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The effect of clean air on pharmaceutical expenditures

Alexander Rohlf [a], Felix Holub [b], Nicolas Koch [a,*], Nolan Ritter [a]

[a] Mercator Research Institute for Global Commons and Climate Change, Torgauer Straße 12-15, 10829 Berlin, Germany
[b] University of Mannheim, Schloss, 68131 Mannheim, Germany

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ABSTRACT

Airborne emissions are detrimental to health. Low emission zones (LEZs) that restrict pollution-intensive vehicles from entering are popular measures to curb local emissions such as particulate matter. We evaluate how LEZs impact defensive pharmaceutical expenditures. To this end, we use the complete medical histories of 2.7M individuals insured with Germany's largest public health insurer AOK. We identify causal effects exploiting the quasi-experimental, staggered introduction of LEZs in 49 cities. We find that LEZs reduce annual pharmaceutical expenditures for heart and respiratory diseases by 15.8M€, representing a significant fraction of policy costs.

1. Introduction

Since 2008, German cities use low emission zones (LEZs) to curb airborne particulate matter emissions by banning the most emission-intensive vehicles from entering. The purpose is to meet EU pollution concentration thresholds, which are meant to create health benefits. Wolff (2014), Gehrsitz (2017) and Pestel and Wozny (2019) provide econometric evaluations of German LEZs with regards to mortality and hospitalizations. This paper instead focuses on defensive behaviors that seek to alleviate morbidity and mortality. Economic theory suggests that individuals invest in defensive measures to prevent harm from pollution (Graff-Zivin and Neidell, 2013). Failing to account for these expenditures means to underestimate the benefits of clean air policies. The use of medication is a prime example of a costly, but often unaccounted for defensive activity. Against this backdrop, we evaluate the effects of LEZs on pharmaceutical expenditures using patient level data by AOK, Germany's largest public health insurance.

The economics literature on pollution costs focuses almost exclusively on direct health outcomes. Guided by the medical literature (Fanta, 2009) and a paper by Deschênes et al. (2017), we argue that health conditions are a function of pollution and compensatory adaptation in terms of drug therapy. Medication reduces the probability of negative health outcomes that otherwise require costly treatments.

With the notable exceptions of Deschênes et al. (2017) and Williams and Phaneuf (2019), the effect of air quality on defensive pharmaceutical expenditures remains largely unevaluated. While they analyze expenditures in the private U.S. health care system, we analyze the benefits of clean air regulation for Germany's universal, public healthcare system which covers all pharmaceutical prescriptions exceeding negligible deductibles. Presently, mandatory health care contributions are set to 14.6% of gross wages equally shared amongst employers and employees. Therefore, the impact of LEZs on defensive expenditures is relevant from a public finance perspective. Significant reductions in pharmaceutical expenditures may lower insurance contributions, lower labor costs for employers, and increase net incomes for households. Menichini and Mudu (2010) review the epidemiological literature. It is mainly based on small samples and finds a positive association between respiratory medication and air pollution.

We analyze 49 LEZs implemented between 2008 and 2013. The combustion of fuel and the abrasion of tyres and brake discs generates particulate emissions. We first estimate that LEZs improve air quality for about 21.3M individuals by reducing the concentration of particulates by about 1.6 $\mu g/m^3$ or 5.9%. We then show that LEZs lower pharmaceutical expenditures for heart and

* Corresponding author.
E-mail address: koch@mcc-berlin.net (N. Koch).

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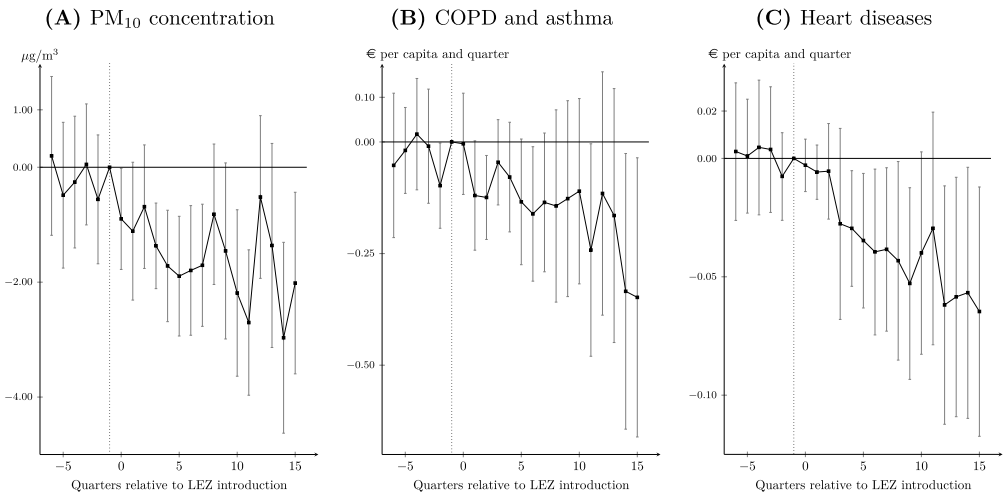

