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The impacts of climate change and air pollution on children's education outcomes: Evidence from Vietnam

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ABSTRACT

Very few studies have examined the impacts of both climate change and air pollution on student education outcomes, particularly in a developing country setting. Analyzing a rich database consisting of household and school surveys, test scores, and temperature and air pollution data over the past decade for Viet Nam, we find that a 1 $\mu g/m^3$ increase in PM2.5 concentration in the month preceding exams leads to 0.015 and 0.010 standard deviation decreases in math and reading scores, respectively. We also find some indicative evidence of stronger impacts of air pollution for younger, primary school students who reside in urban areas and in districts with higher temperatures. While we find some mixed effects of temperature, we do not find significant effects on students' test scores for temperature extremes and air pollution over the past 12 months. Our findings offer policy-relevant inputs for the country's ongoing efforts to fight air pollution.

1. Introduction

Warmer temperatures could negatively affect economic growth and labor productivity (Dell et al., 2012; Somanathan et al., 2021), as well as increasing global poverty (Dang et al., 2024). Recent studies suggest that heat exposure lowers school attendance and reduces the cognitive skills of students in the US and many countries around the world (Graff Zivin et al., 2018; Park et al., 2020; Park et al., 2021). At the same time, there is also an increasing concern that air pollution can impede cognitive function (Conte Keivabu & Rüttenauer, 2022; La Nauze & Severnini, 2021; Zhang et al., 2018). Yet, the literature on the impact of climate change on children's education outcomes in a poorer country context is still growing. Furthermore, little, if any, literature exists on whether *both* climate change and air pollution could exert even more harmful impacts on children's education outcomes in developing countries.

We make several new contributions in this paper. First, we offer the first study to assess the impacts of temperature change (including weather extremes) and air pollution on children's education in a developing country context. Our country of analysis—Viet Nam—presents an interesting case study that is susceptible to climate change and fast-rising air pollution at the same time. The World Bank and the Asian Development Bank (2021), in a joint report, consider Viet Nam to rank among the five countries in the world likely to be most affected by climate change. Among other concerns, rising temperatures could cause negative health outcomes, particularly for poorer communities and outdoor laborers.

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On the other hand, the country's average annual concentration of PM2.5 (fine particulate matter consisting of particles that are 2.5 μm or less in diameter) has been four to five times higher than the World Health Organization's (WHO) safety threshold of 10 $\mu g/m^3$ (micrograms of PM2.5 particles per cubic meter of air volume) (World Bank, 2022). The PM2.5 concentration trend has also been observed to exceed the global average for the past 20 years and to be similar to that of the People's Republic of China (PRC)—a country well-known for high levels of air pollution (Dang & Trinh, 2022). Given the alarmingly high air pollution in some cities, Viet Nam's Ministry of Health recently encouraged primary schools and kindergartens to temporarily close if air quality reached dangerous levels for three successive days (Nam, 2024).[1]

Second, the data that we analyze are nationally representative while most previous studies have focused on population subgroups. We analyze a rich database that we construct from multiple sources, including household surveys, school surveys, and student cognitive test scores, in combination with temperature and air pollution data spanning the past decade for the country.

While we do not find significant effects of temperature extremes or air pollution on educational outcomes, including school enrollment and the number of completed grades for children under 18, we observe *short-term impacts* of low temperatures and air pollution on students' cognitive abilities, as measured by math and literature scores. Specifically, using wind directions to instrument for air pollution endogeneity, our IV estimation results suggest that a 1 $\mu g/m^3$ increase in the monthly concentration of PM2.5 in the month preceding exams (equivalent to 3.9 % of the country's 2019 average) leads to a decrease of 0.015 and 0.010 standard deviations in math and literature scores, respectively. While high temperatures do not generally affect test scores (except for some weak impacts on reading scores), an additional day with temperatures below the 5th percentile in the temperature distribution results in an increase of 0.017 and 0.010 standard deviations in math and literature scores, respectively. Yet, no significant effects are found for temperature extremes and air pollution over the past 12 months on students' test scores. These results further highlight the importance of boosting the country's fight against the harmful effects of air pollution and global warming, at least in the short term.

We also find some evidence suggesting that there are stronger impacts of air pollution for primary students (compared to lower-secondary students), in urban areas (compared to rural areas), and in districts with higher temperatures, particularly in the Southeast and Mekong River Delta regions. But we do not find different effects for boys and girls or between the major Kinh ethnic groups and minor ethnic groups.

