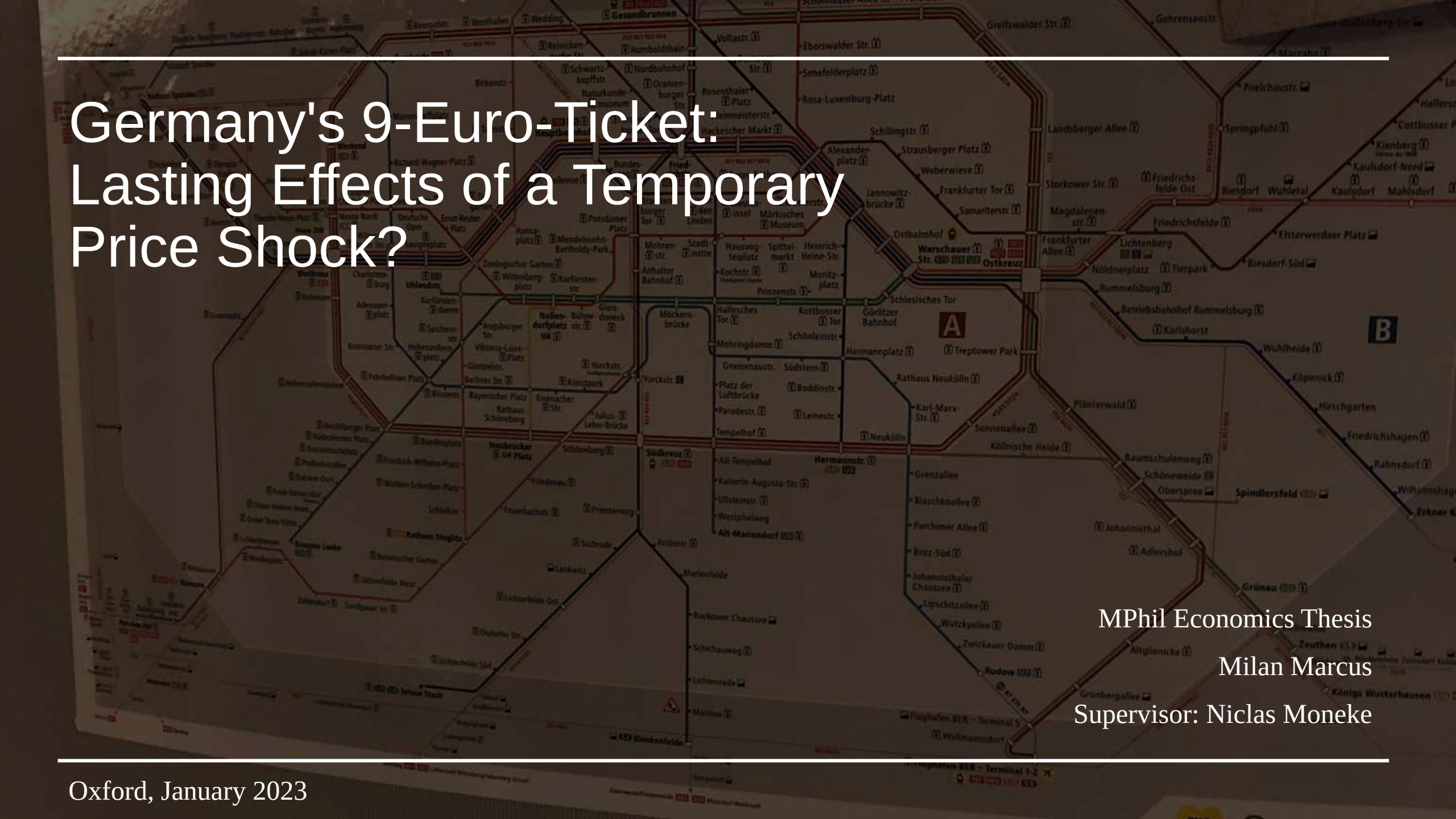


Germany's 9-Euro-Ticket: Lasting Effects of a Temporary Price Shock?

MPhil Economics Thesis

Milan Marcus

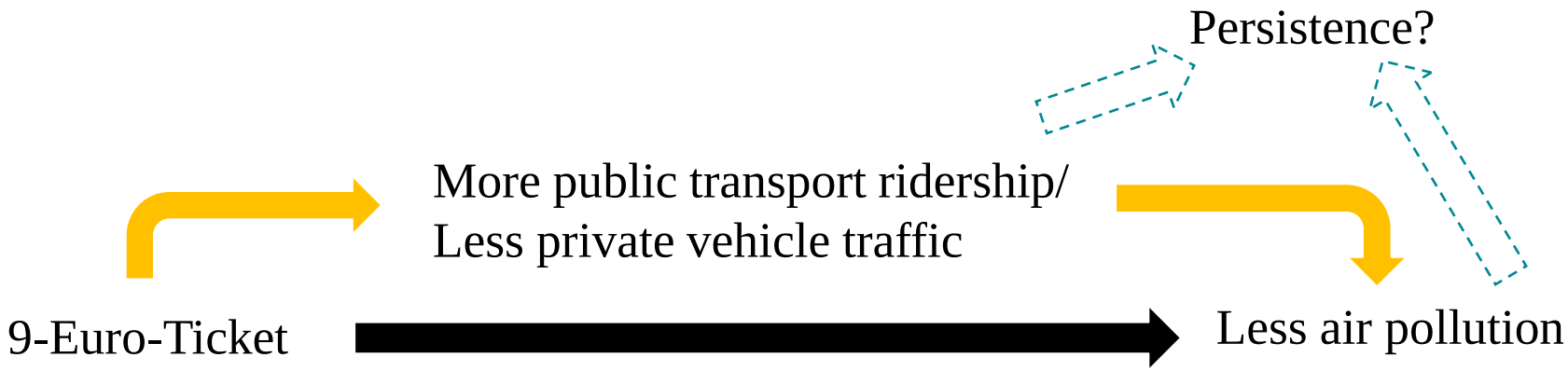
Supervisor: Niclas Moneke

Oxford, January 2023

Road Map (pun intended?)

- What is the 9-Euro-Ticket?
- Why should we care?
- What am I trying to do:
- What related research is out there?
- How am I doing it?
- What are my results?

Short Preview of Results

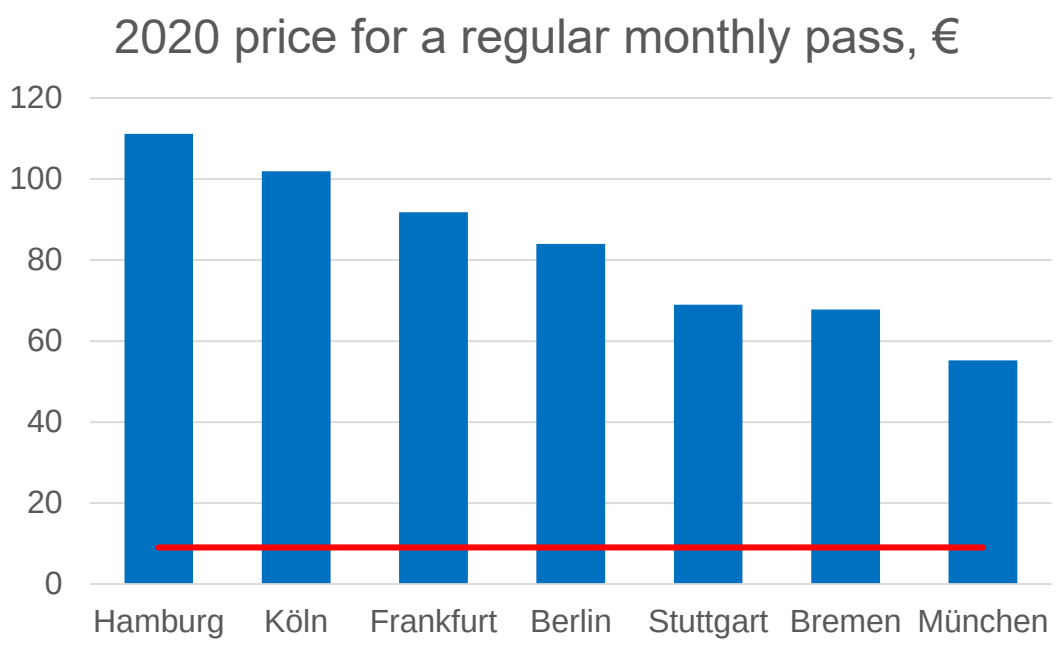


Icon made by Aranagraphics from www.flaticon.com

Background: 9-Euro-Ticket

- 9 Euro monthly travel pass for June, July, August
- Valid on public transport **throughout** Germany
  - Basically everything except long-distance trains