Fig. 1. Effects of LEZs. The whiskers indicate the 5% significance level based on standard errors clustered at the county level. Health regressions weighted by the number of insured.

respiratory diseases by 0.19€ per capita and quarter or 15.8M€ per year in treated cities in total.

While benefits from reduced defensive expenditures accrue over time, the costs of upgrading a vehicle otherwise banned from entering LEZs are due up-front and roughly 600€. With 200,240 vehicles affected, we estimate total costs to reach 120.1M€, which is clearly approximate and may omit some cost components. At a 6% social discount rate, our estimated reductions in pharmaceutical expenditures alone can recover these costs within 11 years.

2. Identification strategy

The staggered introduction of LEZs allows us to estimate causal effects by comparing counties that implement LEZs to counties where LEZs are not implemented yet. To avoid selection bias, we limit our sample to cities that eventually implement LEZs between 2008 and 2013. Recent research highlights that standard panel difference-in-differences (DiD) estimates are likely biased when treatment is staggered and effects are time-varying (Goodman-Bacon, 2018). Therefore, we use event studies that are deemed more appropriate.

Our outcome variables of interest are the concentration of airborne particulates with a diameter below 10μm (PM_{10}) as well as the expenditures for pharmaceuticals for (1) chronic obstructive pulmonary disease (COPD) and asthma (CA) and (2) heart diseases (HD) excluding hypertension. We regress outcome y in county i of state s in quarter q of year t on a binary LEZ indicator which is 1 when the current quarter is l quarters before or after LEZ introduction in a given county (Eq. (1)). Matrix X_{iqts} holds economic and weather controls. We include fixed effects for the county η_c, the season η_q, and a state–year effect η_{st}. ϵ_{iqts} is an error term. All treatment coefficients are normalized to $l = -1$. We include lags and leads corresponding to the availability of medical records since 2006Q3, which ensures a balanced event window. We bin the event window endpoints to identify dynamic treatment effects even when no never-treated units are present (Schmidheiny and Siegloch, 2020).

$$y_{iqts} = \sum_{l=-6}^{15} \psi_l \cdot \mathrm{LEZ}_{iqt}^{l} + X_{iqts}\gamma + \eta_i + \eta_q + \eta_{st} + \epsilon_{iqts} \tag{1}$$

3. Data

AOK's research center (WIdO, 2019) provides pharmaceutical expenditures. One in three publicly insured individuals in Germany are AOK members. We calculate expenditures at the county level using 81M individual observations from about 2.7M AOK members living in LEZs. Pharmaceuticals are classified by the Anatomical Therapeutic Chemical (ATC) system. Pharmaceuticals for CA are in category R03, while those for HD are in C01. C01 does not include pharmaceuticals for hypertension. Because pharmaceuticals may be used for multiple diseases, we use Häussler and Höer (2018) to identify the 20 most often prescribed. Extrapolated to all 21.3M individuals living in LEZ counties, annual expenditures are 533M€. Germany's environmental agency (UBA, 2019) provides PM_{10} readings from ground-level monitors and Germany's meteorological service (DWD, 2019) provides weather controls, such as temperature or precipitation. We average daily station-level observations at the county-quarter level for both. Germany's federal institute for spatial research (BBSR, 2019) provides economic controls: unemployment rates, sectoral employment shares, and household income. The cost–benefit analysis uses data on vehicle registrations from Germany's motor transport authority (KBA, 2019). The individual expenditures per ATC category are aggregated and combined with all explanatory variables at the county-quarter level resulting in a balanced panel spanning 30 quarters between 2006Q3 and 2013Q4.