Our findings add to two separate literatures: one on the impacts of air pollution and the other on the impacts of global warming on education outcomes in developing countries. We review several recent studies that are most related to our study. With regard to the first literature, Zhang et al. (2018) find that long-term exposure to air pollution reduces verbal and math test performance among Chinese individuals, and there are stronger effects on verbal tests as people age, especially for men and the less educated. Studying data on students' English test scores from three major universities in three different cities in the PRC, Deng et al. (2023) observe considerable harmful effects of transitory exposure to air pollution during exams on student cognitive performance. These results concur with those from Yao et al. (2023), who examine a larger sample of students from 22 universities across the PRC. Analyzing data from 18 cities in 13 provinces in the PRC, Chen (2024) finds that a 1 mg decrease in both prenatal and postnatal exposure to total suspended particulates is associated with an increase of 6.41 standard deviations in literature scores and 4.21 standard deviations in math scores for students aged six and 19.

Analyzing data on students' college entrance examination scores in two Brazilian states, São Paulo and Rio de Janeiro, between 2015 and 2017, Carneiro et al. (2021) find negative impacts of air pollution (as measured by PM10) on test scores. Further studying infants born during the period 2001–2008 in São Paulo state, Brazil, Carneiro et al. (2024) find that an increase of 1 $\mu g/m^3$ of $PM_{2.5}$ due to agricultural burning during pregnancy reduces Portuguese and Math scores by 0.2–0.3 standard deviations, with boys more negatively impacted than girls. Balakrishnan and Tsaneva (2021) examine data from rural India and find that high levels of contemporaneous air pollution reduce reading outcomes by 1.11–2.39 percentage points and math outcomes by 0.53–1.90 percentage points, with more decreases for girls and older children. An earlier study by Graff Zivin et al. (2020) also finds negative impacts of agricultural fires on Chinese students' college entrance examination scores but does not offer precise estimates on the causal impacts of air pollution due to a lack of pollution data.[2]

As regards the second literature, there appear to be fewer studies on developing countries. Specifically, Hu and Li (2019) find that Chinese adults who had one additional high-temperature day during the in utero period accomplish 0.02 fewer years of schooling, are 0.18 % more likely to be illiterate, and achieve lower standardized word-test scores by 0.48 %. Analyzing India-wide student test scores, Garg et al. (2020) find that 10 extra days with an average daily temperature above 29 °C (relative to 15 °C – 17 °C) result in decreases of 0.03 and 0.02 standard deviations in math and reading test performance, respectively. Most recently, examining PISA (Programme for International Student Assessment) test scores from 58 developed and developing countries between 2000 and 2015, Park et al. (2021) observe that students have worse test scores on hotter days.

This paper consists of five sections. We describe the various datasets that we analyze in the second section. We lay out the analytical framework in Section 3 before discussing the estimation results in Section 4. We finally conclude in Section 5.

2. Data sources and descriptive analysis

In this study, we construct a rich database from four main data sources. The first dataset comprises student test scores collected under the Viet Nam Escuela Nueva (VNEN) project and the Research on Improving Systems of Education (RISE) project for Viet Nam with technical support from the World Bank and different universities, including the University of Minnesota and University College London. The data include test scores in mathematics and reading for primary and lower-secondary students, spanning Grades 2 to 7. The same tests were applied for all students across different provinces, with most of the tests being conducted in November and December. Specifically, 90 % of students took the tests during these two months, 9 % took them in April and May, and the remaining 1 % took the tests in January.

In this study, we analyze data from 39,033 students, which were

[1] The monetary costs of air pollution were estimated to range between 1 and 3.9 % of Viet Nam's GDP in 2020 (World Bank 2022) and between 60,000 and 99,700 deaths in the country could be linked to air pollution (WHO 2018a; Health Effects Institute 2024). Furthermore, Viet Nam's major urban areas can have exceptionally high seasonal pollution levels (Phung et al. 2016; Khuc, Nong and Vu 2022; World Bank 2022). For example, the capital city, Hanoi, was even reported to be the most air-polluted city in the world on a number of days in the past few years (SGGP News 2023; Reuters 2025; Quynh and Hui 2025; Vietnamplus 2025).