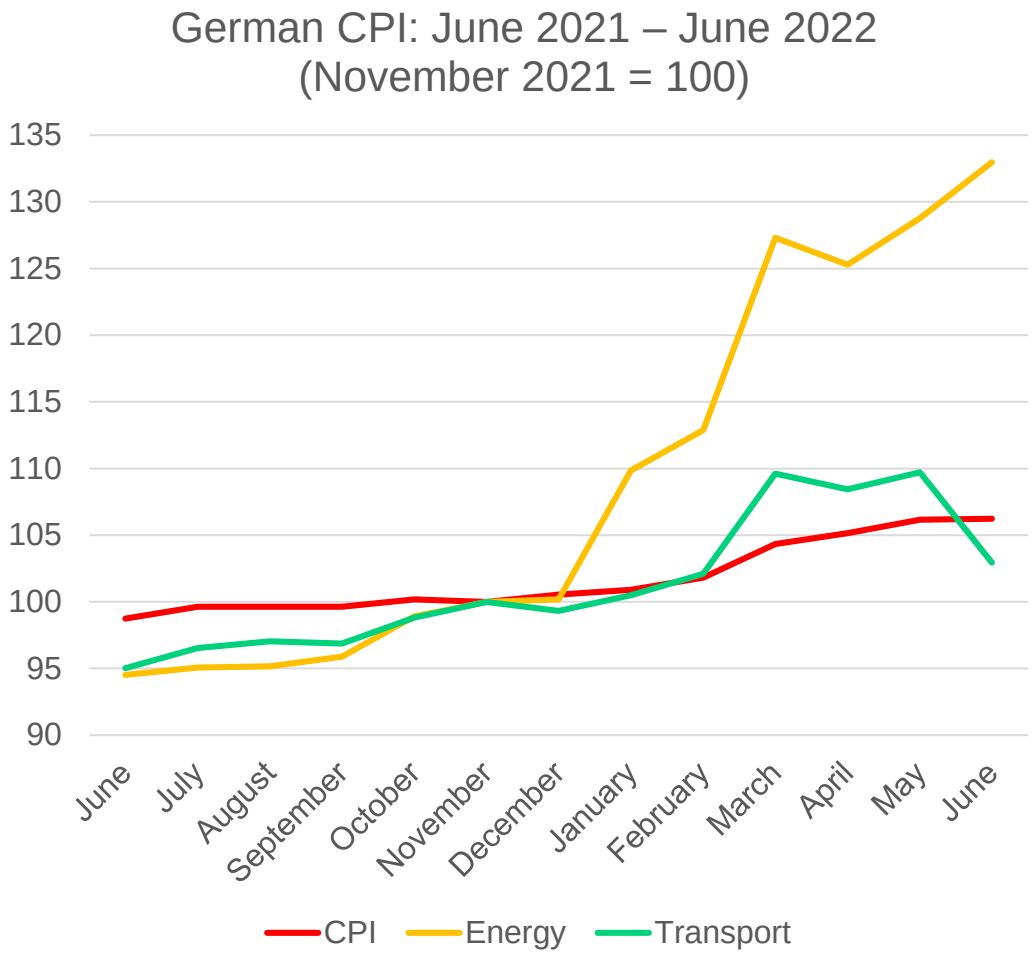
➡ **Cheap** and **simple**

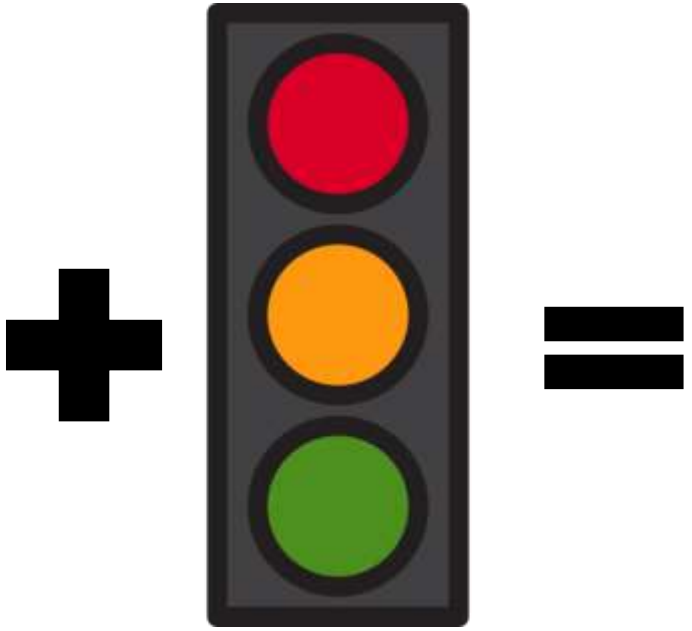


Source: Infrastrukturatlas 2020, Heinrich Böll Stiftung
https://www.boell.de/sites/default/files/2020-11/Infrastrukturatlas%202020.pdf

Map downloaded from Wikipedia, by TUBS (CC BY-SA 3.0) and Maximilian Dörrbecker (Chumwa), NJ Giggie (CC BY-SA 4.0)

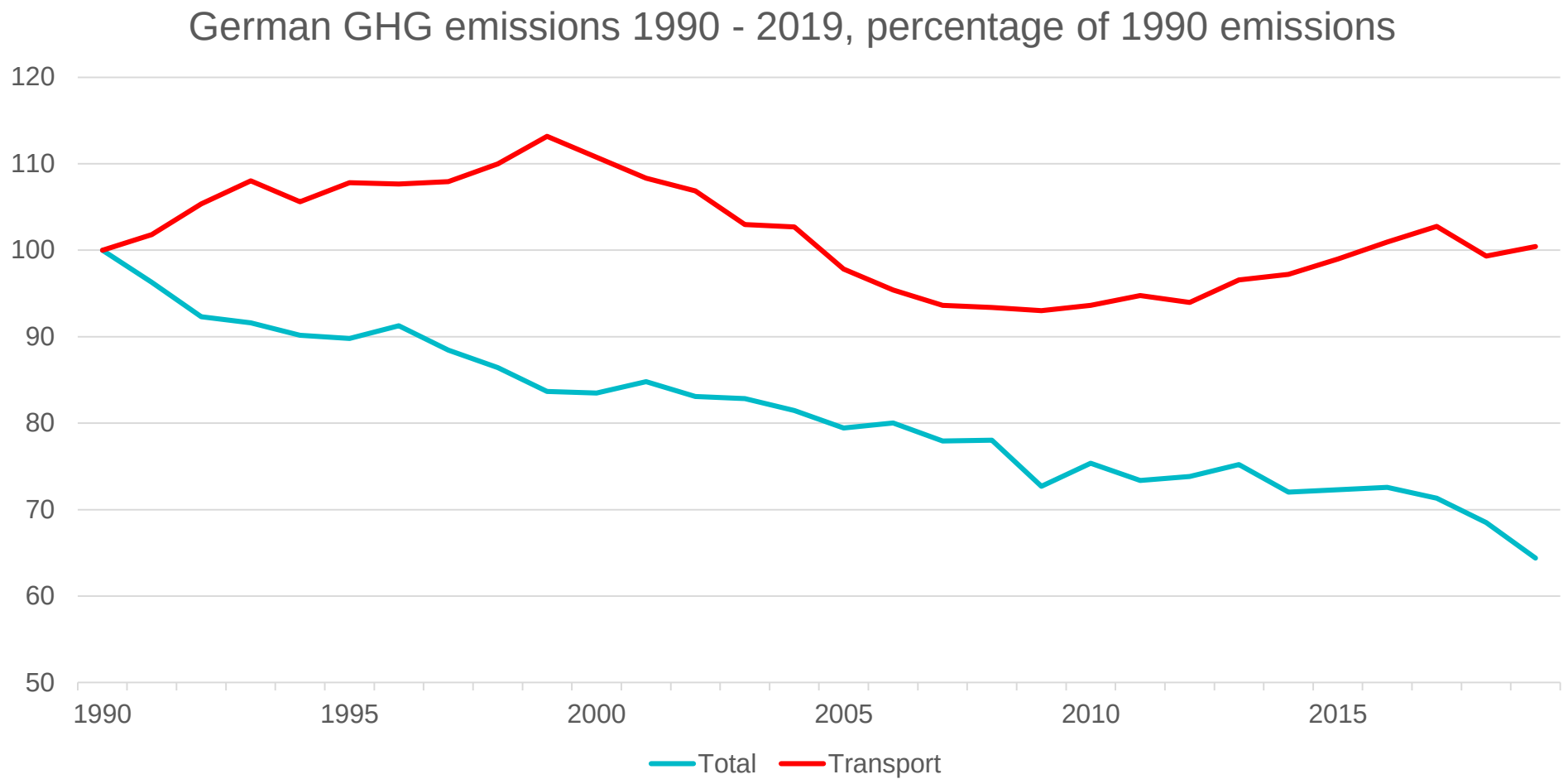
Background: 9-Euro-Ticket



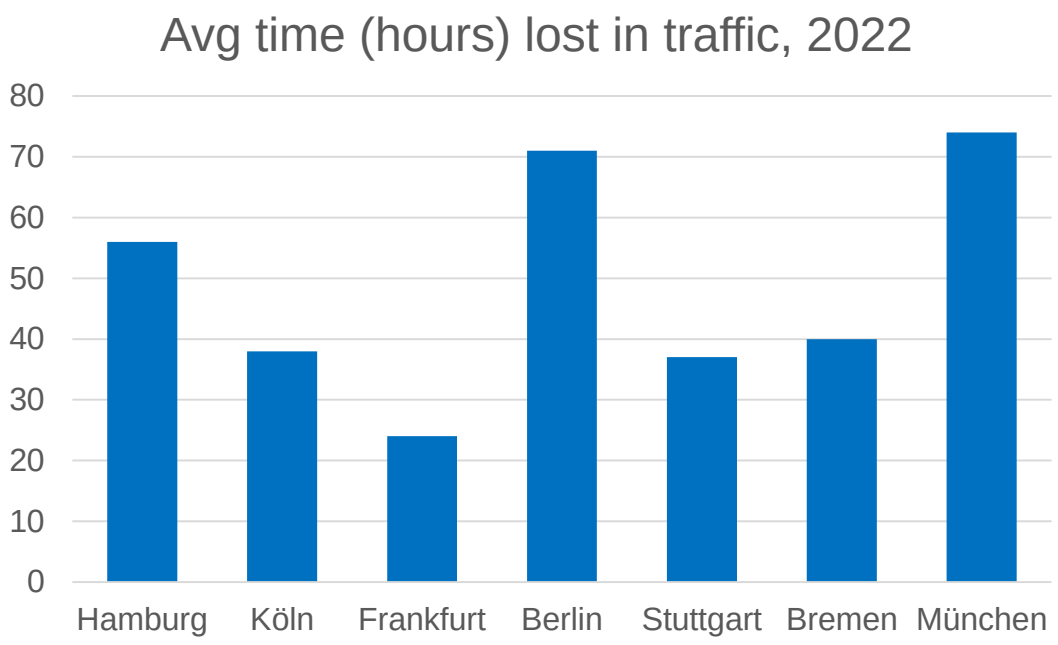


Icon made by xnimrodx from www.flaticon.com

So what? Why should we care?



