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ABSTRACT

"Placebo Tests" for the Impacts of Air Pollution on Health: The Challenge of Limited Healthcare Infrastructure

When examining the impacts of exposure to air pollution on health outcomes, researchers usually carry out "placebo tests" to provide evidence in support of their identification assumption. In general, this exercise targets health conditions seemingly unrelated to air pollution. In this study, we argue that one should proceed with caution when running such falsification tests. If healthcare infrastructure is limited, when we observe health shocks such as those driven by air pollution, the infrastructure needs to be adjusted to meet the increased demand by canceling or rescheduling elective and non-urgent procedures, for example. As a result, even health conditions seemingly unrelated to air pollution may be indirectly affected by pollution.

JEL Classification: I15, Q53, Q56, O13

Keywords: placebo tests, air pollution, healthcare infrastructure, health outcomes, hospitalization for respiratory diseases and other causes

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"Placebo Tests" for the Impacts of Air Pollution on Health: The Challenge of Limited Healthcare Infrastructure

By Bruna Guidetti [*], Paula Pereda[†] and Edson Severnini[‡]

When examining the impacts of exposure to air pollution on health outcomes, researchers usually carry out "placebo tests" to provide evidence in support of their identification assumption. In general, this exercise targets health conditions seemingly unrelated to air pollution. For instance, if the main analysis focuses on the impacts of air pollution on respiratory or cardiovascular diseases, whose effects have been widely documented for decades (e.g., Pope, Dockery and Schwartz, 1995; Schlenker and Walker, 2016), falsification tests may focus on selected gastrointestinal disorders.

In this study, we argue that one should proceed with caution when running such falsification tests. If healthcare infrastructure is limited, when we observe health shocks such as those driven by air pollution (e.g., Chay and Greenstone, 2003; Currie and Neidell, 2005; Schlenker and Walker, 2016; Deryugina et al., 2019), the infrastructure needs to be adjusted to meet the increased demand by canceling or rescheduling elective and non-urgent procedures, for example. As a result, even health conditions seemingly unrelated to air pollution may be indirectly affected by pollution.

To shed light on this issue, we examine how a large metropolitan area in Brazil copes with increased healthcare demand due to high levels of air pollution, under hospital capacity constraints. To identify the health effects of air pollution, we investigate how daily pediatric hospitalizations for respiratory diseases in public hospitals respond to short-term exposure to PM10 in the Sao Paulo Metropolitan Area (SPMA) over the period 2015-2017.[1] For the health conditions seemingly unrelated to air pollution, we focus on epilepsy-related procedures such as video-EEG (electroencephalograph) monitoring, phimosis surgery, appendectomy, and bone fracture repair. The first two are elective care procedures, while the last two are urgent procedures.

Using wind as an instrument for PM10 (e.g., Deryugina et al., 2019), we document two main findings. First, consistent with previous research, exposure to PM10 increases pediatric hospitalization rates for respiratory diseases, and does create a health shock in the SPMA. Second, because of increased demand due to high pollution, the number of planned procedures such as video-EEG monitoring and phimosis surgery decreases in public hospitals. On average, for every four additional pollution-related admissions, one elective care procedure is displaced. Since appendicitis and bone fracture usually need urgent treatment, they do not seem to be displaced.

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[1]The SPMA is the largest metropolitan area in Brazil, with over 21 million inhabitants (10% of the Brazilian population). Brazil has a universal healthcare system. PM10 stands for particulate matter 10 micrometers or less in diameter.

I. Data

We use administrative data on public hospital admissions from the Brazilian Hospital Data System (SIHSUS). We observe all hospital admissions by cause as diagnosed by a physician, and by individuals' zip code of residence from January 2015 to December 2017.[2] We restrict our sample to children aged one to five years. These children are more likely to spend more time outdoors and, therefore, might experience more intense air pollution exposure.[3]

We focus the analysis on individuals living in the SPMA due to the availability of environmental data. The Environmental Company of the State of Sao Paulo (CETESB) collects hourly air pollution and weather variables using 30 monitors throughout the SPMA. Our pollution variable is PM10 (in $\mu g/m^3$), because it is regularly collected by most of the monitors (24 monitors). The two main sources of air emissions in the SPMA are vehicles and manufacturing (Braga et al., 2001).

We match individuals' zip code of residence from the health data with the corresponding district in the SPMA. Environmental data are assigned to a district from the nearest monitor, limiting to a 5-kilometer radius (Figure 1, left). Our final dataset includes data from 85 SPMA districts. For their corresponding municipalities, in the right chart we map the number of pediatric hospital beds per 1,000 children – a measure of healthcare infrastructure.