[2] Examining data from Indonesia, Jayachandran (2009) finds that prenatal exposure to air pollution caused by forest fire could increase under-three mortality by as much as 20%.

Table 1
Average math and reading test scores by survey year.

Year	Math score	Reading score
2013	15.1	22.0
	(0.1)	(0.1)
2014	12.3	18.6
	(0.1)	(0.1)
2015	14.3	20.5
	(0.1)	(0.1)
2017	13.1	14.1
	(0.1)	(0.1)
2018	15.2	18.8
	(0.1)	(0.2)
2019	13.0	14.4
	(0.1)	(0.2)

Note: Standard errors of the means are in parentheses.
Source: Estimation using data from the VNEN and RISE projects.

collected between 2013 and 2019.[3] Appendix Table A.1 presents the number of observations by years and grades. Appendix Table A.2 presents the demographic characteristics of students by year. Male students make up approximately 50 % of the sample. In Viet Nam, children start primary school at the age 6. Thus, most children are between 7 and 12 years old. The average age varies across years because of differences in the grades included each year. Kinh students comprise 47.9 % of the sample, while urban students account for 14.8 %.

Table 1 presents the average math and reading scores for each survey round. It should be noted that the test scores are not comparable across years, as the grade levels of students vary over the years.

The second dataset includes five rounds of the Viet Nam Household Living Standard Surveys (VHLSSs) from 2010 to 2018, which were biennially conducted by the General Statistics Office of Viet Nam. Each VHLSS round samples around 9400 households from 3000 communes across the country and collects consumption, demographics, education, and other data on individuals, households, and communes. Educational data include children's school enrollment and completed grades, as well as household expenditures on various educational items. Table 2 presents the educational variables for children aged 6–17. It shows that the enrollment rate increased from 92 % to 96 % during the 2010–2018 period. The average number of completed grades hovered around 4.3 in this period.

The third dataset comprises temperature and precipitation data, which are provided by Viet Nam's Institute of Meteorology, Hydrology, and Climate Change. The dataset includes daily precipitation as well as the minimum, mean, and maximum temperatures for each day. The daily average temperature and precipitation are estimated at the district level and merged with survey data using information on the district and interview years and months.[4] Fig. 1 presents a box plot of the median and variation (upper quartile, lower quartile, and adjacent values) of the daily mean temperature and the monthly PM2.5 of districts averaged over a year from 2010 to 2021. Panel A of Fig. 1 shows that the average daily temperature was around 25.0 °C during this period (with the lowest temperature being 24.0 °C in 2011 and the highest temperature being 25.5 °C in 2019).

The fourth dataset contains the air pollution data that we compile from the Sentinel-5P/TROPOMI (S5P) instrument of the European Union's Copernicus program. The S5P satellite uses a spatial resolution of 5.5 km and provides global coverage of air pollution measured by PM2.5. Panel B of Fig. 1 presents the monthly PM2.5 averaged across districts and months. The average PM2.5 increased from 19.2 μg/m3 in 1999 to a peak of around 31 μg/m3 in the 2008–2012 period and has then tended to decrease to around 25 μg/m3 in recent years.

Table 2
School outcomes of children aged 6–15 in VHLSSs.

Year	School enrollment rate (%)	Number of completed grades
2010	92.0	4.3
	(0.3)	(0.0)
2012	92.4	4.2
	(0.3)	(0.0)
2014	94.0	4.2
	(0.3)	(0.0)
2016	95.5	4.3
	(0.3)	(0.0)
2018	95.6	4.3
	(0.3)	(0.0)

Note: Standard errors of the means are in parentheses.
Source: Estimation using data from VHLSSs 2010–2018.

In terms of temperatures, Viet Nam, a tropical country, features two distinct climatic regions. Northern Viet Nam experiences four seasons with varying temperatures and precipitation. Winters are significantly cooler and drier than summers. In contrast, southern Viet Nam has just two seasons: a dry season from November to April and a rainy season from May to October. Appendix Fig. A.1 shows temperature variations across months, with June having the highest and January the lowest average temperature.

Fig. 2 presents the spatial distribution of average temperature and air pollution over the 2010–2019 period. The Northern region exhibits the lowest average temperatures, while the Southern region has the highest average temperatures. Regarding air pollution, the North faces the highest levels of air pollution. It's worth noting that the Red River Delta has high population density, which might contribute to more air pollution. However, even in sparsely populated areas like the Northern Mountains, air pollution remains high.[5] On the other hand, the Central Coast and Southeast regions have the lowest levels of air pollution.