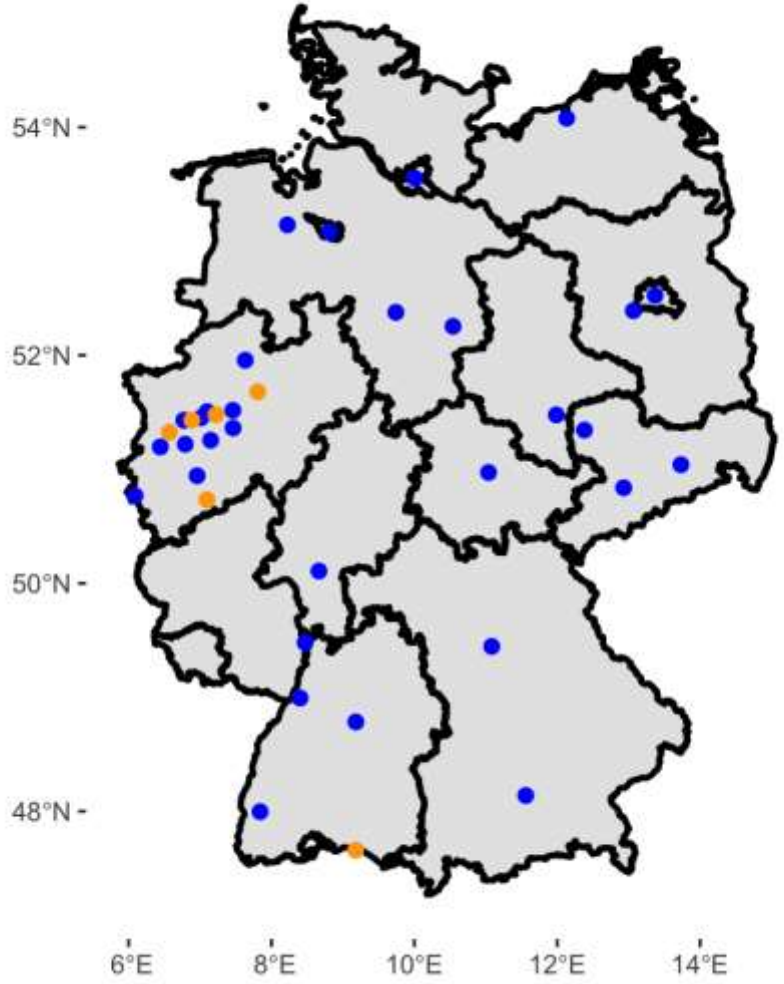
Why should we care?



Source: Inrix 2022 Global Traffic Scorecard
https://inrix.com/scorecard/#city-ranking-list

What am I studying?

- Travel behaviour – price incentives
- Travel behaviour (commute) – habits/persistence
  - Is price shock enough to change habits?
  - Does ‘regular’ behaviour resume after prices return to normal?
- **Effects on air pollution**
- **31 German cities (plus 6 without air pollution data)**



What are others saying?

- O’Sullivan (2012), simple model for mode choice:
  Travellers choose mode to minimise:

$$C = m + (T_a * d_a) + (T_v * d_v)$$

  - m: monetary cost; T_a: access time; d_a: marginal disutility of access time; T_v: in-vehicle time; d_v: marginal disutility of in-vehicle time.

- Goodwin (1977): Habit and Hysteresis in Mode Choice
  - Commuters don’t engage in optimisation every day, likely only prompted by larger shocks

- Larcem, Rauch, Willems (2017): London Tube Strike
  - ‘Forced experimentation’ is welfare enhancing because commuters re-optimise

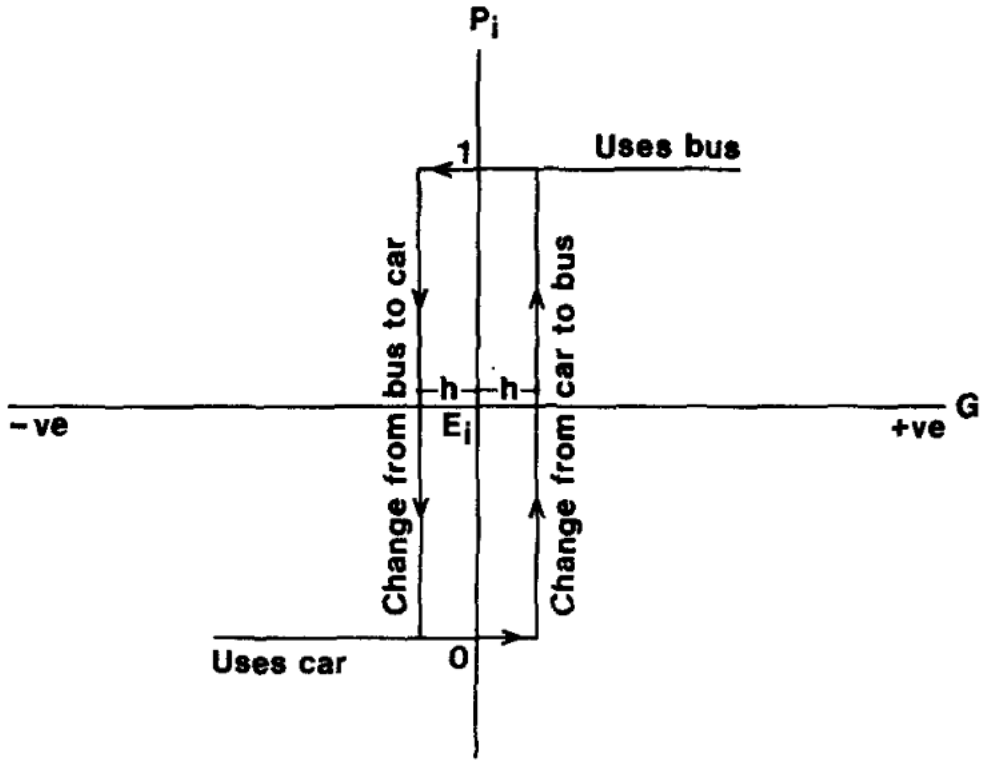
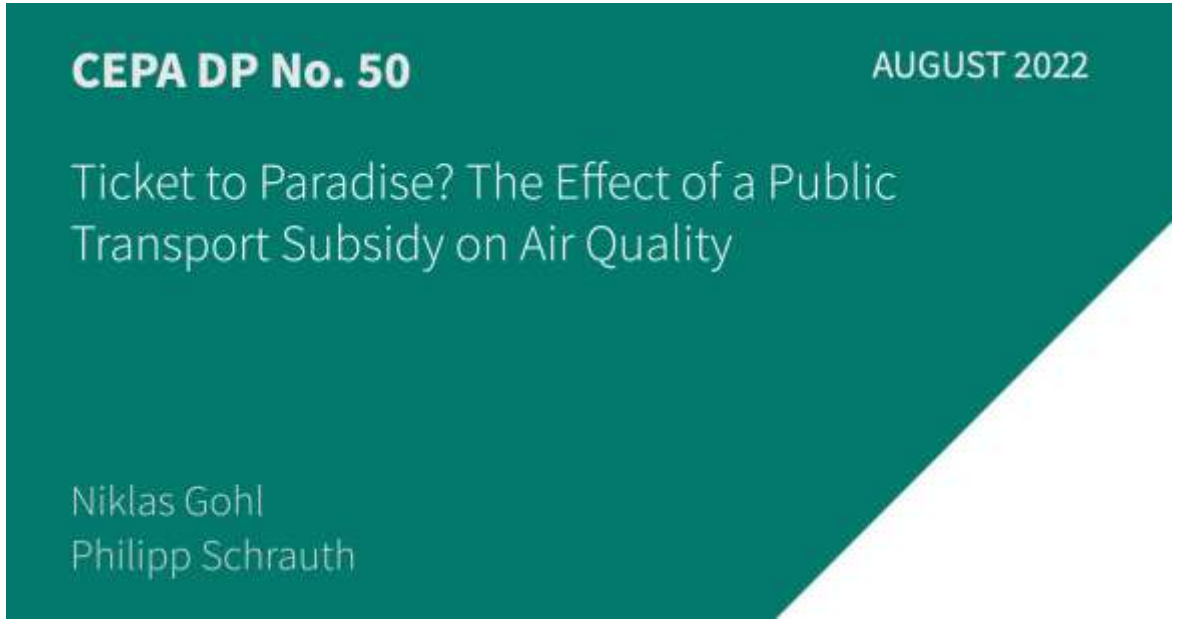


Fig. 3. Mode choice for the individual, incorporating habit.

