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Impact of the Clean Air Act on air pollution and infant health: Evidence from South Korea[☆]

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HIGHLIGHTS

- We estimate the impact of a pollution reduction law in a middle-income country.
- We study the South Korea's Clean Air Act that focused on Seoul and its surroundings.
- The DID estimates suggest that the Act successfully reduced air pollutants.
- The Act's impact on infant mortality was not statistically significant.

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ABSTRACT

This paper examines the extent to which the 2005 Clean Air Act introduced in South Korea affected air pollution and infant health. To identify the causal effect, we exploit the time and geographical variations in the adoption of the Act between 2003 and 2006. During this period, the Clean Air Act indeed significantly reduced air pollutants. For example, the PM_{10} level was reduced by 9 percent. However, the Act's impact on infant mortality was not statistically significant.

1. Introduction

Air pollution has received considerable attention from researchers, practitioners, and the general public. While a growing number of empirical studies have identified the causal impact of air pollution on health and other outcomes, research examining policy interventions to reduce air pollution, particularly in a non-US setting, has been scarce (Arceo et al., 2016).

This paper examines an environmental protection policy aimed to reduce air pollution in South Korea, and estimates its impact on pollution reduction and infant health. Although South Korea is steadily ranked as one of the world's upper middle-income countries, its ambient air pollution level is much higher than that of its peers, indeed the worst among the OECD countries (66% higher than that of the US in terms of urban-population weighted average of annual PM_{10} in 2010). While responding to public outcry concerning poor air quality has become a major political agenda, there are also strong reservations from local business groups, who oppose tightening environmental laws. These groups rely on the finding that a large portion of air pollution in South Korea is due to pollutants traveling from China, and thus such law enforcement would have little impact on air quality in South Korea (Fifield and Seo, 2017). Given the severity of South Korea's air pollution and the political disputes with respect to environmental policies, it is important to examine the extent to which a domestic environmental protection policy has an impact on pollution reduction. This paper addresses this need by examining the 2005 Clean Air Act (CAA) in South Korea.

☆ The Supplementary Materials are available at: www.soohyunglee.com/research.

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The CAA, announced in June 2004 and implemented in January 2005, tightened pollution monitoring for diesel emission cars. The CAA was imposed only in the areas with high air pollution levels in Seoul and its surrounding areas but not the rest of the country. Using these geographical and time variations, we identify the causal impact of the law using a Difference-in-Difference (DID) framework. Subsequently, by employing the CAA as an instrument variable (IV) for air pollutant level (PM_{10}), we assess the impact of ambient air quality on infant mortality. Our identification crucially relies on the assumption that the districts affected by the CAA and the non-affected districts share the same time trend. Using the pre-treatment periods, we present supporting evidence that this assumption is likely to hold.

Conditional on weather conditions, we find the PM_{10} concentration was reduced due to the CAA. Additional analyses suggest that the positive impacts are larger for the areas in which the initial air pollution levels were high. However, we find that the CAA did not reduce the infant mortality rate significantly.

2. Institutional background

South Korea has been infamous for its severe air pollution, the worst among the OECD countries. Although not as severe as that in metropolitan areas in developing countries such as Beijing and New Delhi, the air pollution levels in major cities of South Korea exceed the level considered unsafe by World Health Organization (WHO, 2016). To address this serious problem, the South Korean Congress introduced the Clean Air Act in December 2003. Details, including the criteria for selecting target areas, were announced in June 2004 and became effective in January 2005. The CAA targeted high pollution areas in Seoul and its surroundings. Although it aimed to reduce overall levels of air pollutants such as SO_2 (Sulfur Oxides), NO_2 (Nitrogen Oxides), VOC_s (Volatile Organic Compounds), and O_3 (Ozone), its main objective was to reduce PM_{10} (Particulate Matter). Specifically, its target was an ambient concentration of PM_{10} lower than 50 $\mu g/m^3$ by 2011 as an annual average to meet the WHO guideline; this target is often referred to as Interim Target-2 (IT-2). The CAA consists of various policies with different phases. This paper examines the first one, targeting emissions of diesel cars. This regulation mandates that all diesel automobiles registered in the treated areas need to be regularly checked for emission levels. If a car does not meet the emission criteria, its owner has to install an emission reduction device or change the car's engine. Otherwise, the government may charge a fine of up to USD 5000, approximately 2 times the average household income in 2003. See details in Section A of the Supplementary Materials.