Finally, we use monthly wind direction data, which are processed from the North American Regional Reanalysis (NARR) database. The wind conditions are recorded on a 32-by-32-km grid, presenting vector pairs for both east-west (u-component) and north-south (v-component) wind directions. Following the method of Deryugina et al. (2019), we interpolate between grid points to estimate daily u- and v-components for all districts in Viet Nam. Then, we transform the average u- and v-components into wind directions. We return to more discussion on this variable in the next section.

3. Estimation method

We first estimate the short-term effects of temperature extremes and air pollution on cognitive ability, which are measured by math and reading test scores. Specifically, we estimate the following regression:

$$y_{idmy} = \theta_0 + \sum_{j=1}^{k} \beta_j Temp_{dmy} + \theta_1 PM_{2.5,dmy} + X_{idmy}\theta_2 + T_{my} + D_d + \varepsilon_{idmy}, \quad (1)$$

where y_{idmy} is the (math or reading) test score of student i in district d in month m and year y (when the test was conducted). $Temp_{dmy}$ denotes

[3] The dataset contains some short-running and unbalanced panel data on approximately a third of students. For example, a portion of students in Grade 3 in 2013 was followed up in 2014 and 2015. But the panel data have a small sample size, so we focus on analyzing the cross sectional data. For more information on the VNEN data, see Dang et al. (2022).

[4] At the time of our analysis, Viet Nam has 63 provinces covering 705 districts.

[5] Some studies find that northerly winds flow from South China into Northern Vietnam during the monsoon season (October–March) may bring air pollution from Chinese cities in that region (Hien et al., 2011; Lasko et al., 2018).

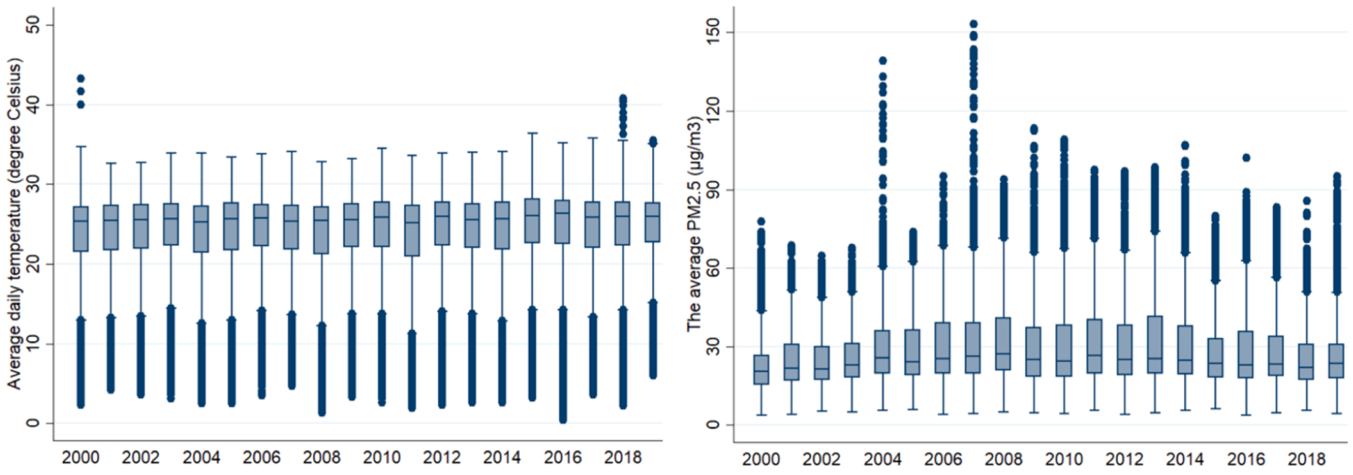

Fig. 1. Average temperature and air pollution over time.
Note: This figure presents a box plot of the median and variation (upper quartile, lower quartile, and adjacent values) of the daily mean temperature and the monthly PM2.5 of districts averaged over a year.