What are others saying?

What are others saying?

"Using DiD estimation strategies on air pollutant data, we show that this intervention causally reduced a benchmark air pollution index by more than six percent."



$$\log(Pollution_{it}) = \alpha_i + \beta_1\, June + \beta_2 2022 + \beta_3\, June * 2022 + \beta_4 \boldsymbol{X}_{it}$$

$\boldsymbol{X}_{it}$: Covariates including weather, fuel prices, holidays

My aims

1) Replicate Gohl and Schrauth (2022)
2) Extend their model: Persistence of effects?
3) Investigate direct link to reduced car traffic and increased public transport usage

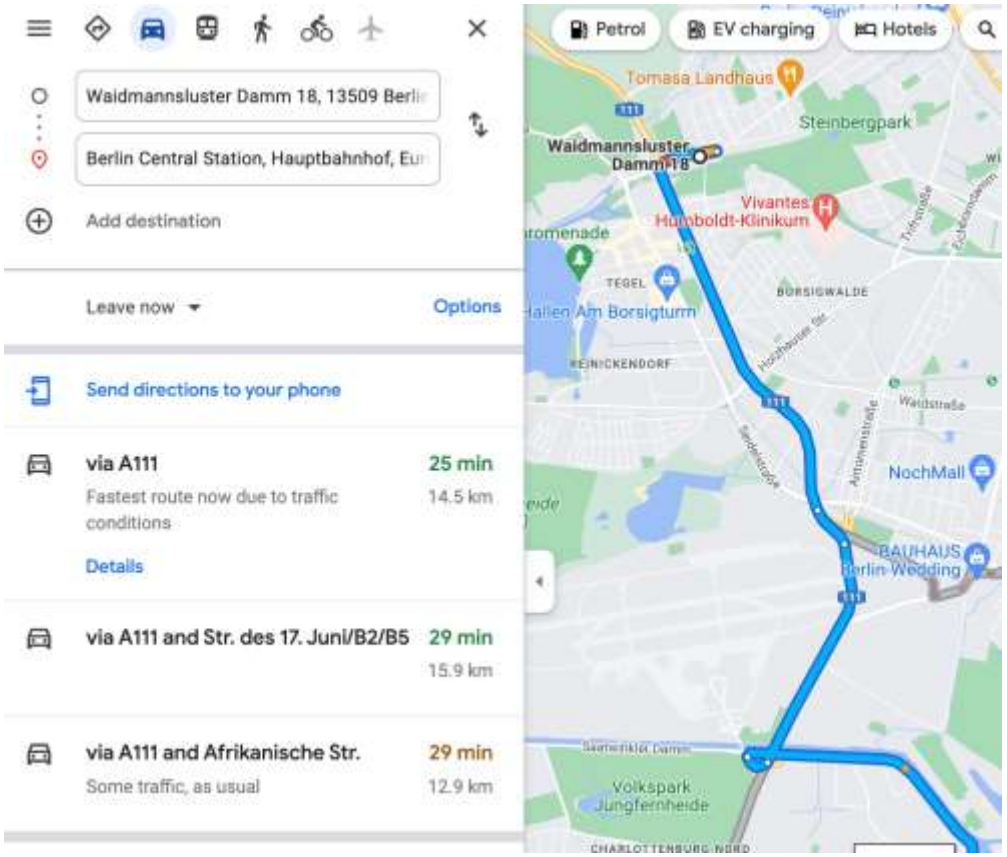
9-Euro-Ticket → More public transport ridership/ Less private vehicle traffic → Less air pollution

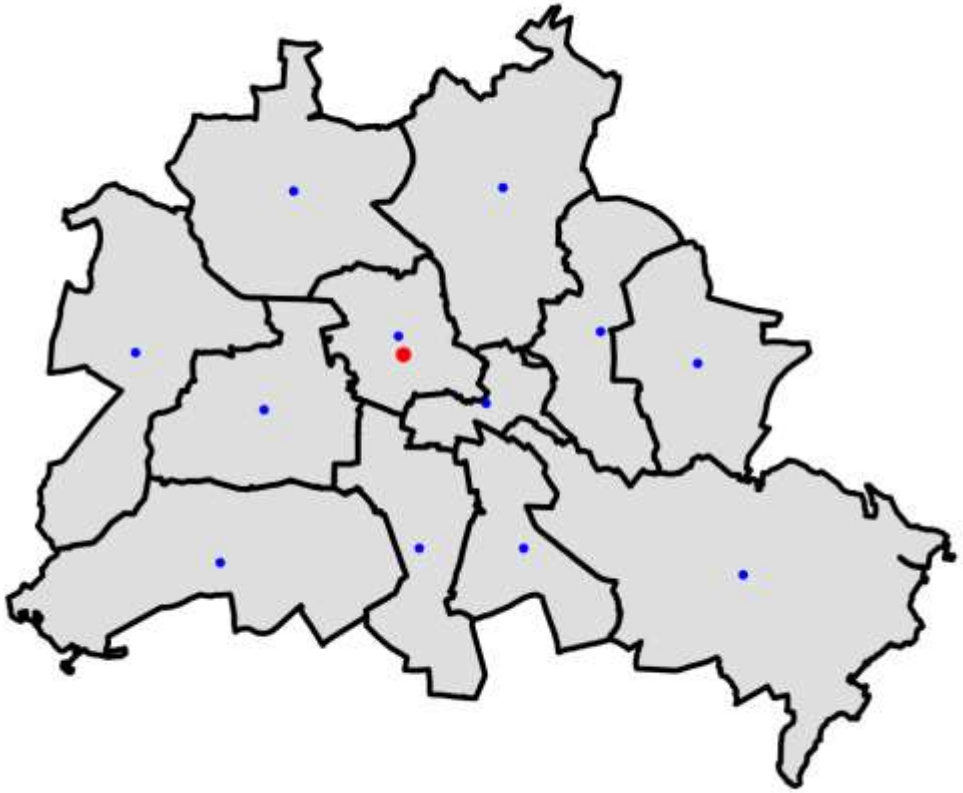
Data, data, data

For my 30+ German cities I collect data on:

- Air pollution: PM_{10}, NO_2, Air Quality Index (AQI)
  - AQI contains PM_{10}, NO_2 , O_3
- Fuel prices: petrol and diesel
- Weather: temperature, wind, precipitation
- Traffic: Google Maps peak-hour travel time
- Public transport: **limited** data on ridership