[2]We consider hospital admissions for the following respiratory diseases: pneumonia; bronchitis; allergic rhinitis; asthma; pneumoconiosis due to inorganic dust; respiratory disease due to inhalation of chemical gases, fumes and vapors; respiratory failure; among others. These classifications are from the ICD-10.

[3]We exclude children under one as they may be less exposed to external agents, such as air pollution, because they likely spend more time indoors.

II. Empirical Strategy

Because pollutants are not randomly assigned to individuals, we need to address the endogenous exposure to air pollution when identifying its effects on health outcomes. Also, because exposure is not measured exactly where individuals live, but approximated by measurements in the closest available pollution monitors, we introduce an unavoidable measurement error. To overcome such endogeneity problems, we exploit an instrument capable of dealing with non-stationary sources: wind speed. Inspired by Deryugina et al. (2019), the idea is that wind speed dissipates particle pollution, reducing PM10 concentration, but does not affect health directly.[4]

Our main estimating equation is:

$$Hosp_{it} = \gamma + \delta PM_{it} + X_{it}\phi + \eta_i + \lambda_t + \varepsilon_{it},$$

where i denotes districts, and t calendar dates from 2015 to 2017. $Hosp$ represents pediatric hospitalization rates, and PM is the level of PM10. X represents time-varying controls, including a quadratic function of temperature, humidity, and their interaction. η_i represents district fixed effects, while λ_t represents time fixed effects to correct for potential seasonality and aggregate shocks (day-of-week, month-of-year, and year fixed effects). ε is an idiosyncratic term. We instrument PM with contemporaneous and lagged wind speed.[5]

III. Results

Table 1 presents the instrumental variable estimates of the PM10 effects on pe-

[4]Although there is weak evidence that wind speed is associated with chronic obstructive pulmonary disease (Ferrari and et al., 2012), no biological mechanism has been proposed to explain such a correlation.

[5]For more details on the data description and empirical strategy, see Guidetti, Pereda and Severnini (2020).

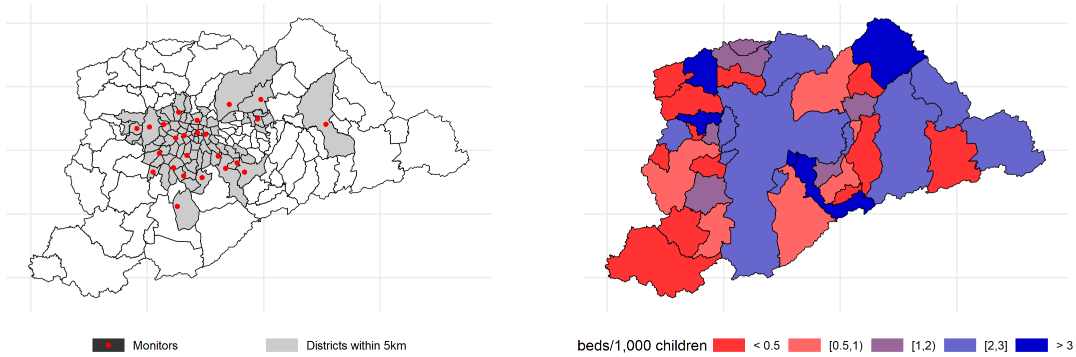

Figure 1. : Pollution monitors and districts (left) and pediatric hospital beds per 1,000 children in Sao Paulo (right)

Notes: Left figure displays the location of pollution monitors in the Sao Paulo Metropolitan Area (SPMA) (red dots), and the districts within 5km from any monitor (gray polygons). Right figure displays the number of pediatric beds per 1,000 children aged one to five in public hospitals across municipalities in the SPMA.

diatric hospitalization rates.[6] Because each unit of PM10 in the regressions represents $10\mu g/m^3$, all marginal effects should be interpreted as arising from a variation of $10\mu g/m^3$ in PM10 levels. The IV estimates are much larger than the OLS estimates – reported in Appendix Table A2 – suggesting a negative bias in OLS likely due to the omission of avoidance behavior, and attenuation bias due to measurement error in exposure to air pollution.

We find significant impacts of exposure to PM10 on hospital admissions for all respiratory diseases, and asthma and pneumonia, in particular. Our results indicate that a $10\mu g/m^3$ increase in PM10 causes an increase in pediatric hospitalization rates for all respiratory diseases by 4.55 per million children aged one to five. If we consider the number of children in this age group in the whole SPMA, and the median length of stay in our data, the additional hospitalization costs are $1,481/day and the annual government expenditure would increase by $540,696.[7] This represents 11.5% of all 2016 public expenditures with hospital admissions due to respiratory diseases for children aged one to five in the city of Sao Paulo.