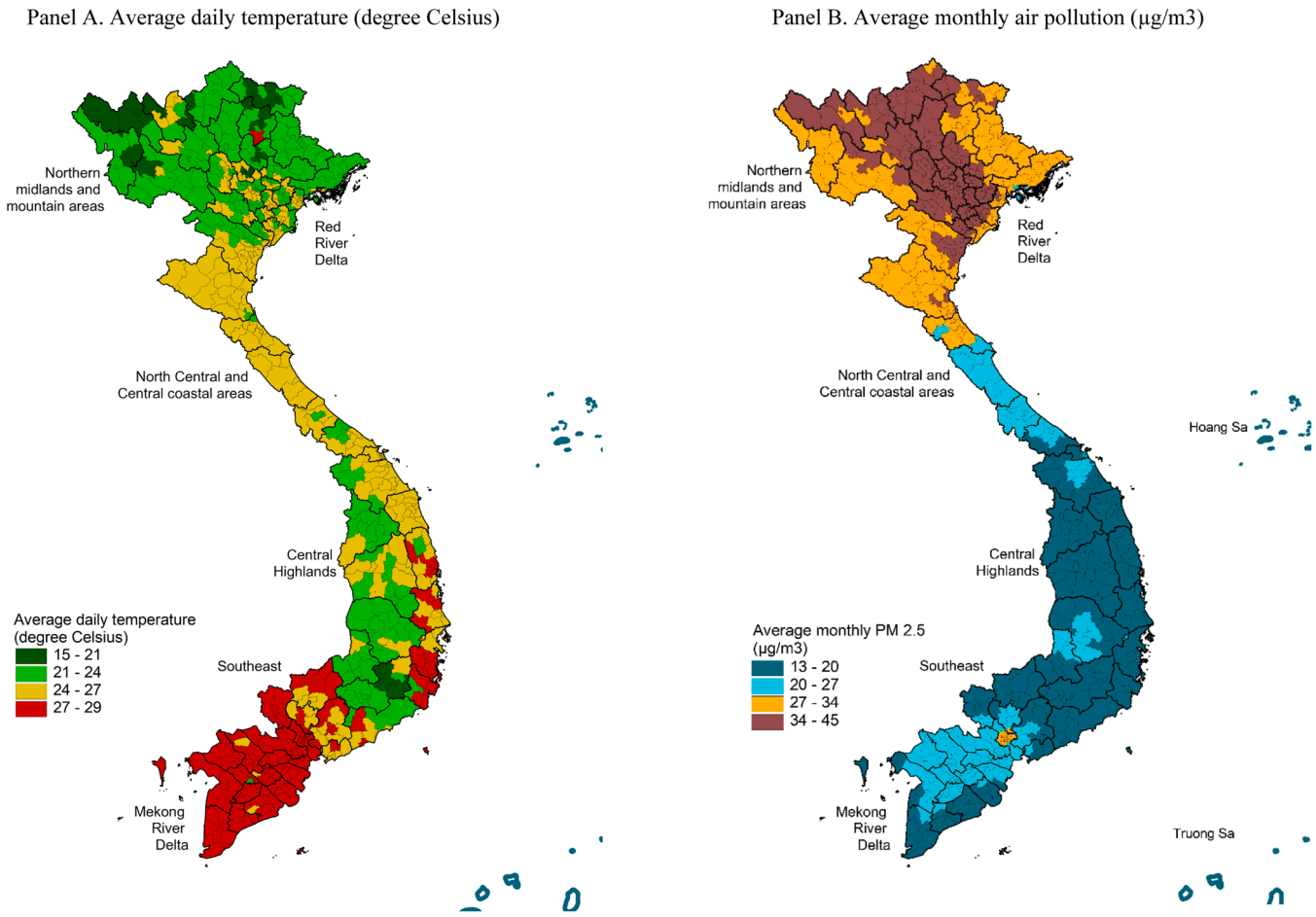

Fig. 2. District-level maps of average temperature and air pollution in Vietnam.
Note: Panel A presents the daily mean temperature of each district averaged over the 2010–2019 period, and Panel B shows the monthly PM2.5 of each district averaged over the same period.

variables indicating the number of days in a district-month with the daily mean temperature falling in different corresponding bins. To ease interpretation, we standardize students' test scores by grade and year so that the test scores for students in a given grade and year have a mean of zero and a standard deviation of one. Air pollution is measured by $PM2.5_{dmy}$, the average level of PM2.5 in district d in month m in year y. X_{idmy} is a vector of control variables including both student-level and district-level variables. These include age and gender of students, a dummy variable indicating the major Kinh ethnic group,[6] a dummy variable indicating urban residence, the yearly temperature, monthly precipitation, monthly wind speed, monthly humidity, year-by-month fixed effects (T_{my}), and district fixed effects (D_d). Year-by-month fixed effects can address the seasonal effects of temperature and air pollution variables. We control for monthly precipitation, monthly wind speed, and monthly humidity, since these variables can affect both air pollution and the educational outcomes of students.