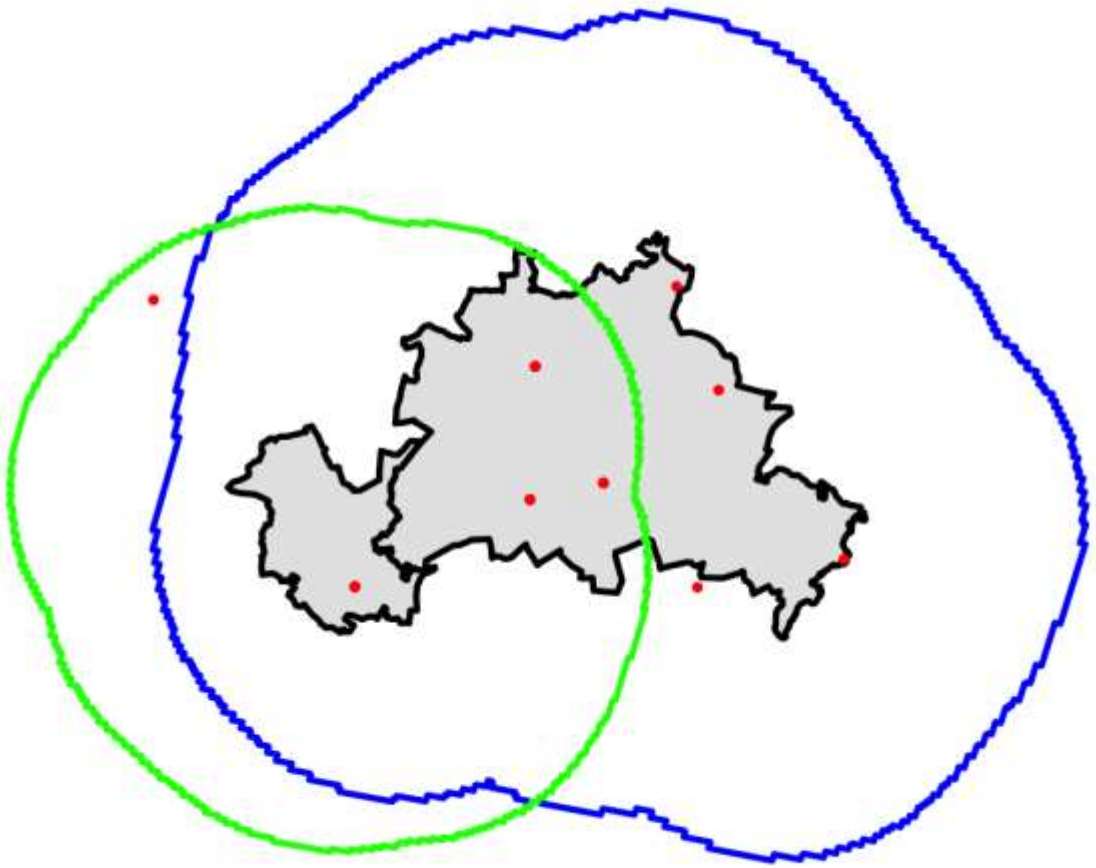
Google Maps



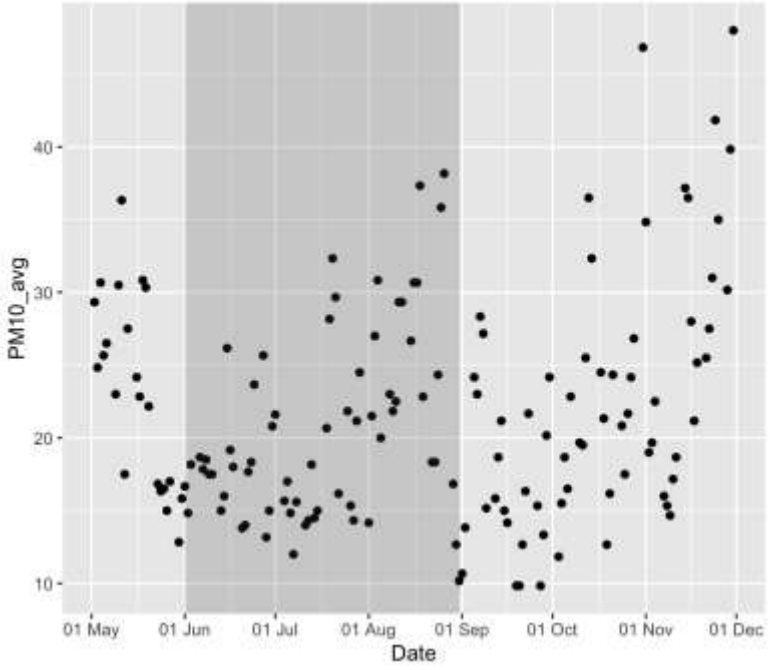


Added traffic time =
Real travel time at 8am - GMaps baseline time

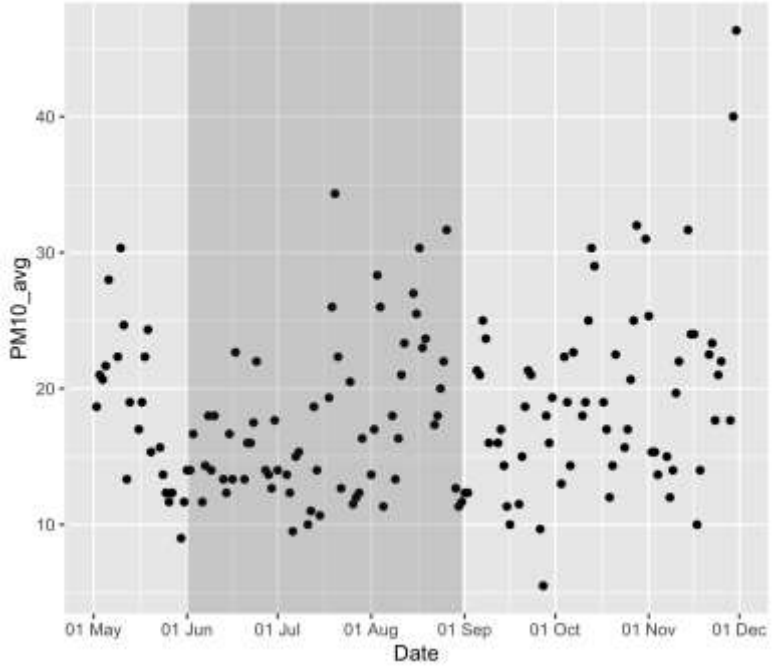
Air Pollution, Fuel, Weather



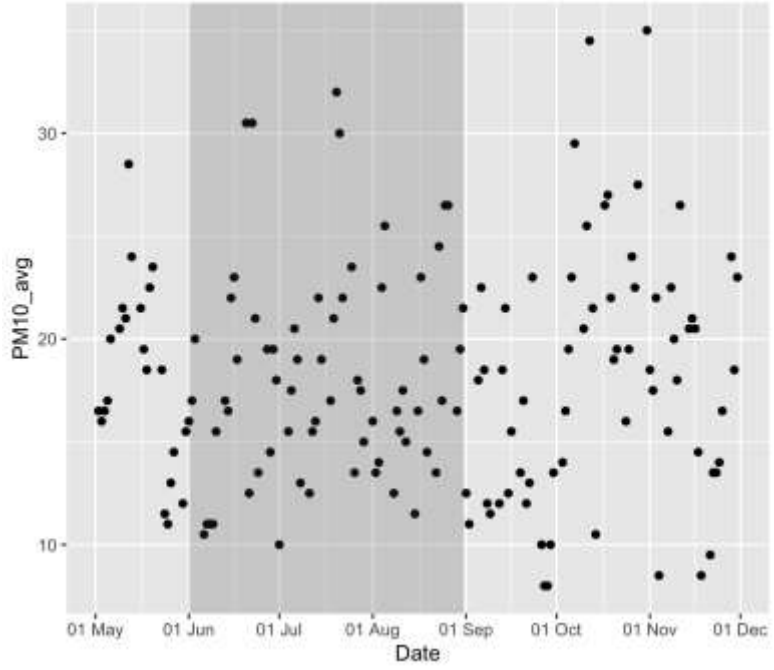
Stylised Facts – Pollution from Traffic



Berlin

