Can a low emission zone improve academic performance? Evidence from a natural experiment in the city of Madrid

1 Introduction

Air pollution is a pressing global concern. On the one hand, polluted air is linked to the emission of CO_2 and methane, which contribute to global warming. On the other, it is associated to a range of individual risks, deteriorating the health of people living in highly polluted areas (König & Heisig, 2023) and other related outcomes. As a result, numerous policies have been put in place to reduce air pollution. The aim of this work is to assess whether the introduction of a low emission zone in the city of Madrid (Spain) had a positive impact on the academic performance of students schooled in that area.

2 Low emission zones, air pollution, and academic performance

One popular measure to reduce air pollution is the implementation of low emission zones (LEZ): urban areas with some kind of mobility restriction for vehicles. In Madrid, a LEZ was implemented in late-2018 in Distrito Centro, one of the twenty-one districts of the city of Madrid. It was designed as a traffic-restriction plan seeking to eliminate transit traffic, that is, non-resident vehicles whose origin or destination was not the restricted area. Only electric and hybrid cars were allowed to cross it.

Existing research has already documented that Madrid's LEZ was effective in reducing air pollution over the first year of implementation (Galdon-Sanchez et al., 2023; Lebrusán & Toutouh, 2021; Salas et al., 2021). In this work, we extend the analysis to years 2020, 2021, and 2022. The intuition is that, if traffic-related emissions remained low within the LEZ area for a long enough period of time, that could have created the conditions for an improvement in other related outcomes. In particular, we focus on academic performance since numerous studies have documented the adverse consequences of air pollution on educational outcomes (Amanzadeh et al., 2020; Balakrishnan & Tsaneva, 2021; Duque & Gilraine, 2022; Grineski et al., 2020; Heissel et al., 2022; Shier et al., 2019). Therefore, if Madrid's LEZ was effective in generating a sustained improvement in air quality, that could have increased the academic performance of students schooled in that area.

3 Data

Our data on air pollution comes from 24 monitoring stations spread all over the city of Madrid. We use daily values of NO_2 to compute yearly averages for each of the monitoring stations.

As for academic performance, we aexamine the scores in the *Evaluación para el Acceso a la Universidad* (EvAU), a high-stakes examination aimed at ranking Spanish students for university admission. We use the school-average EvAU scores of all high schools in the city of Madrid that operated over the period 2015-2022, four years before and after the implementation of Madrid's LEZ. EvAU scores are standardized within year with a mean of 0 and a standard deviation of 1.

Finally, we exploit the databank of the city of Madrid to control for the following time-varying, district-level variables: the percentage of the population over 25 that attained university education, the percentage of the population that was born

abroad, and the number of students in the academic track of upper secondary education.

4 Method

To estimate the effect of Madrid's LEZ, we use a Difference-in-Differences (DiD) design and compare the pollution readings and school-average EvAU scores within and outside the restricted area before and after the implementation of the LEZ. Importantly, we satisfactorily test for parallel trends for both NO_2 readings and EvAU scores.

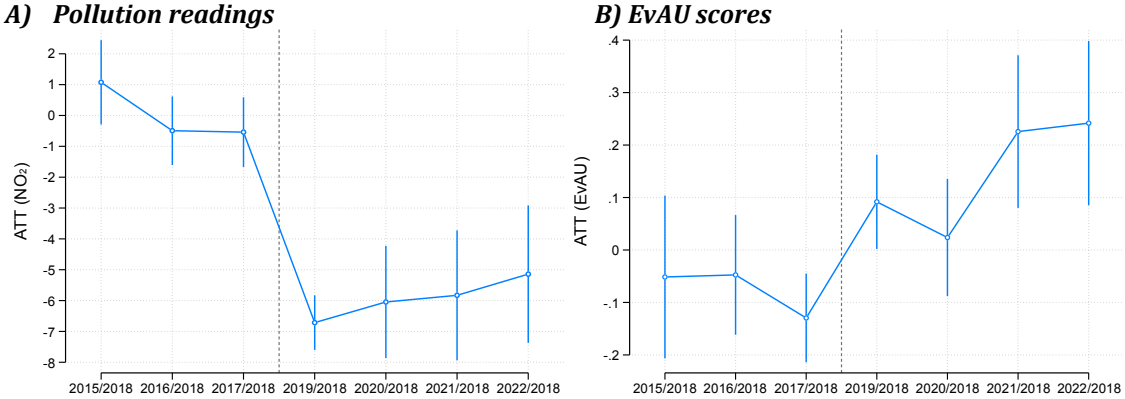
To estimate the effect of interest, we use a standard two-way fixed effect model. However, to test whether the treatment effect evolved over time, we also conduct a dynamic DiD. The analyses are weighted by the number of students taking the EvAU in each school to correct for the volatile mean EvAU scores of small schools.

5 Results

Figure 1 below illustrates our findings. The X-axis represents different time periods, each compared to the base year 2018 (dashed-line), when the LEZ policy was introduced. Meanwhile, the Y-axis represents effect size measured in SDs.

For starters, we report a significant decline in pollution readings following the implementation of Madrid's LEZ. In the first year, NO_2 readings in the LEZ area fell by about 6 $\mu g/m^3$ (p-value = 0.000). The results for the next years also reveal a statistically and economically significant effect, which, however, is slightly diluted as we move away from the implementation date. Nevertheless, we can affirm that there was a sustained improvement in air quality within the restricted area in the years following the implementation of Madrid's LEZ.

Figure 1. Results of the dynamic DiD estimates for air pollution and EvAU scores.



