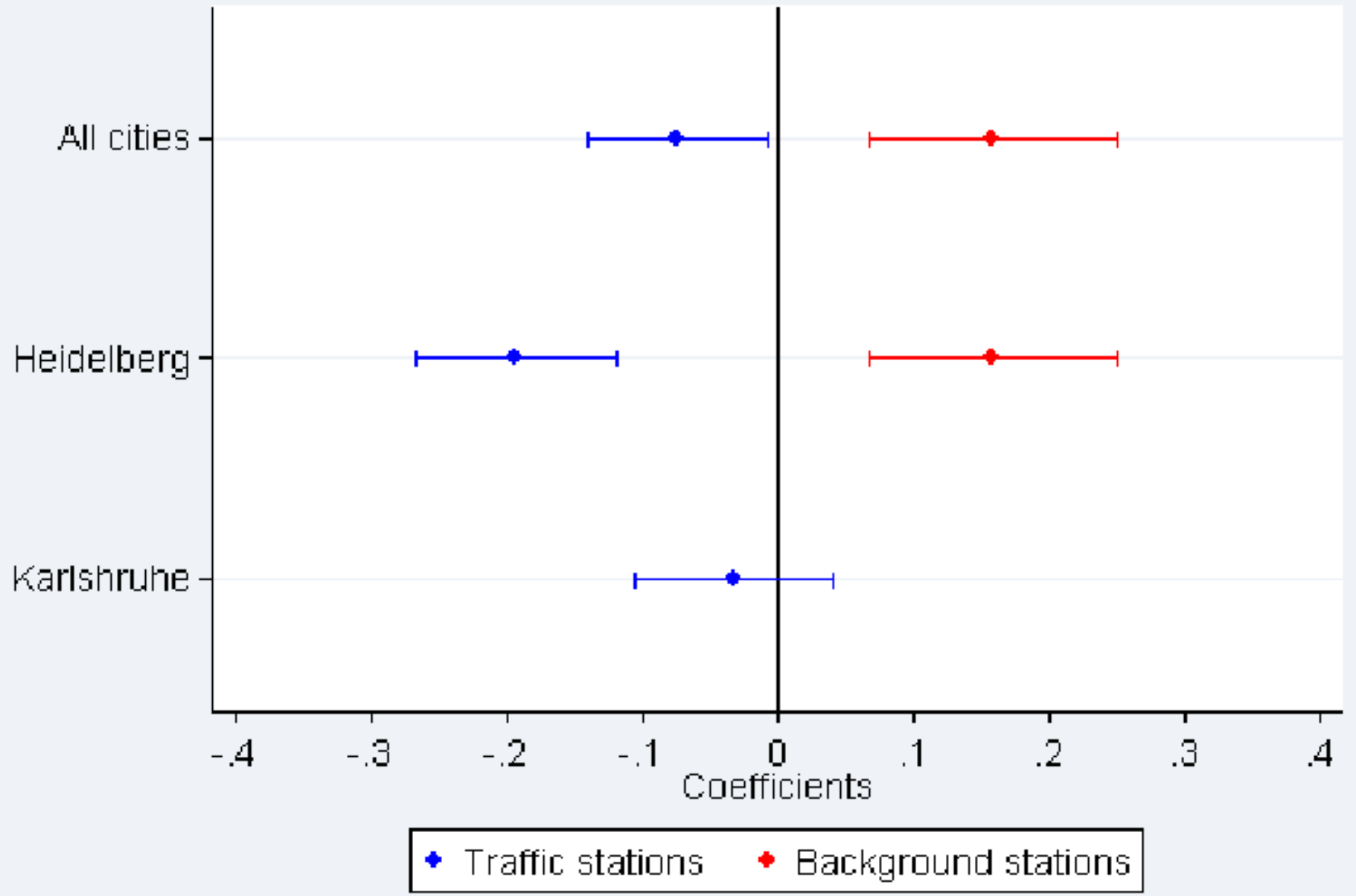
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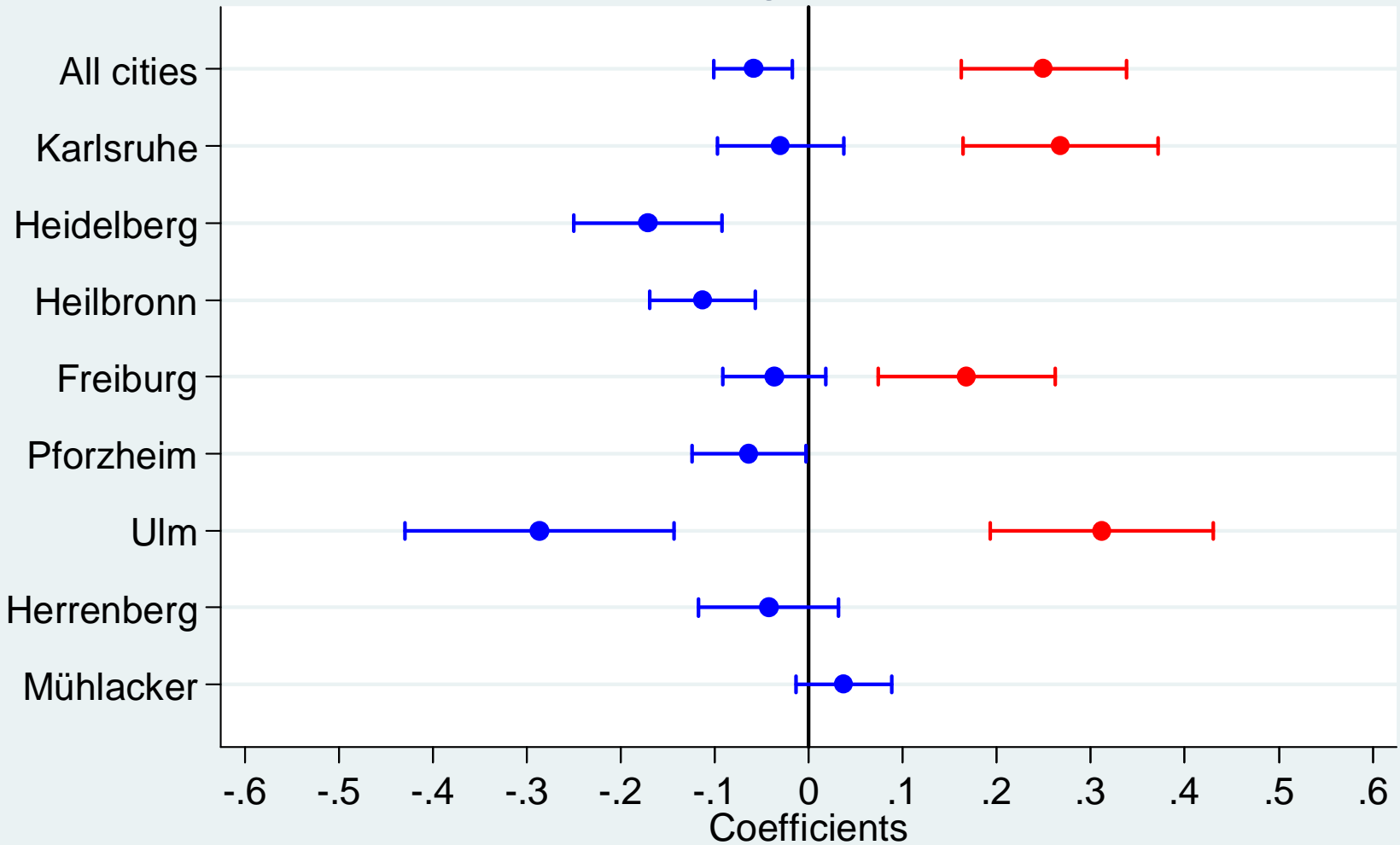
Mannheim LEZ