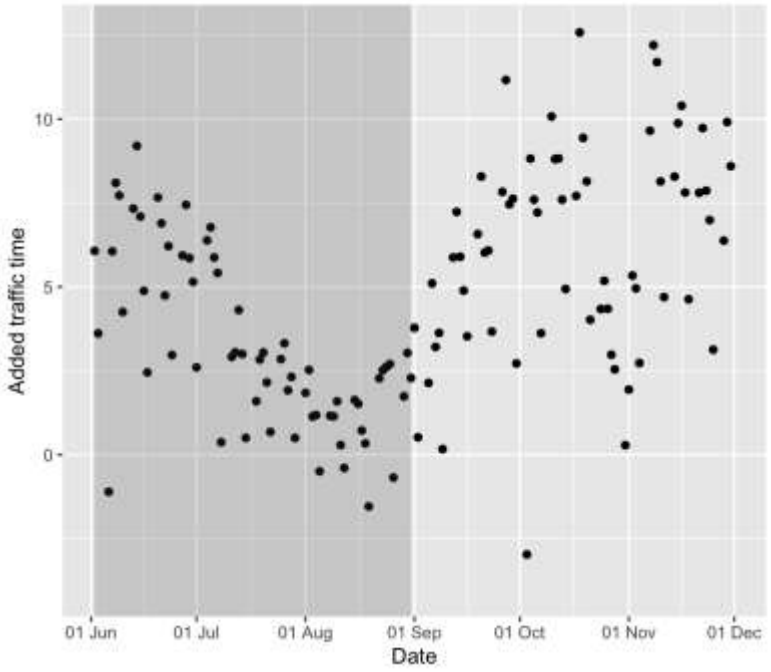


Hamburg

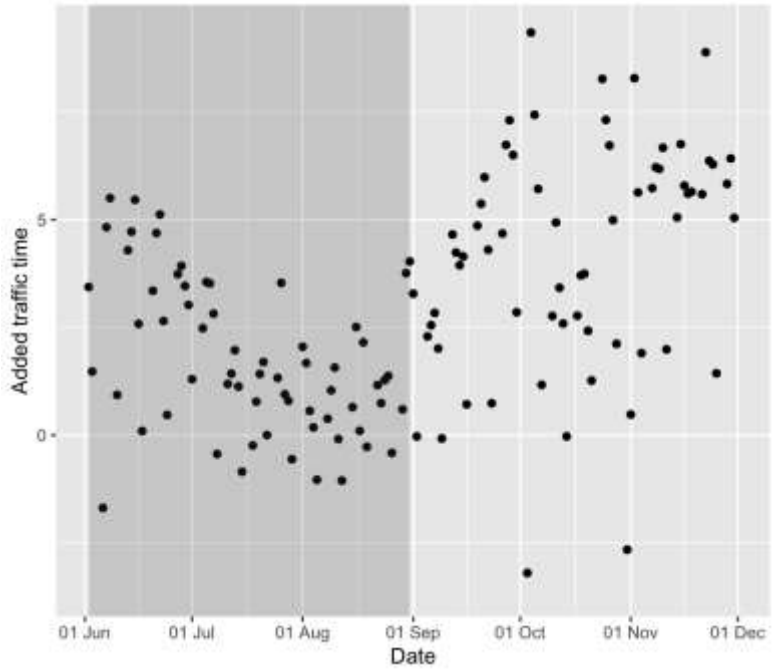


Munich

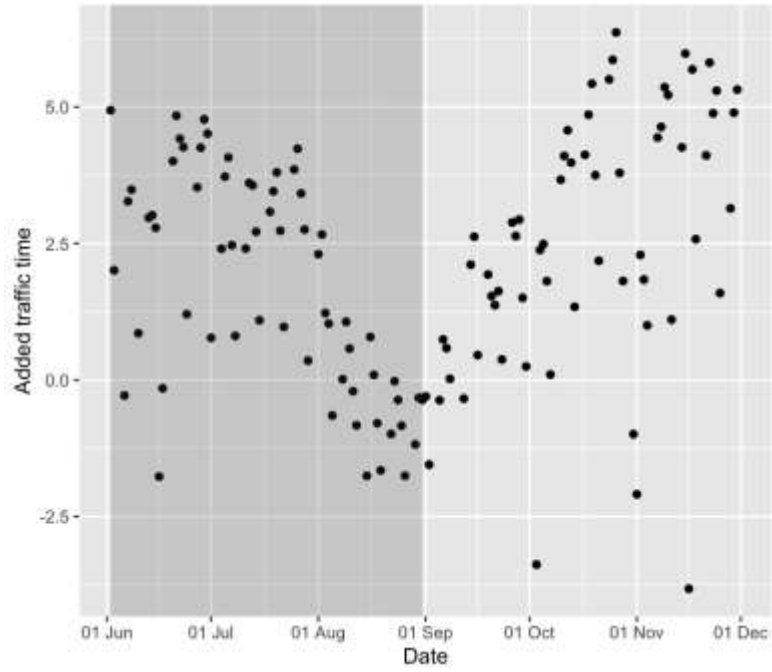
Stylised Facts - Traffic



Berlin

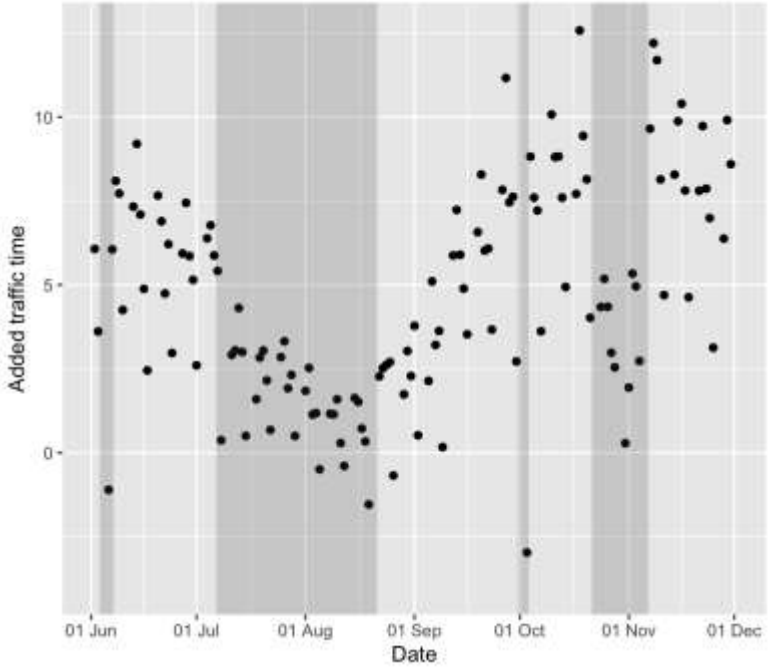


Hamburg

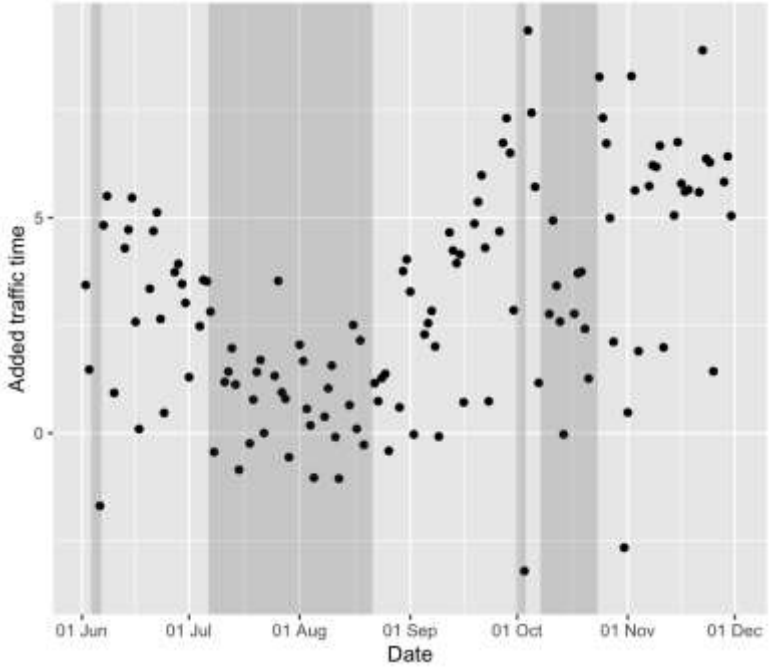


Munich

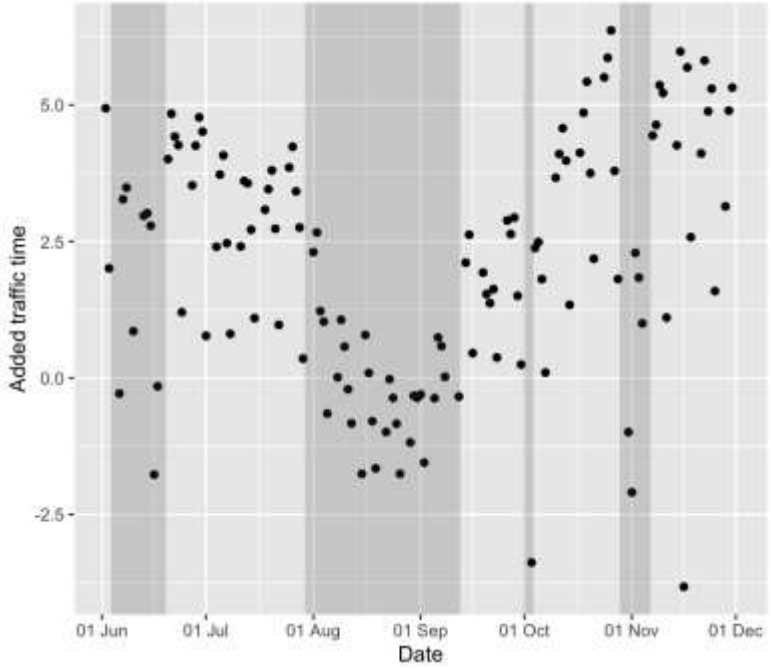
Stylised Facts – Traffic (2)