3. Data and sample

We compile a dataset with pollution measures, weather conditions, and mortality rates for South Korea during the period from January 2003 to December 2006. The air quality information is based on the monthly average of the ambient air pollution levels for each monitor, provided by the National Institute of Environment Research. Weather conditions such as wind speed and precipitation are found to greatly affect the amount of air pollutants. Thus, we separately collect weather data measurements from the Korea Meteorological Administration.[1] The mortality information is based on the restricted-use microdata of death and birth records, provided by South Korea's Statistics Bureau. We classify deaths based on their causes since certain causes are more likely to be affected than others (e.g., Arceo et al., 2016; Chay and Greenstone, 2003). For example, air pollution may be more likely to increase risk of internal deaths (e.g., due to respiratory diseases) than that of external deaths (e.g., due to car accidents). Similarly, among internal deaths, air pollution may be more likely to increase risk of death due to cardiovascular–respiratory diseases. For this reason, we first analyze all deaths, narrow the analysis to only deaths due to internal causes, and then analyze the deaths due to cardiovascular–respiratory diseases.[2] We merge these three datasets by aggregating up to district by month levels. Thus, the unit of observation in our analysis is district by month, a total of 34 districts in a given month, 25 of which were treated by the CAA.[3] Table 1 shows the summary statistics of our sample depending on the stage of the CAA: before the CAA was introduced (column (1)), the period when the CAA was announced but not yet implemented (column (2)), and the period when the CAA was implemented (column (3)).

4. Econometric framework and identification strategy

We examine the difference in air pollution levels between the districts affected by the CAA and those not affected by estimating the following DID specification:

$$\begin{aligned} &Pollutant_{d,m,y} \\ &\quad = \theta_1 \cdot \mathbb{1}(d \in Treat; announce) + \theta_2 \cdot \mathbb{1}(d \in Treat; implement) \\ &\qquad + \omega X_{d,m,y} + \alpha_d + \beta_m + \gamma_y + \varepsilon_{d,m,y} \end{aligned} \tag{1}$$

where $Pollutant_{d,m,y}$ is the level of air pollutant in district d, month m, and year y.

Variables $\mathbb{1}(d \in Treat; announce)$ and $\mathbb{1}(d \in Treat; implement)$ are the indicators covering July to December 2004, and January 2005 to December 2006, respectively. The former is the period when the CAA was announced to the public but not yet implemented; the latter is the period when the CAA was implemented. By including the former indicator, we allow for the possibility that agents may respond to the CAA in expecting its implementation starting from January 2005. Parameters α_d, β_m, and γ_y capture district-, month-, and year-fixed effects. Variable $X_{d,m,y}$ includes district-specific weather conditions: precipitation, wind speed, whether a district is subject to dust blows from China, and dummies indicating main wind direction in a given month.[4] See details in Section B of the Supplementary Materials for construction of variables. Variable $\varepsilon_{d,m,y}$ captures unexplained random shock, clustered at the district level.

Our identifying assumption is that, absent the CAA, the trends in air pollution would have been the same for the districts affected by the CAA and the non-affected districts. To test the plausibility of our assumption, we restrict our sample to January 2003 to June 2004, and estimate a linear regression model including the

1 We gathered data from the Korea Meteorological Administration. (2003–2006) "Annual Climatological Report", which provides average of wind speed, monthly total precipitation, number of days affected by yellow dust, and most frequent wind direction in a month collected from each monitor.

2 Our classification is in line with the International Statistical Classification of Diseases and Related Health Problems (10th edition, ICD-10) produced by the WHO. See details in Section B of the Supplementary Material.

3 Although there are 247 districts in South Korea, air pollution monitors covered 127 districts in 2003. Among the 127 districts, we exclude 34 districts located in remote rural areas or islands in South Korea. Finally, among the resulting 93 districts, the Korea Meteorological Administration provides weather condition information only for the 34 districts that we use for our analysis (25 treated and 9 untreated districts). Although eliminating those observations substantially reduces the sample size, our main findings qualitatively remain the same if we use all 93 districts but do not control for the weather variables (see Section C.2 in the Supplementary Material).