Mannheim LEZ

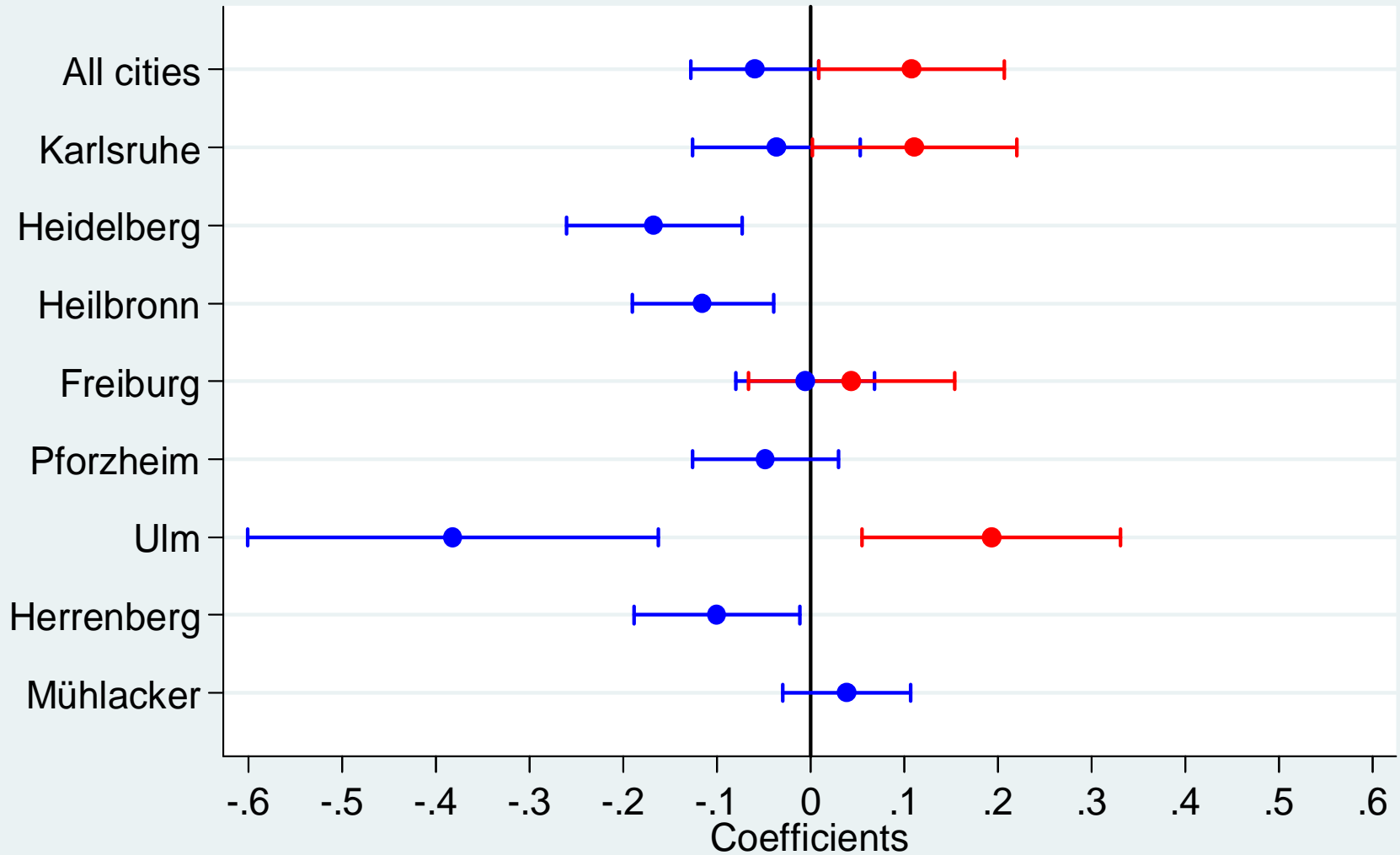


Suttgart LEZ



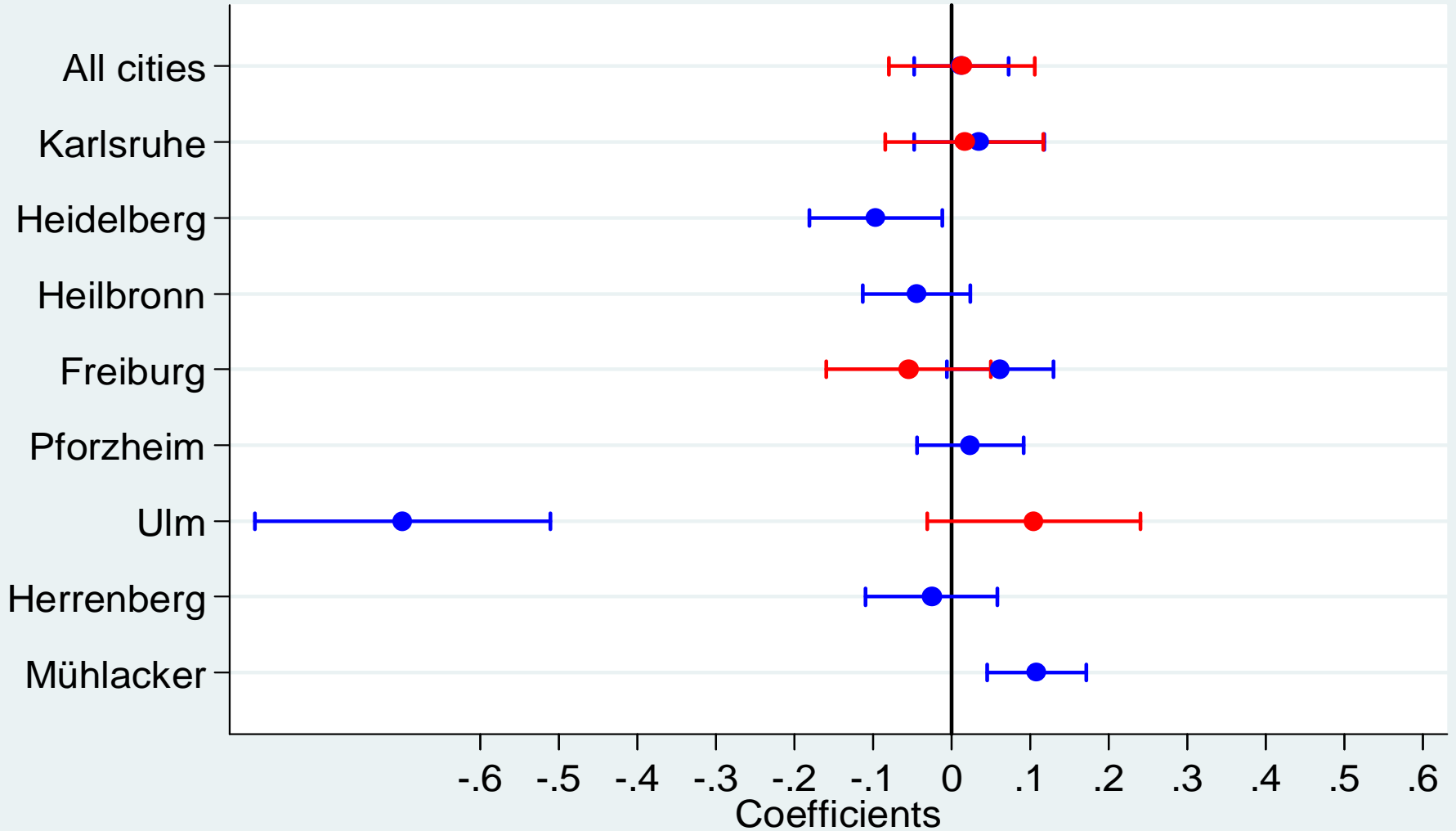