Berlin



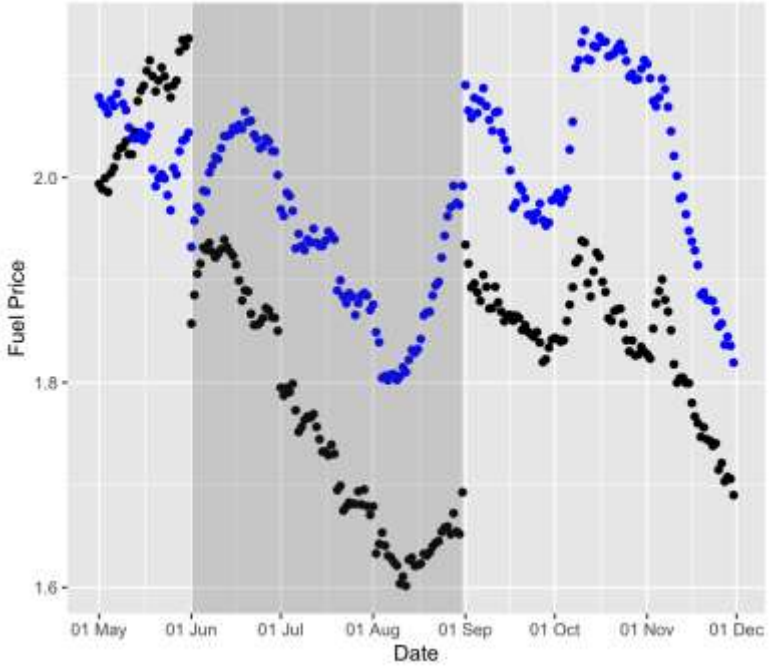
Hamburg



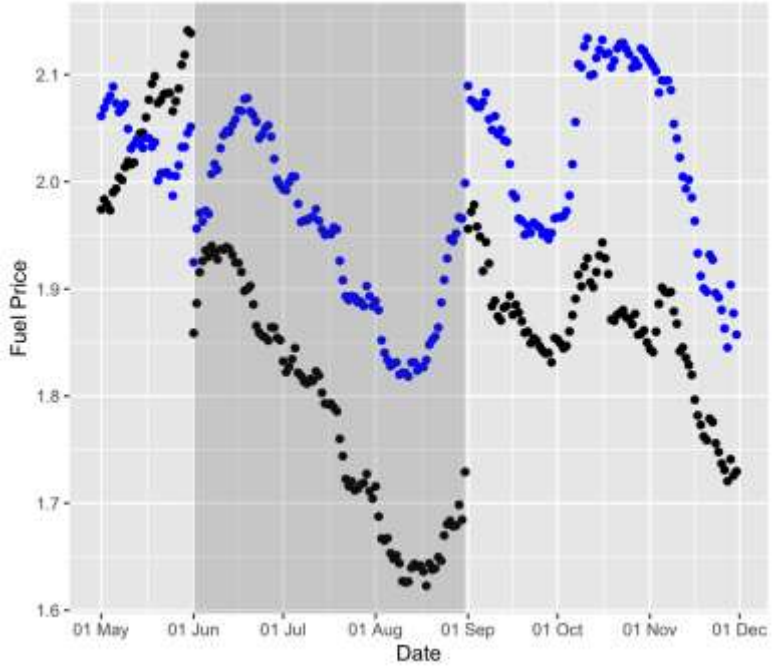
Munich

Stylised Facts – Fuel Prices

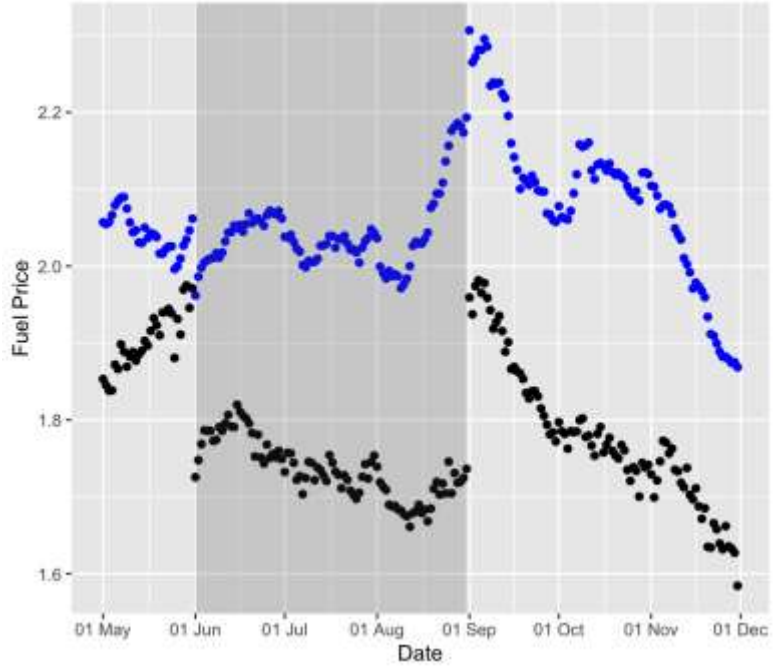
Black: Petrol (E10)
Blue: Diesel



Berlin



Hamburg



Munich

So let's bring in some econometrics…

Observation period:
1 May to 30 Nov 2022

	Dependent variable:			
	log(PM10 emissions)			
	(1)	(2)	(3)	(4)
9 Euro	-0.223***	-0.207***	-0.339***	-0.346***
	(0.046)	(0.046)	(0.050)	(0.051)
Temperature	0.025***	0.025***	0.029***	0.030***
	(0.005)	(0.005)	(0.004)	(0.005)
Wind	-0.128***	-0.128***	-0.129***	-0.129***
	(0.014)	(0.014)	(0.013)	(0.013)
Rain	-0.008**	-0.009***	-0.009***	-0.009***
	(0.003)	(0.003)	(0.003)	(0.003)
No School		-0.077**	-0.034	-0.033
		(0.031)	(0.027)	(0.027)
Fuel Price			-0.680***	-0.863**
			(0.155)	(0.341)
Fuel Price (7 Day Avg)				0.198
				(0.332)
City Fixed effects	Yes	Yes	Yes	Yes
Day of Week Fixed effects	No	No	Yes	Yes
Observations	6,556	6,556	6,556	6,556
R^2	0.279	0.288	0.334	0.335
Adjusted R^2	0.276	0.285	0.330	0.330
Residual Std. Error	0.335 (df = 6521)	0.333 (df = 6520)	0.323 (df = 6513)	0.323 (df = 6512)
Note:				*p<0.1; **p<0.05; ***p<0.01
				Standard errors in parentheses clustered by city and date

Observation period:
1 May to 30 Nov 2022

	Dependent Variable (log):		
	PM10	NO2	AQI
	(1)	(2)	(3)
9 Euro	-0.346***	-0.344***	-0.472***
	(0.051)	(0.037)	(0.058)
Temperature	0.030***	0.017***	0.034***
	(0.005)	(0.003)	(0.005)
Wind	-0.129***	-0.158***	-0.194***
	(0.013)	(0.011)	(0.016)
Rain	-0.009***	0.001	-0.009***
	(0.003)	(0.001)	(0.003)
No School	-0.033	-0.098***	-0.069*
	(0.027)	(0.027)	(0.034)
Fuel Price	-0.863**	-1.123***	-1.336***
	(0.341)	(0.210)	(0.384)
Fuel Price (7 Day Avg)	0.198	0.451**	0.463
	(0.332)	(0.204)	(0.382)
City Fixed effects	Yes	Yes	Yes
Day of Week Fixed effects	Yes	Yes	Yes
Observations	6,556	6,610	6,609
R^2	0.335	0.629	0.398
Adjusted R^2	0.330	0.627	0.394
Residual Std. Error	0.323 (df = 6512)	0.231 (df = 6566)	0.399 (df = 6565)
Note:			*p<0.1; **p<0.05; ***p<0.01
	Standard errors in parentheses clustered by city and date		

Aim 1: Replicate Gohl and Schrauth (2022)

$$\log(Pollution_{it}) = \alpha_i + \beta_1\, June + \beta_2 2022 + \beta_3\, June * 2022 + \beta_4 \boldsymbol{X}_{it}$$

Observation period: 1 May to 30 June
2018, 2019, 2022

	Dependent Variable (log):		
	PM10	NO2	AQI
	(1)	(2)	(3)
Month = June	-0.234***	-0.151***	-0.286***
	(0.018)	(0.024)	(0.022)
Year = 2019	-0.126***	-0.046***	-0.132***
	(0.016)	(0.015)	(0.018)
Year = 2022	0.324***	-0.229***	0.199*
	(0.099)	(0.074)	(0.111)
Temperature	0.036***	0.016***	0.039***
	(0.002)	(0.002)	(0.002)
Wind	-0.076***	-0.146***	-0.136***
	(0.006)	(0.006)	(0.008)
Rain	0.006***	0.005***	0.006***
	(0.001)	(0.001)	(0.001)
No School	-0.126***	-0.243***	-0.218***
	(0.014)	(0.012)	(0.015)
Fuel Price	-0.272	-0.277**	-0.375*
	(0.184)	(0.134)	(0.207)
Fuel Price (7 Day Avg)	-0.691***	0.017	-0.634***
	(0.101)	(0.103)	(0.137)
June * 2022	-0.110***	-0.019	-0.092***
	(0.030)	(0.025)	(0.035)
City Fixed effects	Yes	Yes	Yes
Day of Week Fixed effects	Yes	Yes	Yes
Observations	5,611	5,656	5,660
R^2	0.411	0.710	0.505
Adjusted R^2	0.406	0.708	0.501
Residual Std. Error	0.284 (df = 5564)	0.230 (df = 5609)	0.336 (df = 5613)
Note:			*p<0.1; **p<0.05; ***p<0.01
			Standard errors in parentheses clustered by city-year

	$\log(PM_{10})$	$\log(NO_2)$	(4)
Interaction	-0.0511**	-0.0380*	-0.0642***
	(0.0231)	(0.0227)	(0.0236)
Covariates	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Station FE	Yes	Yes	Yes
Day of Week FE	Yes	Yes	Yes
Observations	19,925	23,142	24,103

Aim 2: Persistence?

Treatment: June, July August

Post Treatment: September, October, November

Observations for 2018, 2019, 2022

$$\log(Pollution_{it}) = \alpha_i + \beta_1 Treat + \beta_2 Post + \beta_3 2022 + \beta_4 \boldsymbol{X}_{it} + \gamma_1 Treat * 2022 + \gamma_2 Post * 2022$$

	Dependent Variable (log):					
	PM10	NO2	AQI	PM10	NO2	AQI
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-0.165***	-0.174***	-0.244***	-0.157***	-0.097***	-0.214***
	(0.018)	(0.014)	(0.020)	(0.015)	(0.016)	(0.020)
Post Treatment				0.009	0.123***	0.046**
				(0.016)	(0.023)	(0.021)
Year = 2019	-0.211***	-0.162***	-0.278***	-0.217***	-0.150***	-0.279***
	(0.014)	(0.013)	(0.018)	(0.014)	(0.014)	(0.018)
Year = 2022	-0.160***	-0.227***	-0.242***	-0.046	-0.300***	-0.175***
	(0.041)	(0.039)	(0.047)	(0.054)	(0.042)	(0.061)
Temperature	0.014***	0.012***	0.017***	0.014***	0.014***	0.018***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Wind	-0.135***	-0.149***	-0.189***	-0.135***	-0.150***	-0.189***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)	(0.006)
Rain	-0.006***	0.002***	-0.006***	-0.006***	0.001**	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
No School	-0.050***	-0.087***	-0.089***	-0.049***	-0.088***	-0.089***
	(0.009)	(0.007)	(0.010)	(0.009)	(0.007)	(0.010)
Fuel Price	-0.379***	-0.848***	-0.703***	-0.491***	-0.629***	-0.722***
	(0.103)	(0.104)	(0.136)	(0.105)	(0.100)	(0.140)
Fuel Price (7 Day Avg)	0.154	0.469***	0.322**	0.161	0.439***	0.317**
	(0.104)	(0.108)	(0.137)	(0.103)	(0.102)	(0.133)
Treatment * 2022	-0.005	-0.100***	-0.032	-0.087***	-0.084***	-0.091***
	(0.025)	(0.025)	(0.030)	(0.029)	(0.024)	(0.035)
Post Treatment * 2022				-0.092***	-0.012	-0.076**
				(0.026)	(0.029)	(0.031)
City Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Day of Week Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,454	19,852	19,848	19,454	19,852	19,848
R^2	0.344	0.663	0.448	0.345	0.671	0.448
Adjusted R^2	0.342	0.663	0.447	0.343	0.670	0.447
Residual Std. Error	0.337 (df = 19407)	0.245 (df = 19805)	0.391 (df = 19801)	0.336 (df = 19405)	0.242 (df = 19803)	0.391 (df = 19799)
Note:						*p<0.1; **p<0.05; ***p<0.01
						Standard errors in parentheses clustered by city-year

Aim 2: Persistence?