4. Empirical results

Fig. 1 shows the causal effects of LEZs on PM_{10} concentrations (Panel A) and pharmaceutical expenditures for CA (Panel B) and HD (Panel C), based on Eq. (1). Note that the parallel trends assumption for all outcomes is satisfied prior to LEZ introduction ($l = 0$). All but one pre-LEZ coefficients are statistically indistinguishable from zero. While some quarterly event study estimates remain noisy, the general post-treatment patterns suggest persistent reductions across all outcomes.

We deliberately sacrifice precision in Fig. 1 by using quarterly estimates to assess the research design and the timing of treatment effects. Having provided this evidence, we summarize the magnitudes and the joint statistical significance of the event study estimates in Table 1 by averaging over the pre- and post-policy period. LEZs lower PM_{10} concentrations on average by about $1.576\mu g/m^3$ ($t = -3.35$) or by 5.9% compared to the

Table 1
Mean effects.

Outcome	Unit	Mean effects		Benefits (M€)		
		Pre-period	Post-period	Quarterly	Yearly	rel. to 2007
PM_{10}	$\mu g/m^3$	−0.211 (0.493)	$-1.576^{***,+++}$ (0.470)			5.9%
COPD & asthma	€/capita	−0.032 (0.052)	-0.149^{*} (0.084)	3.176	12.702	2.8%
Heart diseases	€/capita	0.001 (0.011)	$-0.037^{**,+}$ (0.016)	0.786	3.142	3.8%

$^{***}(^{**}, ^{*})$ indicates statistical significance at the 1% (5%, 10%) level. $^{+++}(^{+})$ indicates statistical significance at the 1% (10%) level after applying the Bonferroni correction for multiple hypotheses testing. Standard errors clustered at the county level in parentheses. 2007 levels: Population $\approx$ 21.272M, PM_{10} = 26.614 $\mu g/m^3$, CA = 449.369M€, HD = 83.776M€. Amounts in prices of 2007. Health regressions weighted by number of insured.

Table 2
Costs and benefits.

	Up-front	Annual	Over 5 years		Over 10 years	
Discount rate			2%	6%	2%	6%
Costs						
Affected vehicles	200,240					
Upgrade cost per vehicle (€)	600					
Total (M€)	120.1					
Benefits						
COPD and asthma (M€)		12.7	59.9	56.5	114.1	103.0
Heart diseases (M€)		3.1	15.0	14.1	28.5	25.8
Total (M€)		15.8	74.7	66.7	142.2	116.6

Amounts in prices of 2007.

2007 level. LEZs reduce quarterly per capita pharmaceutical expenditures for CA by 0.149€ ($t = -2.27$) and those for HD by 0.037€ ($t = -1.78$). Multiplying per capita effects (column 3) with the 21.3M individuals living in LEZ counties yields quarterly reductions of 3.176M€ for CA and 0.786M€ for HD (column 4). Annual reductions are 12.702M€ for CA and 3.142M€ for HD (column 5). This implies relative reductions of 2.8% and 3.8% compared to 2007 levels. Overall, LEZs reduce annual pharmaceutical expenditures for CA and HD by about 15.8M€.

We use our causal estimates for a cost–benefit analysis (Table 2). LEZs impose costs on owners of vehicles that fail to meet LEZ standards. There are 200,240 such vehicles registered in LEZ counties (KBA, 2019). Required vehicle upgrades to meet LEZ standards entail costs of approximately 600€ including installation (ADAC, 2019). These expenditures represent upgrade costs or lost resale value to vehicle owners, so the total up-front costs are $200{,}240 \times 600 = 120.1$M€. This cost calculation is clearly approximate and may omit cost components, e.g. vehicle upgrades in LEZ neighbor counties. With annual reductions in defensive pharmaceutical expenditures of 15.8M€ for CA and HD alone, health benefits recover the initial costs over 9 and 11 years assuming a social discount rate of 2 and 6%, respectively.

5. Discussion

Pharmaceuticals account for only 17% of public health costs (AOK, 2018). Yet, we show that the reductions in defensive expenditures for pharmaceuticals are substantial compared to the costs of LEZ implementation. We underestimate the effect of LEZs because we do not account for any effects on mortality, labor supply, productivity, or other treatment methods beyond select pharmaceuticals. While the magnitudes of these effects remain uncertain, they are surely positive, and possibly large (Graff-Zivin and Neidell, 2013). Thus, we reasonably expect the overall benefits of LEZs to greatly exceed our estimate.

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