● Traffic stations ● Background stations

Tübingen LEZ



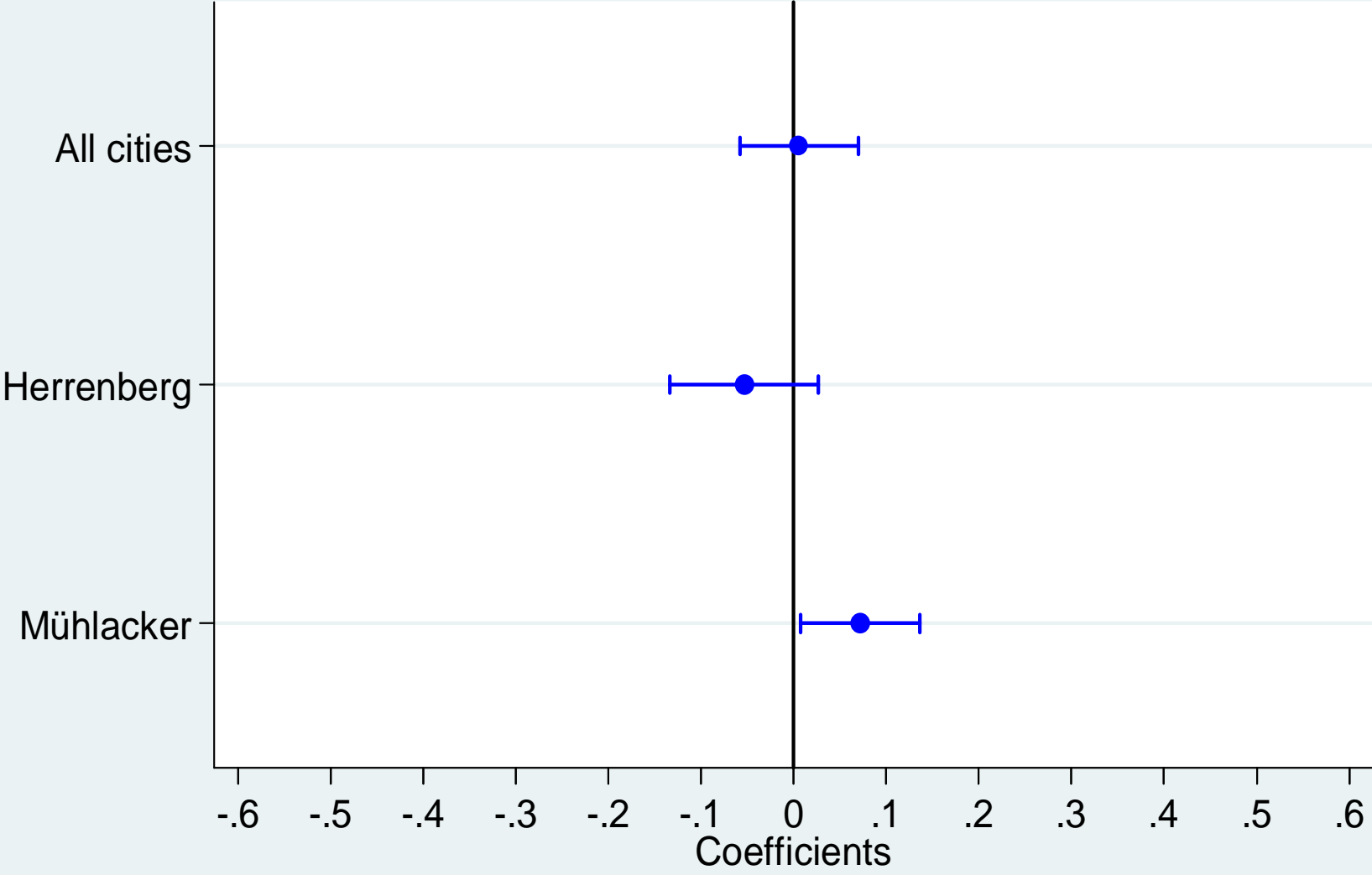
● Traffic stations ● Background stations