Next, we test whether the academic performance of students schooled in that area improved under these more favourable environmental conditions. Results are reported in Table 1 (TWFE model) and Figure 1B (dynamic DiD model). First, we find a positive effect of Madrid's LEZ on the average EvAU scores of schools located in *Distrito Centro* (first column of Table 1). As of 2019, performance at EvAU increased almost one-fifth of a standard deviation compared with the schools in the other twenty districts of the city of Madrid (ATT = 0.174; p-value = 0.025). This finding is highly robust to different methodological decisions, as shown in columns 2-5 in Table 1. Particularly, if exclude the covid year (atypical regarding both pollution and the EvAU examination), the estimated effect grows even larger.

We also test for spillover effects in columns 6 and 7 of Table 1. The introduction of the LEZ had a positive impact on the average EvAU scores of schools 0.5km away from the LEZ area, although the effect is around 40% the one previously identified for schools within the LEZ (ATT = 0.063; p-value = 0.099). In turn, if we extend the buffer zone to 1km away from the LEZ area, the effect is virtually zero.

Finally, Figure 1B shows that, comparing with the last pre-treatment year (2018), the effect on academic performance is larger the further away from the introduction of the LEZ: while it was one-tenth of a standard deviation in 2019, it reached almost one-fourth of a standard deviation by 2022.

Table 1. DiD estimates for the effect of Madrid's LEZ on academic performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Model 1	Model 2a	Model 2b	Model 2c	Model 2d	Model 3a	Model 3b
ATT	0.174 (0.072) **	0.171 (0.075) **	0.147 (0.063) **	0.160 (0.058) **	0.236 (0.077) ***	0.063 (0.037)*	-0.004 (0.035)
Year-fixed effects	**X**	**X**	**X**	**X**	**X**	**X**	**X**
School-fixed effects	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Weighted by number of students taking EvAU	**X**	**X**	**X**		**X**	**X**	**X**
EvAU scores standardized within year	**X**	**X**			**X**	**X**	**X**
Only schools with data for the whole period	**X**		**X**	**X**		**X**	**X**
Excluding year 2020					**X**		
Treatment group: 0.5 km away from the LEZ						**X**	**X**
Treatment group: 1 km away from the LEZ						**X**	**X**

Note: *** p-value ≤ 0.01, **p-value ≤ 0.05, *p-value ≤ 0.10. Standard errors are clustered at the district level and reported between parentheses.

6 Conclusions

The Madrid's LEZ implemented in late-2018 was an effective policy in reducing traffic-related emissions, enhancing air quality over the next four years. We argue that, in this more favourable environmental context, we should observe better academic outcomes among students schooled in that area. Consistently with that expectation, the EvAU scores of students schooled within the restricted area notably increased after the implementation of the LEZ. This is a highly relevant finding since university entrance in Spain is highly competitive in many degrees, and being in or out can be determined by less than a hundredth of a point. Thus, the improvement in performance caused by the LEZ greatly enhanced the opportunities of students schooled in the restricted area to access university education.

Importantly, we report that the effect grows larger for students taking the EvAU further away from the implementation date. This means that the effect of the LEZ is

stronger for students exposed to less pollution during more years (length of exposure) and from a younger age (timing of exposure). Interestingly, we also reveal positive spillover effects on schools 0.5km away from the LEZ, a finding consistent with previous works that documented a slight reduction in pollution levels also in the surroundings of *Madrid Central* (Lebrusán & Toutouh, 2021; Salas et al., 2021). Importantly, our findings are also consistent with the fact that, according to the last Household Mobility Survey (2018), underage students in the city of Madrid commute an average distance of 0.5km to go from home to school every day.

In sum, our work provides important insights on the positive externalities that the introduction of a low emission zone might have if successful in improving air quality. Other outcomes such as car accidentality, work productivity, or general well-being might also be positively impacted by this kind of policies.

7 References

Amanzadeh, N., Vesal, M., & Ardestani, S. F. F. (2020). The impact of short-term exposure to ambient air pollution on test scores in Iran. Population and Environment, 41(3), 253–285.

Balakrishnan, U., & Tsaneva, M. (2021). Air pollution and academic performance: Evidence from India. World Development, 146.

Duque, V., & Gilraine, M. (2022). Coal use, air pollution, and student performance. Journal of Public Economics, 213.

Galdon-Sanchez, J. E., Gil, R., Holub, F., & Uriz-Uharte, G. (2023). Social Benefits and Private Costs of Driving Restriction Policies: The Impact of Madrid Central on Congestion, Pollution, and Consumer Spending. Journal of the European Economic Association, 21(3).

Grineski, S. E., Collins, T. W., & Adkins, D. E. (2020). Hazardous air pollutants are associated with worse performance in reading, math, and science among US primary schoolchildren. Environmental Research, 181.

Heissel, J. A., Persico, C., & Simon, D. (2022). Does Pollution Drive Achievement? The Effect of Traffic Pollution on Academic Performance. The Journal of Human Resources, 57(3), 747–776.

König, C., & Heisig, J. P. (2023). Environmental inequality and health outcomes over the life course. In Handbook of Health Inequalities Across the Life Course (pp. 327–348). Edward Elgar Publishing Ltd.

Lebrusán, I., & Toutouh, J. (2021). Car restriction policies for better urban health: a low emission zone in Madrid, Spain. Air Quality, Atmosphere and Health, 14(3), 333–342.

Salas, R., Perez-Villadoniga, M. J., Prieto-Rodriguez, J., & Russo, A. (2021). Were traffic restrictions in Madrid effective at reducing NO2 levels? Transportation Research Part D: Transport and Environment, 91.

Shier, V., Nicosia, N., Shih, R., & Datar, A. (2019). Ambient air pollution and children's cognitive outcomes. Population and Environment, 40(3), 347–367.