In Brazil, it is widely known that the public healthcare system has excess demand. One relevant question we ask is: what are the effects of a pollution-driven health

[6]Appendix Table A1 reports first stage results. As expected, the estimated coefficients of wind speed on the same day and one day before hospital admission are both negative and statistically significant. Because wind carries pollution, the stronger the wind blows, the more particulate matter is taken away, the cleaner the air. Not surprisingly, however, wind speed on the day before admission has a lower impact on the contemporaneous levels of air pollution when compared to its impact on the same day. The Kleibergen-Paap rk Wald F-statistics of the joint significance of instruments is over 84, indicating strong instruments.

[7]This may be a lower bound estimate since we do not consider other health costs related to air pollution and the average public expenditure does not reflect market prices in Brazil.

shock on hospital demand? To understand that, we examine potential impacts on hospital admissions for causes seemingly unrelated to air pollution. We keep the focus on children, because hospital beds for children are separated from all other age groups. If the number of hospital beds is not large enough to meet demand, what is supposed to be a placebo outcome becomes an outcome of interest itself.

Results are reported in Panel B of Table 1. We examine the effects on pediatric hospitalization for the following other causes: epilepsy-related procedures such as video-EEG (electroencephalograph) monitoring, phimosis surgery,[8] appendectomy, and bone fracture repair. The results show negative and statistically significant impacts of PM exposure on hospital admissions for elective care procedures, such as epilepsy and phimosis. On average, for every four additional admissions for respiratory diseases in public hospitals, one elective care procedure is displaced. Admissions for appendectomy and bone fracture repair, however, do not appear to be affected by higher levels of PM, probably due to their urgent nature.

To provide additional evidence on this mechanism, Table 2 reports heterogeneous PM10 impacts by hospital capacity, as measured by pediatric hospital beds per 1,000 children in 2014 (before our period of analysis). In this table, the coefficients associated with PM10 should be interpreted as the impact of PM10 on admissions in districts whose hospital infrastructure is below the median, and the coefficients of the interactions as the differential effects on admissions in districts with that measure above the median. Our results indicate larger negative effects in capacity constrained districts, i.e., those with infrastructure indicators below the median. For example, the negative impact of PM10 on epilepsy-related procedures drops by 70% when the number of pediatric beds is above the median in the SPMA, a large offset of the impacts of pollution-driven health shocks.

[8]Unlike in the United States, phimosis surgery (circumcision) is not a common practice in Brazil.

IV. Concluding Remarks

In this study, we argue that in the presence of limited healthcare infrastructure, hospitalizations for causes usually considered in “placebo tests” should be seen as outcome variables when evaluating the health impacts of air pollution. Because of strained hospitals, elective procedures might be canceled or rescheduled. Therefore, they are indirectly affected by the health shocks driven by air pollution. In our setting, exposure to PM10 caused a large short-term increase in pediatric hospitalizations for respiratory diseases in the SPMA. As a result, for every four additional pollution-related admissions, one elective care procedure was displaced, on average.

Interestingly, it appears that the healthcare system absorbed the additional demand without imposing large costs to the SPMA society. This is remarkable given the capacity constraints of the healthcare system in developing countries such as Brazil. In any case, these results highlight the shortcomings of using health outcomes seemingly unrelated to air pollution as falsification tests in studies examining the consequences of exposure to air pollution.

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Table 1—: PM impacts on public hospitalization, respiratory and non-respiratory diseases – Children 1-5 years old

	Panel A: Respiratory Diseases			
	All	Asthma	Pneumonia	Influenza
PM_t	4.55***	0.99**	2.35**	0.08*
	(1.346)	(0.408)	(0.998)	(0.044)
Dep. var. mean	62.57	6.63	34.21	0.18
	Panel B: Non-respiratory Diseases			
	Epilepsy	Phimosis	Appendicitis	Fracture
PM_t	-0.28**	- 0.84*	- 0.06	0.00
	(0.127)	(0.490)	(0.088)	(0.097)
Dep. var. mean	2.32	7.60	0.82	0.94
F-statistic	84.39	84.39	84.39	84.39
Observations	89492	89492	89492	89492