Ludwigsburg LEZ



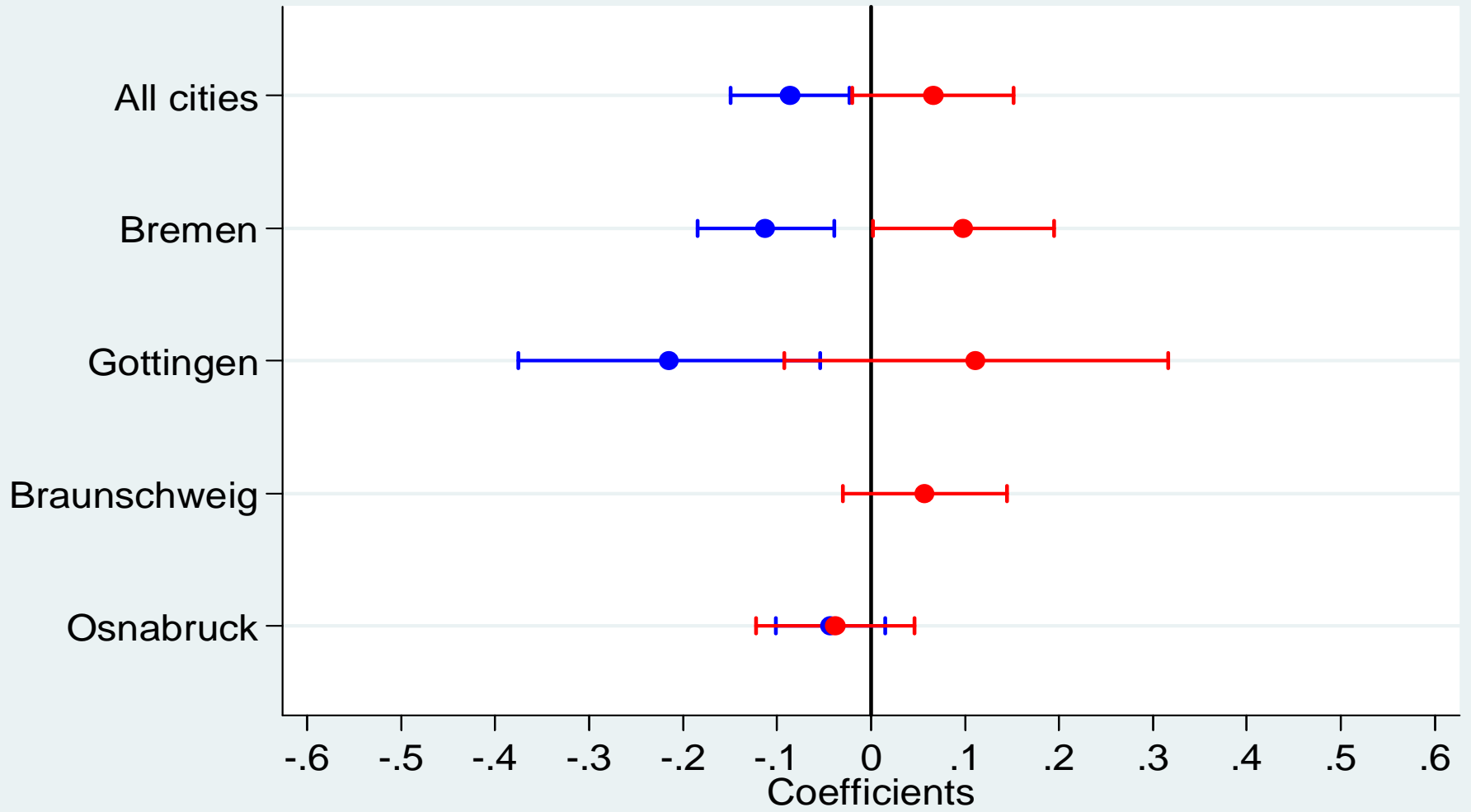
● Traffic stations ● Background stations