4 We include these variables because air pollution levels hinge on the weather conditions and season (Barmpadimos et al., 2011; Lee et al., 2006; Hooyberghs et al., 2005). For example, PM_{10} formation requires dry and stagnant air (Barmpadimos et al., 2011).

Table 1
Summary statistics.

	Before Jan 2003–June 2004 (1)	Announcement July 2004–Dec. 2004 (2)	Enforcement Jan 2005–Dec.2006 (3)
Panel A. Treatment Group			
PM_{10} ($\mu g/m^3$)	69.166	51.272	59.430
NO_2 (ppb)	37.223	32.869	33.656
Infant deaths			
– All causes	37.000	25.449	27.029
– Internal causes	36.488	25.194	26.788
– Cardio–Respiratory causes	15.555	13.721	11.202
Panel B. Control Group			
PM_{10} ($\mu g/m^3$)	60.962	49.575	56.126
NO_2 (ppb)	25.795	24.432	24.452
Infant deaths			
– All causes	49.728	44.171	34.167
– Internal causes	48.891	44.171	33.310
– Cardio–Respiratory causes	17.995	9.396	11.303

Note: This table provides mean values of key variables in each period by group. The unit of observations is district by month. The infant deaths are the number of deaths (age less than 1 year old) per 100,000 live births.

Table 2
Impact of the 2005 CAA on pollution and infant mortality.

Panel A. Impact on air pollution[a]

Dep. / Model	PM_{10} Identification test (1)	PM_{10} Treatment effect (2)	PM_{10} Treatment effect (3)	NO_2 Treatment effect (4)
1 (*i*: Treat, Jan–Jun. 2004)	−4.537			
	(3.576)			
1 (*i*: Treat, Announce)		−3.080		−1.860
		(1.887)		(1.304)
x Initial PM_{10}			−0.090*	
			(0.047)	
1 (*i*: Treat, Enforcement)		−5.667**		−1.344
		(2.370)		(1.671)
x Initial PM_{10}			−0.116***	
			(0.039)	
Obs.	576	1550	1550	1571
Mean dep.	67.101	60.703	60.703	32.190

Panel B. Impact on infant mortality[b]

Dep.	All deaths (1)	Internal causes (2)	Cardio/respiratory causes (3)
1 (*i*: Treat, Announce)[(a)]	−8.970*	−8.982*	−1.111
	(5.029)	(5.009)	(2.627)
1 (*i*: Treat, Enforcement)[(b)]	3.894	4.390	−0.313
	(4.086)	(4.049)	(1.992)
Mean dep.	33.427	32.976	13.264

[a] The unit of observation is district by month. We include weather controls such as precipitation, wind speed, wind direction, and days of yellow dust. We also control for district, month, and year fixed effects. The unit of PM_{10} is $\mu g/m^3$ and that of NO2 is ppb (parts per billion). There are 34 districts (25 treated districts and 9 untreated districts). Standard errors are clustered at the district level, reported in parentheses.

[b] The unit of observation is district by month. Each coefficient corresponds to a separate regression. We include weather controls such as precipitation, wind speed, wind direction, and days of yellow dust. We also control for district, month, and year fixed effects. The results reported in the table are weighted by the number of births in the respective cohort. There are 34 districts (25 treated districts and 9 untreated districts). Standard errors are clustered at the district level, reported in parentheses.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

interaction effects between the two indicators: one for the treated districts and the other for the year 2004. If the two groups of districts share the time trend, then the interaction effects should not be different from 0, which indeed we find. Column (1) of Table 2 (Panel A) reports the estimate of that interaction term, which is not statistically significant at conventional levels.