Event Study

Observations for 2018, 2019, 2022

	Dependent Variable (log):		
	PM10	NO2	AQI
	(1)	(2)	(3)
Jun 22	-0.160***	-0.124***	-0.185***
	(0.022)	(0.017)	(0.026)
Jul 22	-0.182***	-0.104***	-0.227***
	(0.040)	(0.035)	(0.047)
Aug 22	-0.097*	-0.050	-0.115**
	(0.050)	(0.044)	(0.058)
Sep 22	-0.275***	0.018	-0.258***
	(0.022)	(0.021)	(0.028)
Oct 22	0.079***	0.137***	0.129***
	(0.026)	(0.029)	(0.028)
Nov 22	-0.007	0.166***	0.063
	(0.041)	(0.038)	(0.046)
Year = 2018	0.097	0.390***	0.234***
	(0.072)	(0.070)	(0.084)
Year = 2019	-0.116	0.238***	-0.045
	(0.076)	(0.078)	(0.090)
Regular Covariates	Yes	Yes	Yes
City Fixed effects	Yes	Yes	Yes
Day of Week Fixed effects	Yes	Yes	Yes
Observations	19,454	19,852	19,848
R^2	0.349	0.651	0.442
Adjusted R^2	0.347	0.650	0.440
Residual Std. Error	0.335 (df = 19403)	0.249 (df = 19801)	0.393 (df = 19797)
Note:			*p<0.1; **p<0.05; ***p<0.01
			Standard errors in parentheses clustered by city-year

Potential explanation for September 2022 result: Did people ‘front load’ their travel?

Aim 3a: Effect of 9-Euro-Ticket on Car Traffic

Observation period:
1 June to 30 Nov 2022

	Dependent variable:			
	Added Traffic (seconds)		Speed in Traffic (m/s)	
	Full Period	Weekdays only	Full Period	Weekdays only
	(1)	(2)	(3)	(4)
9 Euro	-9.418	-14.651	0.102*	0.151**
	(8.539)	(10.805)	(0.055)	(0.071)
Temperature	-2.596***	-3.577***	0.011***	0.016***
	(0.725)	(0.853)	(0.004)	(0.005)
Wind	7.218***	9.816***	-0.042***	-0.056***
	(1.989)	(2.385)	(0.013)	(0.015)
Rain	-0.433	0.026	-0.00005	-0.004*
	(0.277)	(0.382)	(0.002)	(0.002)
No School	-93.360***	-85.712***	0.680***	0.631***
	(8.917)	(8.849)	(0.060)	(0.062)
Fuel Price	-124.106***	-143.809***	0.851***	0.959***
	(45.386)	(51.862)	(0.270)	(0.318)
Fuel Price (7 Day Avg)	176.658***	202.703***	-1.078***	-1.240***
	(41.203)	(46.189)	(0.264)	(0.299)
City Fixed effects	Yes	Yes	Yes	Yes
Day of Week Fixed effects	Yes	Yes	Yes	Yes
Observations	6,502	4,644	6,502	4,644
R^2	0.788	0.674	0.921	0.867
Adjusted R^2	0.786	0.671	0.920	0.866
Residual Std. Error	66.686 (df = 6452)	61.225 (df = 4596)	0.409 (df = 6452)	0.400 (df = 4596)
Note:				*p<0.1; **p<0.05; ***p<0.01
				Standard errors in parentheses clustered by city and date

IV Regression (exploratory)

First stage regresses speed in traffic on the following outside instruments:

- 9 Euro
- No School
- Fuel Price
- Fuel Price (7 Day Avg)

But… 9 Euro alone is too weak an insturment

	Dependent Variable (log):		
	PM10	NO2	AQI
	(1)	(2)	(3)
Temperature	0.014**	0.005	0.013**
	(0.005)	(0.003)	(0.006)
Wind	-0.121***	-0.143***	-0.178***
	(0.016)	(0.013)	(0.018)
Rain	-0.009**	0.002	-0.008*
	(0.004)	(0.002)	(0.004)
Speed in Traffic (m/s)	-0.056	-0.173***	-0.124**
	(0.045)	(0.040)	(0.057)
F-Statistic (First Stage)	35.90	36.08	35.92
City Fixed effects	Yes	Yes	Yes
Day of Week Fixed effects	Yes	Yes	Yes
Observations	3,851	3,886	3,887
R^2	0.283	0.446	0.301
Adjusted R^2	0.276	0.441	0.294
Residual Std. Error	0.328 (df = 3812)	0.251 (df = 3847)	0.400 (df = 3848)
Note:			*p<0.1; **p<0.05; ***p<0.01
			Standard errors in parentheses clustered by city and date

Aim 3b: Effect on PT (exploratory)

Data for tram and bus lines in Chemnitz, 2019 and 2022

9-Euro: Jun, Jul, Aug 2022
Post 9-Euro: Sep, Oct 2022

Treatment: Jun, Jul, Aug both years
Post Treatment: Sep, Oct both years

	Dependent variable:		
	log(mean passengers)		
	(1)	(2)	(3)
9-Euro	0.109***	0.084**	
	(0.028)	(0.035)	
Post 9-Euro		-0.097*	
		(0.043)	
Treatment			-0.040
			(0.036)
Post Treatment			-0.039
			(0.028)
Year = 2022			-0.216**
			(0.083)
Treatment * 2022			0.278***
			(0.050)
Post Treatment * 2022			0.094*
			(0.048)
Line Fixed effects	Yes	Yes	Yes
Observations	98	98	98
R^2	0.852	0.865	0.893
Adjusted R^2	0.837	0.850	0.876
Residual Std. Error	0.127 (df = 88)	0.122 (df = 87)	0.111 (df = 84)
Note:			*p<0.1; **p<0.05; ***p<0.01
			Standard errors in parentheses clustered by Line

Conclusion

- 9-Euro Ticket reduced air pollution (at least initially)
- Some evidence that this is directly due to less car traffic/more public transport
- Persistence is unclear – seems to be driven by abnormality in September 2022

- Reminder: This is very much still work in progress
  - Many puzzles still to solve!
- Important to continue discussion/research in run-up to (permanent) 49-Euro Ticket!

Additional Tables

Aim 1: Replicate Gohl and Schrauth (2022)

	Dependent variable:			
	log(PM10 emissions)			
	(1)	(2)	(3)	(4)
Month = June	-0.037**	-0.032*	-0.244***	-0.234***
	(0.017)	(0.018)	(0.018)	(0.018)
Year = 2019		-0.234***	-0.133***	-0.126***
		(0.013)	(0.015)	(0.016)
Year = 2022	-0.119***	-0.229***	0.253**	0.324***
	(0.036)	(0.018)	(0.098)	(0.099)
Temperature			0.036***	0.036***
			(0.002)	(0.002)
Wind			-0.078***	-0.076***
			(0.006)	(0.006)
Rain			0.006***	0.006***
			(0.001)	(0.001)
No School			-0.123***	-0.126***
			(0.014)	(0.014)
Fuel Price			-0.831***	-0.272
			(0.162)	(0.184)
Fuel Price (7 Day Avg)				-0.691***
				(0.101)
June * 2022	-0.049**	-0.060***	-0.119***	-0.110***
	(0.022)	(0.022)	(0.030)	(0.030)
Constant	2.954***			
	(0.027)			
Observations	5,622	5,622	5,611	5,611
R^2	0.040	0.214	0.408	0.411
Adjusted R^2	0.039	0.209	0.404	0.406
Residual Std. Error	0.362 (df = 5618)	0.328 (df = 5581)	0.285 (df = 5565)	0.284 (df = 5564)
Note:				*p<0.1; **p<0.05; ***p<0.01
				Standard errors in parentheses clustered by city-year

Aim 2: Extend the model - Persistence

Was this only an initial shock?

Same regression but including the entire treatment period:
observations from
1 May to 31 Aug
2018, 2019, 2022

	Dependent Variable (log):		
	PM10	NO2	AQI
	(1)	(2)	(3)
9-Euro Period	-0.303***	-0.153***	-0.366***
	(0.015)	(0.023)	(0.025)
Year = 2019	-0.091***	-0.087***	-0.164***
	(0.013)	(0.014)	(0.020)
Year = 2022	0.068*	-0.287***	-0.175***
	(0.037)	(0.036)	(0.058)
Temperature	0.045***	0.026***	0.050***
	(0.002)	(0.002)	(0.002)
Wind	-0.079***	-0.156***	-0.147***
	(0.005)	(0.006)	(0.007)
Rain	0.006***	0.005***	0.006***
	(0.001)	(0.001)	(0.001)
No School	-0.116***	-0.117***	-0.161***
	(0.010)	(0.009)	(0.012)
Fuel Price	0.016	-0.275***	0.063
	(0.108)	(0.102)	(0.157)
Fuel Price (7 Day Avg)	-0.499***	0.090	-0.439***
	(0.106)	(0.086)	(0.142)
9-Euro Period * 2022	-0.066***	-0.062***	-0.022
	(0.022)	(0.021)	(0.036)
City Fixed effects	Yes	Yes	Yes
Day of Week Fixed effects	Yes	Yes	Yes
Observations	11,066	11,404	11,404
R^2	0.446	0.717	0.515
Adjusted R^2	0.444	0.716	0.513
Residual Std. Error	0.275 (df = 11019)	0.235 (df = 11357)	0.352 (df = 11357)
Note:			*p<0.1; **p<0.05; ***p<0.01
			Standard errors in parentheses clustered by city-year