Leonberg LEZ



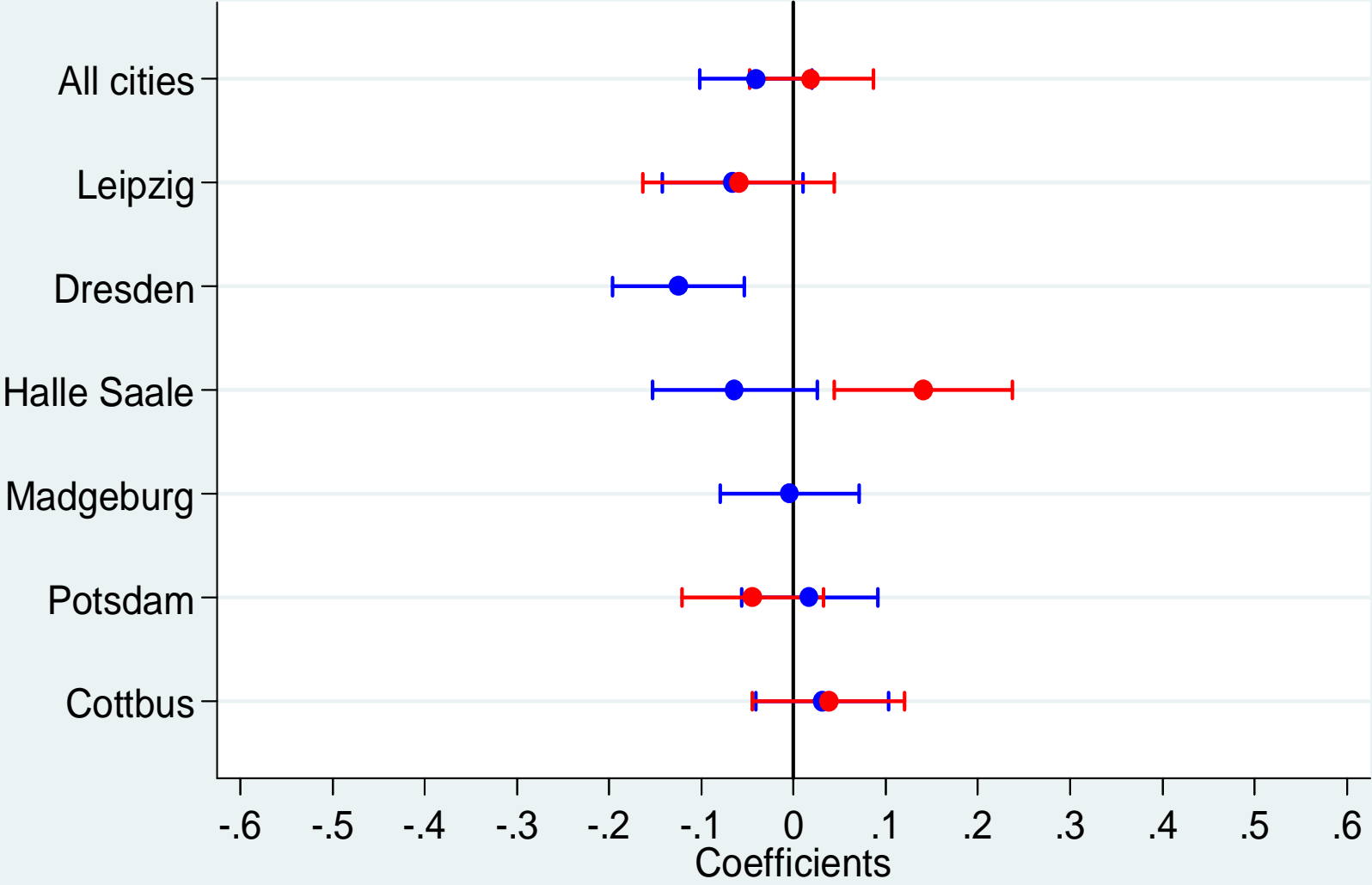
Traffic stations

Hannover



● Traffic stations ● Background stations

Berlin LEZ: All Stations



● Traffic stations ● Background stations

Cologne LEZ

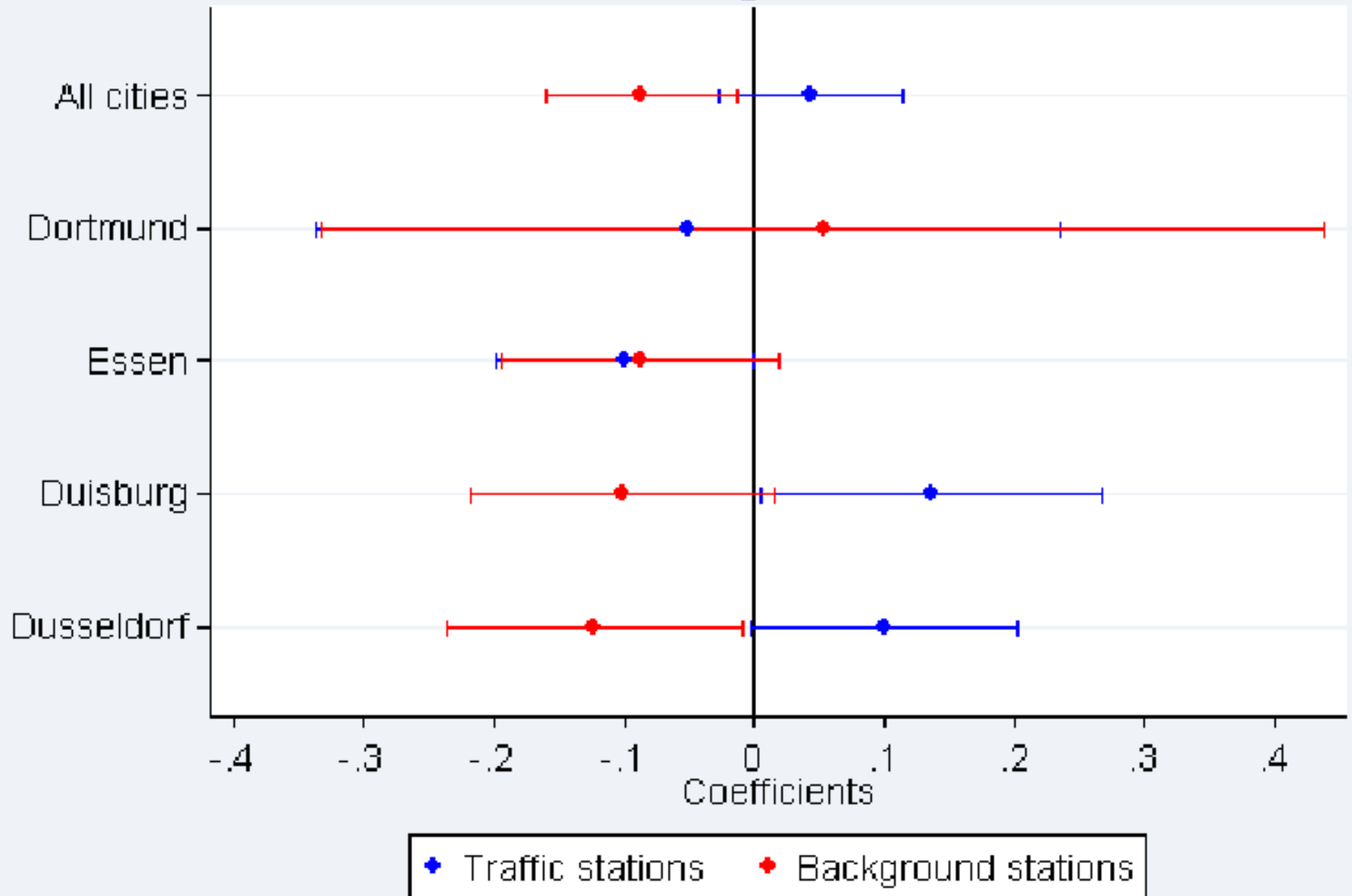