5. Results

Column (2) of Panel A, Table 2 presents our estimates of the impact of the CAA on air pollution. Conditional on weather conditions, time and district fixed effects, the PM_{10} concentration was reduced by 3.080 $\mu g/m^3$ or 5.07% during its announcement period, although the effect just missed standard statistical significance (e.g., *P*-value is 0.11). During the period when the CAA was implemented, the PM_{10} concentration was reduced even more -5.667 $\mu g/m^3$ or 9.34%, statistically significant at the 5% level.[5]

Next, we examine whether the impact of CAA depends on the initial pollution level. To test this possibility, we interact the two policy variables in Eq. (1) with a district's initial PM_{10} concentration.[6] As shown in column (3) of Table 2, the districts with high initial air pollution show greater reduction due to the CAA in both the announcement and enforcement periods. For the average districts in the treatment group whose initial PM_{10} is 68.260 $\mu g/m^3$, the CAA reduced the PM_{10} level by 6.123 $\mu g/m^3$ (8.97%) during the announcement period and by 7.918 $\mu g/m^3$ (11.59%) during the enforcement period.

Since the CAA may affect other air pollutants as well, we examine the impact of the CAA on NO_2 levels. Column (4) of Panel A in Table 2 suggests that the CAA reduced NO_2 by 1.860 ppb during the announcement period and by 1.344 ppb during the enforcement period, but neither is statistically significant at conventional levels.

Finally, we examine the extent to which the CAA impacted infant mortality. We regress the number of deaths per 100,000 live births, among those whose age is less than 1 year old in district *d*, month *m*, and year *y* on the explanatory variables in Eq. (1).[7] Panel B of Table 2 reports the results. During the announcement period, the CAA reduced infant mortality from all causes and that from internal causes by 8.970 and 8.982, respectively (columns (1) and (2)), although these effects are significant at only the 10% level. However, we do not find any statistically significant reduction in infant mortality during the enforcement period or in terms of infant deaths caused by cardio–respiratory causes (column (3)).

6. Conclusion

This paper examines the impact of South Korea's 2005 Clean Air Act on pollution levels and infant mortality. Using the DID method, we find that the 2005 CAA substantially reduced PM_{10}, and other air pollutants, which lead to a reduction in the infant mortality rate. Our findings suggest that, despite external factors such as pollutants transferred from China, South Korea may benefit from stricter environmental regulations related to improving air quality. Furthermore, even in a developed country with nationwide health care, namely South Korea, air pollution imposes significant health risks to the population, measured by infant mortality, which should not be taken lightly when designing environmental policies.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econlet.2018.04.010.

References

Arceo, E., Hanna, R., Oliva, P., 2016. Does the effect of pollution on infant mortality differ between developing and developed countries? Evidence from Mexico City. Econom. J. 126 (591), 257–280.

Barmpadimos, I., Hueglin, C., Keller, J., Henne, S., Prévôt, A.S.H., 2011. Influence of meteorology on PM_{10} trends and variability in Switzerland from 1991 to 2008. Atmos. Chem. Phys. 11 (4), 1813–1835.

Chay, K., Greenstone, M., 2003. The impact of air pollution on infant mortality: evidence from geographic variation in pollution shocks induced by a recession. Q. J. Econ. 118 (3), 1121–1167.

Fifield, A., Seo, Y., 2017, April 27. Smog becomes a political issue in South Korean election. The Washington Post. Retrieved from www.washingtonpost.com.

Hooyberghs, J., Mensink, C., Dumont, G., Fierens, F., Brasseur, O., 2005. A neural network forecast for daily average PM_{10} concentrations in Belgium. Atmos. Environ. 39 (18), 3279–3289.

Lee, C.T., Chuang, M.T., Chan, C.C., Cheng, T.J., Huang, S.L., 2006. Aerosol characteristics from the Taiwan aerosol supersite in the Asian yellow-dust periods of 2002. Atmos. Environ. 40 (18), 3409–3418.

WHO, 2016, May. Ambient air pollution database. Retrieved from http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/.

[5] We examine the possibility that the Clean Air Act may affect some districts in control group (externality) but find no strong evidence supporting this possibility. See Section C.3 in the Supplementary Materials.

[6] Specifically, we use the average PM_{10} level between January 2003 and June 2004 in a district as the district's initial PM_{10} level.

[7] This analysis measures the reduced-form effect of the CAA on infant mortality. Note that we decide not to estimate the causal impact of PM_{10} on infant mortality using the IV approach because the CAA's impact during the announcement period is not statistically significant, resulting in a weak instrument problem. For the purpose of this study, this reduced-form analysis is suitable because we are primarily interested in the possible impact of CAA on infant mortality, not the causal impact of PM_{10}.