Our main variables of interest are temperature and air pollution. Following previous studies including Barreca et al. (2016), Deryugina and Hsiang (2017), Deschenes and Greenstone (2011), and Mullins and White (2020), we classify days within a month into different temperature bins. According to the WHO (2018b), the range of minimum risk for higher temperatures is between 15 °C and 30 °C. For the case of Viet Nam, we construct seven temperature bins in degrees Celsius as follows: 0–15; 15–18; 18–21; 21–24; 24–27; 27–30; 30+. Fig. 3, Panel A presents the average number of days per year with daily mean temperatures falling into seven bins for the 2000–2019 period. Most of the days have temperatures of between 15 °C and 30 °C. On average, only 16 days have a temperature below 15 °C and 19 days have a temperature above 30 °C.

In addition to temperature bins, we also consider temperature extremes as measured by abnormally warm weather. Most studies use a threshold of a given percentile such as the 90th and 95th percentile of the temperature distribution of a specific location (see, for example, Perkins, 2015). Using common or absolute temperature thresholds may not be appropriate in a country with varying climates (Anderson & Bell, 2011; Kent et al., 2014), since people in warm areas are familiar with high temperatures and have adapted to them. The impact of a 30 °C temperature may be more pronounced in colder regions than in warmer ones. Consequently, we opt for relative temperature thresholds, which are considered more exogenous. We define the temperature extremes that a district is exposed to by the number of days within a month or a year that are below the 5th or above the 95th percentile of the temperature distribution of a district during the 2000–2019 period. As such, the temperature thresholds vary across districts. Fig. 3, Panel B presents the average number of days per year below the 5th percentile and those above the 95th percentile of the district-specific temperature distribution during the 2000–2019 period.

We estimate the effects of temperature extremes on children's education using the following equation:

$$y_{idmy} = \gamma_0 + \gamma_1 Low_{dmy} + \gamma_2 High_{dmy} + \gamma_3 PM_{2.5,dmy} + X_{idmy}\gamma_4 + T_{my} + D_d + u_{idmy}, \quad (2)$$

where Low_{dmy} and $High_{dmy}$ denote the number of days with low and high temperatures in district d in month m and year y, respectively. These "low temperature" and "high temperature" measurements are based on the number of days in the preceding month with temperatures falling below the 5th percentile and exceeding the 95th percentile, respectively, of the daily temperature distribution within the same district during the period 2000–2019.

[6] There are 54 ethnic groups in Viet Nam. Vietnamese Kinh people accounted for around 85% of the population of Viet Nam in the 2019 census. Compared with other ethnic minorities, Kinh people have higher living standards and are more likely to reside in delta regions.

One problem with estimating the impacts of air pollution is its endogeneity. Widely used instruments for air pollution are thermal or temperature inversions (Arceo et al., 2016; Chen et al., 2022; Deschenes et al., 2020; He et al., 2019; Jans et al., 2018; Xie et al., 2023), and wind patterns consisting of wind directions (Austin et al., 2023; Deryugina et al., 2019; Heyes & Zhu, 2019; Isphording & Pestel, 2021; Li & Meng, 2023; Rangel & Vogl, 2019). We use wind directions as the instrumental variable for air pollution.

We construct the wind direction using monthly averaged data from the ERA5 global reanalysis (Hersbach et al., 2020). Specifically, we first record the u and v wind components on an hourly basis, and we subsequently compute their monthly averages by averaging all hourly observations within each month. This approach yields the prevailing wind direction for that month. Applying this process at the district level for Viet Nam, we generate for each district a monthly measure of the prevailing wind direction based on the corresponding ERA5 data. We subsequently construct binary variables for wind direction, classifying them into eight bins: [0, 45) and [45, 90) degrees for the east; [90, 135) and [135, 180) degrees for the south; [180, 225) and [225, 270) degrees for the west; and [270, 315) and [315, 360) degrees for the north. The advantage of the instrumental variable (IV) approach is that it does not require controlling for the sources of air pollution (Deryugina et al., 2019). Given that we control for district fixed effects as well as year-by-month fixed effects, we expect that the wind directions are exogenous.