Figure 13: Change of share of Green Sticker vehicles 2009 to 2008 as function of distance of the county to LEZ (privately owned cars)

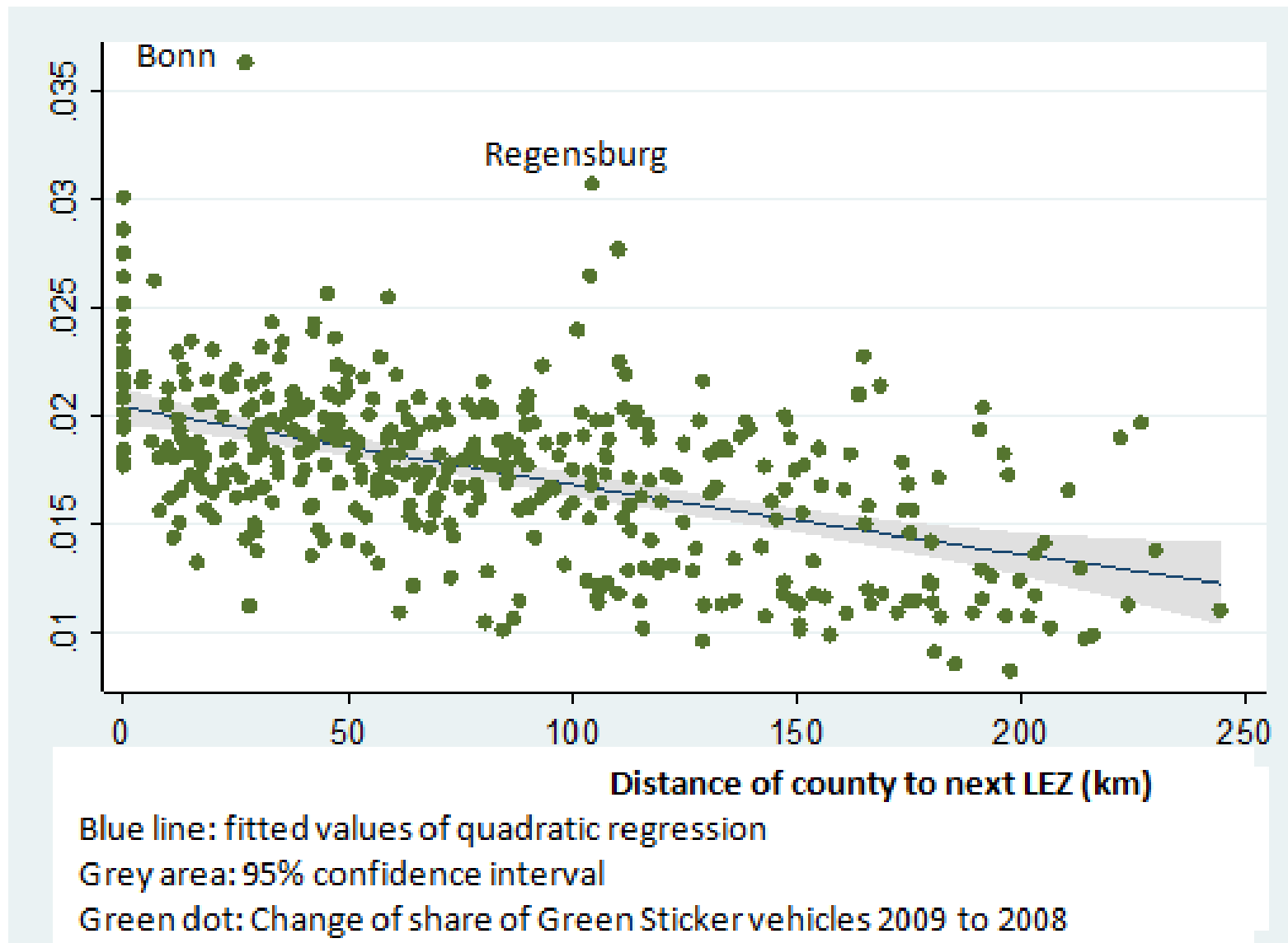
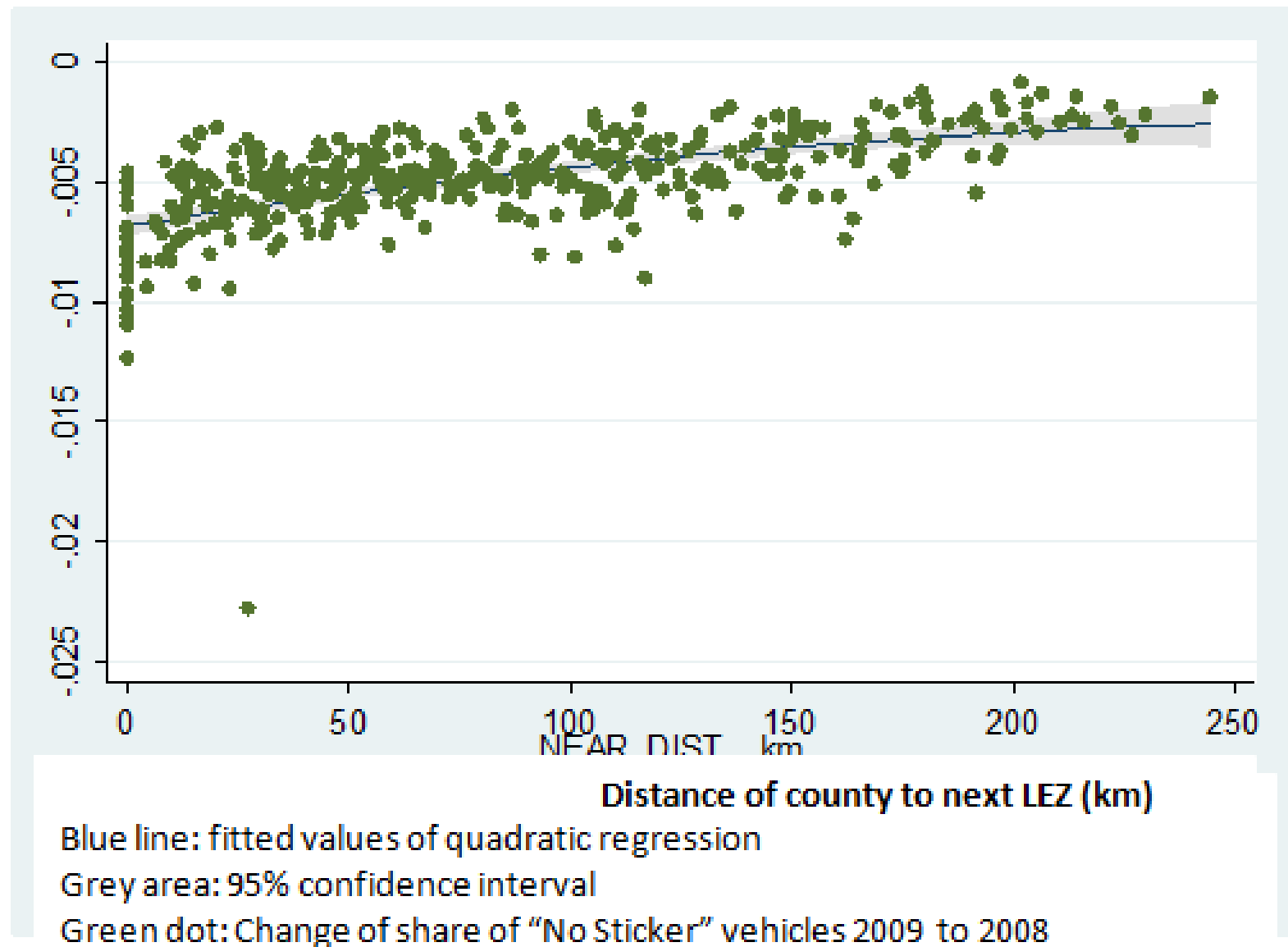