Notes: Hospitalization rate is measured as the number of hospital admissions per million children aged one to five. Panel A presents the results for respiratory diseases and Panel B displays the effects on non-respiratory diseases (elective procedures: epilepsy-related procedures and phimosis surgery; and urgent procedures: appendectomy and bone fracture repair). Each column in each panel reports coefficients from a different regression. We use 85 districts, whose centroid is within 5km from a pollution monitor, and 1,095 days. We include district, day-of-week, month-of-year, and year fixed effects, as well as temperature and humidity in quadratic form as controls. Standard errors in parentheses are two-way clustered by district and calendar date and regressions are weighted by the total children in the district. F-statistic refers to the Kleibergen-Paap rk Wald F-statistic of the first stage results for PM_t (in $10\mu g/m^3$) on wind speed (in t and $t-1$). *** p<0.01, ** p<0.05, * p<0.1.

Table 2—: PM impacts on public hospitalizations, non-respiratory diseases – Children 1-5 years old

	Epilepsy	Phimosis	Appendicitis	Fracture
PM_t	-0.42***	- 1.08*	- 0.02	0.04
	(0.122)	(0.558)	(0.105)	(0.099)
$PM_t * 1[\text{high}]$	0.29*	0.51	- 0.10	- 0.08
	(0.147)	(0.433)	(0.102)	(0.120)
Dep. var. mean	2.32	7.60	0.82	0.94
F-statistic	39.47	39.47	39.47	39.47
Observations	89492	89492	89492	89492

Notes: Hospitalization rate is measured as the number of hospital admissions per million children aged one to five. The table displays the effects on elective procedures, epilepsy-related procedures and phimosis surgery, and urgent procedures, appendectomy, and bone fracture repair. We explore the heterogeneity of the results by hospital capacity indicators for pediatric beds in 2014 (year before our sample). The capacity rate is calculated per total district children population. 1[high] is a dummy variable indicating that the pediatric beds are above the SPMA median in that district. Each column in each panel reports coefficients from a different regression. We use 85 districts within 5km from a pollution monitor, and 1,095 days. We include district, day-of-week, month-of-year, and year fixed effects, as well as temperature and humidity in quadratic form as controls. Standard errors in parentheses are two-way clustered by district and calendar date and regressions are weighted by the total children in the district. *** p<0.01, ** p<0.05, * p<0.1.

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Online appendix for "Placebo Tests" for the Impacts of Air Pollution on Health: The Challenge of Limited Healthcare Infrastructure

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Table A1—: Impacts of wind speed on PM10 – First stage

	PM_t
ws_t	- 0.68***
	(0.056)
ws_{t-1}	- 0.21***
	(0.050)
Dep. var. mean	2.99
Kleibergen-Paap rk Wald F-statistic	84.39
Number of districts	85
Number of days	1095
Observations	89492

Notes: This table reports the first stage results for PM_t (in $10\mu g/m^3$). We use districts whose centroid is within 5km from a pollution monitor. We include district, day-of-week, month-of-year, and year fixed effects. We also add temperature and humidity in quadratic form as controls. Standard errors in parentheses are two-way clustered by district and calendar date. Regressions are weighted by children population. *** p<0.01, ** p<0.05, * p<0.1.

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Table A2—: OLS coefficients of PM impacts on public hospitalizations – Children 1-5 years old

	Panel A: Respiratory Diseases			
	Respiratory	Asthma	Pneumonia	Influenza
PM_t	0.65 (0.465)	0.10 (0.113)	0.27 (0.278)	0.03* (0.017)
Dep. var. mean	62.57	6.63	34.21	0.18
	Panel B: Non-respiratory Diseases			
	Epilepsy	Phimosis	Appendicitis	Bone Fracture
PM_t	0.07 (0.053)	0.13 (0.145)	0.03 (0.029)	0.03 (0.034)
Dep. var. mean	2.32	7.60	0.82	0.94
Number of districts	85	85	85	85
Number of days	1095	1095	1095	1095
Observations	89492	89492	89492	89492

Notes: Hospitalization rate is measured as the number of hospital admissions per one million children aged one to five. The table displays the effects on respiratory and non-respiratory diseases (elective care procedures: epilepsy-related procedures and phimosis surgery; and urgent procedures: appendectomy, and bone fracture repair). Each column in each panel reports coefficients from a different regression. We use 85 districts whose centroid is within 5km from a pollution monitor, and 1,095 days. We include district, day-of-week, month-of-year, and year fixed effects, as well as temperature and humidity in quadratic form as controls. Standard errors in parentheses are two-way clustered by district and calendar date. Regressions are weighted by children population. *** p<0.01, ** p<0.05, * p<0.1.