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AIR POLLUTION CHALLENGES IN DEVELOPING COUNTRIES[‡]

"Placebo Tests" for the Impacts of Air Pollution on Health: The Challenge of Limited Health Care 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), then 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 health care infrastructure is limited, then 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, for example, canceling or rescheduling elective and nonurgent procedures. 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 health care 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.

I. Data

We use administrative data on public hospital admissions from the Brazilian Hospital Data System. We observe all hospital admissions by

[‡]*Discussants:* Marcos Rangel, Duke University; Eric Zou, University of Oregon and NBER; Arthur A. van Benthem, University of Pennsylvania and NBER; Teevrat Garg, University of California–San Diego and IZA.

*Guidetti: Department of Economics, University of Michigan (email: guidetti@umich.edu); Pereda: Department of Economics, University of Sao Paulo (email: pereda@usp.br); Severnini: Heinz College, Carnegie Mellon University, and IZA (email: edsons@andrew.cmu.edu).

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

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 collects hourly air pollution and weather variables using 30 monitors throughout the SPMA. Our pollution variable is PM10 (in micrograms per cubic meter, or $\mu g/m^3$), because it is regularly collected by most (24) of the 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 five-kilometer (km) radius (Figure 1, top). Our final dataset includes data from 85 SPMA districts. For their corresponding municipalities, in the bottom chart, we map the number of pediatric hospital beds per 1,000 children—a measure of health care infrastructure.

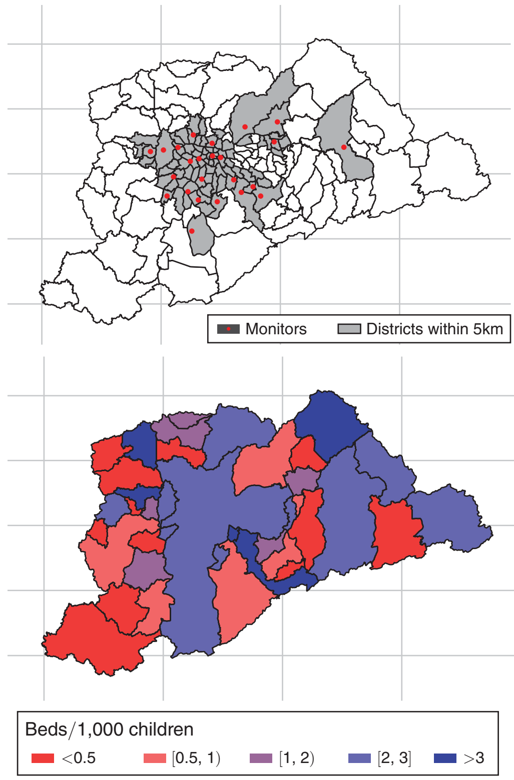

Figure 1. Pollution Monitors and Districts (top) and Pediatric Hospital Beds per 1,000 Children in Sao Paulo (bottom)

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

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 is 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 nonstationary 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. The variable *Hosp* represents

[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; and respiratory failure; among others. These classifications are from the International Classification of Diseases, Tenth Revision.

[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.

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

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); and 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 pediatric 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, 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 1 to 5. 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 per day and the annual government expenditure would increase by \$540,696.[7] This represents 11.5 percent of all 2016 public expenditures for hospital admissions due to respiratory diseases for children aged 1 to 5 in the city of Sao Paulo.

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

Table 1—PM Impacts on Public Hospitalization, Respiratory and Nonrespiratory Diseases: Children One to Five Years Old

	Panel A. Respiratory diseases			
	All	Asthma	Pneumonia	Influenza
PM_t	4.55	0.99	2.35	0.08
	(1.35)	(0.41)	(1.00)	(0.04)
Dep. var. mean	62.57	6.63	34.21	0.18
	Panel B. Nonrespiratory diseases			
	Epilepsy	Phimosis	Appendicitis	Fracture
PM_t	−0.28	−0.84	−0.06	0.00
	(0.13)	(0.49)	(0.09)	(0.10)
Dep. var. mean	2.32	7.60	0.82	0.94
F-statistic	84.39	84.39	84.39	84.39
Observations	89,492	89,492	89,492	89,492

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 nonrespiratory diseases (elective procedures: epilepsy-related procedures and phimosis surgery, 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 5 km of 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 number of 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 $t-1$).

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

[6] Online 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 PM is taken away and 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-statistic 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.

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 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 related to 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 should be interpreted 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 percent when the number of pediatric beds is above the median in the SPMA, a large offset of the impacts of pollution-driven health shocks.

Table 2—PM Impacts on Public Hospitalizations, Nonrespiratory Diseases: Children One to Five Years Old

	Epilepsy	Phimosis	Appendicitis	Fracture
PM_t	−0.42	−1.08	−0.02	0.04
	(0.12)	(0.56)	(0.11)	(0.10)
$PM_t \times \mathbf{1}[\text{high}]$	0.29	0.51	−0.10	−0.08
	(0.15)	(0.43)	(0.10)	(0.12)
Dep. var. mean	2.32	7.60	0.82	0.94
F-statistic	39.47	39.47	39.47	39.47
Observations	89,492	89,492	89,492	89,492

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 per 1,000 children in 2014 (the 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 5 km of 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.

IV. Concluding Remarks

In this study, we argue that in the presence of limited health care 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 health care system absorbed the additional demand without imposing large costs on the SPMA society. This is remarkable given the capacity constraints of the health care 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.

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

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