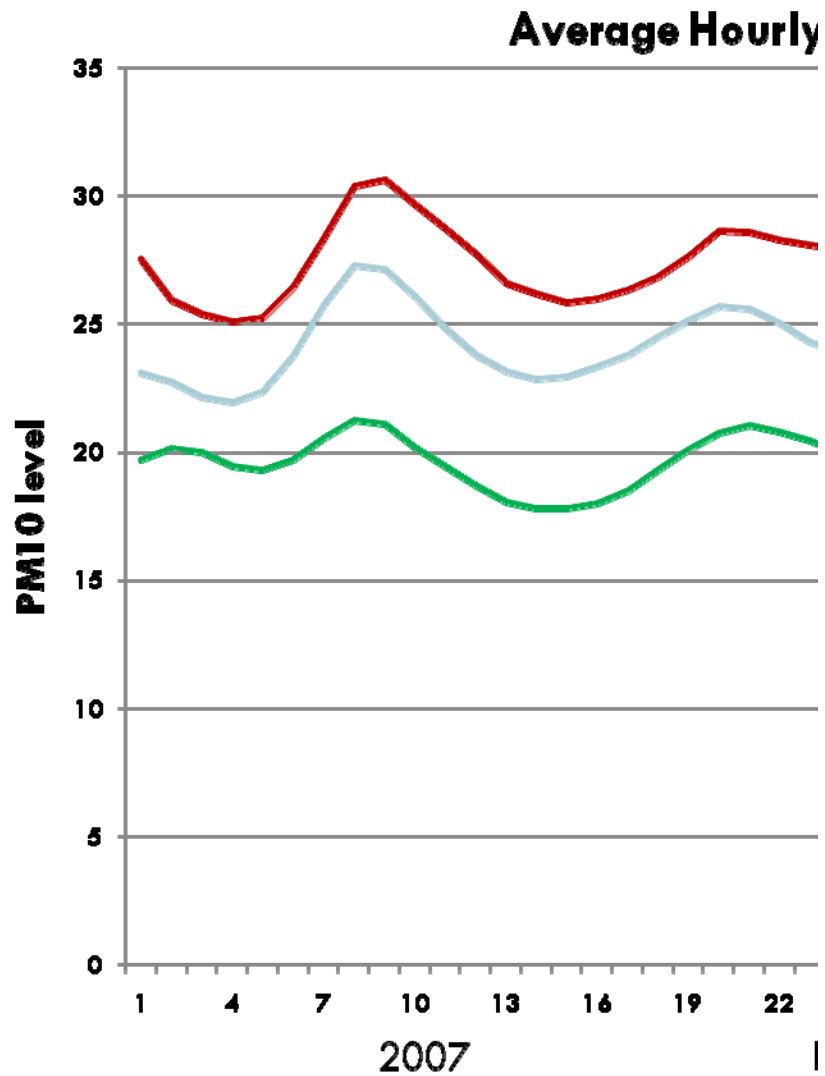
Figure 14: Change of share of No Sticker vehicles 2009 to 2008 as function of distance of the county to LEZ (privately owned cars)



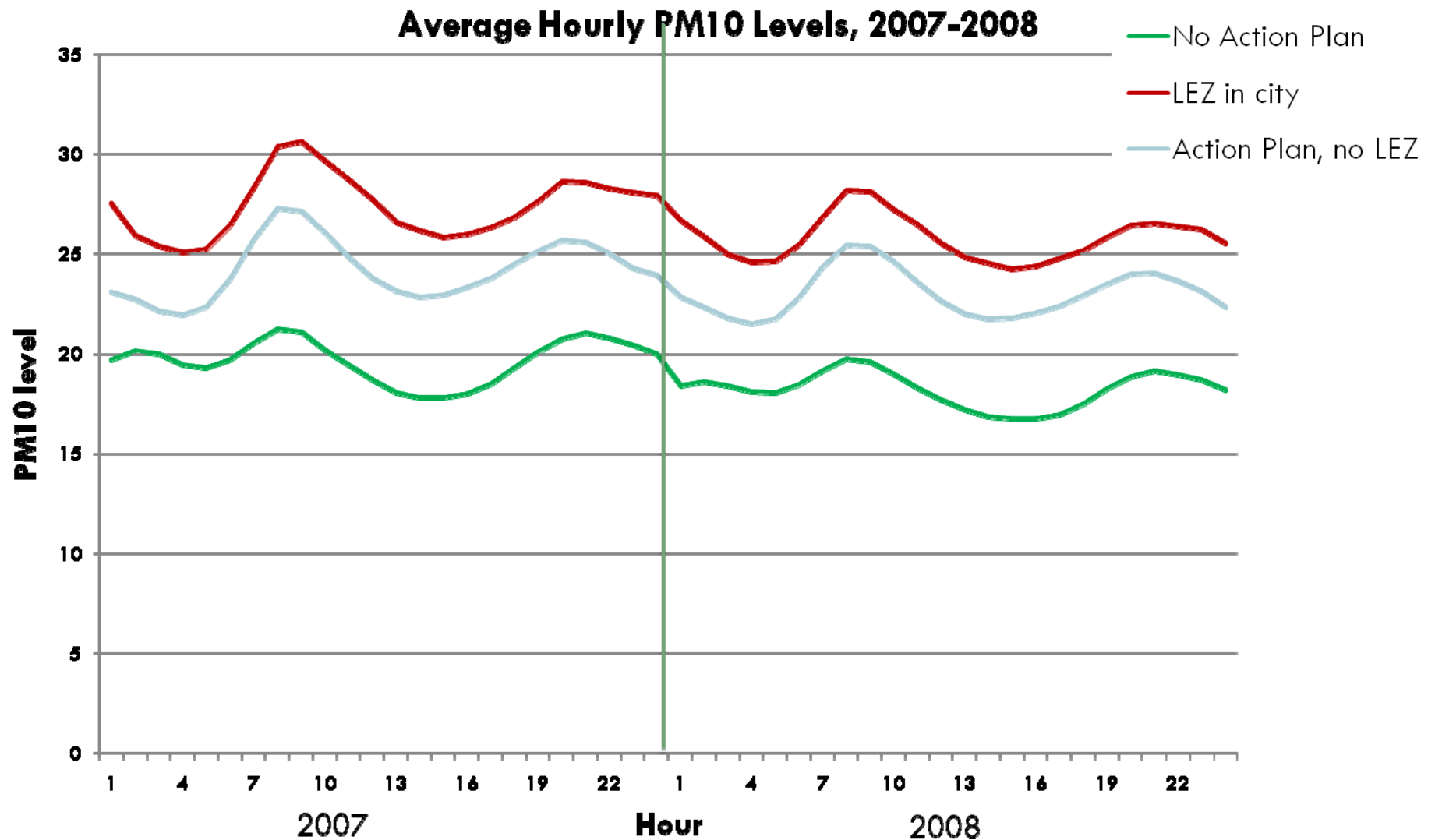
Conclusion

- Morbidity estimates: PM10 public health concern
- All major cities world-wide confronted with question how to reduce air pollution
- LEZ popular (but much debated) tool in Europe
- Little empirical evidence
- Multiple staggered LEZs in Germany provide opportunity for empirical analysis
- PM10 decreases, but we observe donut effect
- Adoption of clean technology at faster rate the closer driver lives to LEZ
- If marginal damages are convex, LEZ beneficial on health

PM10 levels over a day



PM10 levels over a day



Berlin: Stations within LEZ vs. Stations outside of LEZ

Table 10: Berlin LEZ: Stations within LEZ compared to those outside

	(1)	(2)	(3)	(4)
	Traffic stations		Background stations	
	All days	Mon-Fri	All days	Mon-Fri
LEZ treatment	-0.0668***	-0.0768***	0.0568***	0.0585***
	[0.0217]	[0.0243]	[0.0127]	[0.0145]
Observations	1960	1400	2938	2098
Adjusted R-squared	0.628	0.632	0.675	0.69

Robust standard errors in brackets, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$