We use Eqs. (1) and (2) to estimate the effects of temperature extremes and air pollution on the test scores of students, using the data from the VNEN and RISE projects. We matched climate and air pollution data with student data at the district level, based on the months and years when students took the tests. To measure the effects on school enrollment and children's grades, we use data from VHLSSs. It should be noted that VHLSS data on children's school enrollment and grades are collected using the 12-month reference period. Thus, we measure the effects of the temperature extremes and the air pollution intensity during the past 12 months on the school enrollment and the number of completed grades of children. We matched climate and air pollution data with VHLSS data based on the districts of household residence and the months and years of their interviews.

We cluster standard errors at the primary sampling unit level (Abadie et al., 2023), which is the school level for the data from the VNEN and RISE projects and the commune level for the VHLSS data. For robustness checks, we use heteroscedasticity-robust standard errors and robust standard errors clustered at the district level.

4. Empirical results

4.1. Impacts of temperature extremes and air pollution

We start with the short-term effects of temperature extremes and air pollution on students' math and reading test scores. For each dependent variable, we employ two models corresponding to Eqs. (1) and (2): Model 1 to estimate the effects of temperature bins and Model 2 to estimate the effects of temperature extremes.

Air pollution is instrumented by wind directions, and the instrument needs to be strongly correlated with air pollution. Table A.3 in the Appendix presents the first-stage regression of air pollution on wind directions and other control variables in the sample of students from the VNEN and RISE data. Additionally, Appendix Tables A.4 and A.5 report the first-stage regression of air pollution for the samples of children and households in the VHLSS data. All the results show a strong correlation

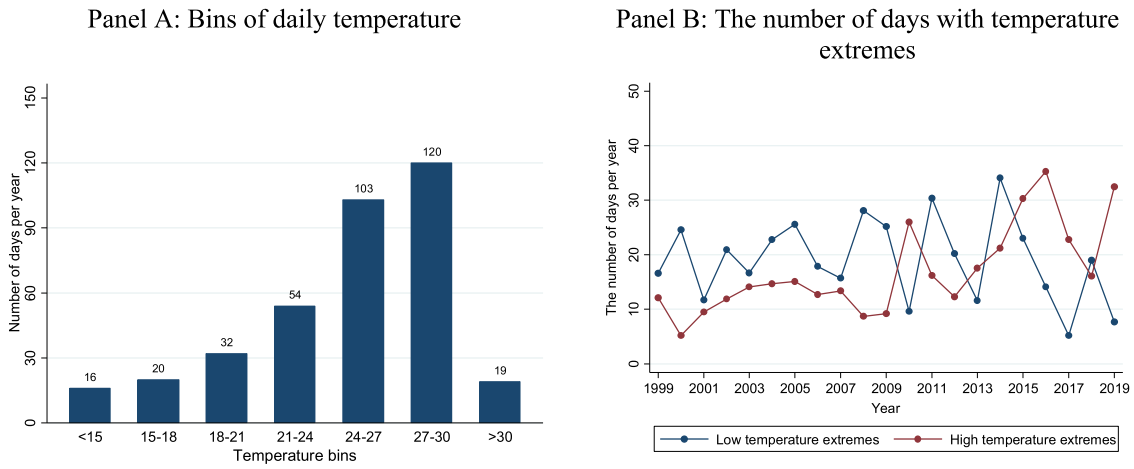

Fig. 3. Bins of daily temperature and temperature extremes.
Note: This figure presents the average number of days per year in different temperature bins averaged across districts and the 2010–2019 period.
Note: This figure shows the average number of days per year below the 5th and those above the 95th percentile of the district-specific temperature distribution during the 2000–2019 period.

between the wind direction dummy variables and air pollution. The tables also present the Cragg-Donald Wald *F* statistics (F- test of excluded instruments) and effective *F* statistics using the approach of Olea and Pflueger (2013) to examine a potential weak IV issue (Cragg & Donald, 1993; Kleibergen & Paap, 2006; Staiger & Stock, 1997). The test statistics are very high, thus supporting the strength of the IV.[7]

Table 3 shows that air pollution has negative and statistically significant effects on math and reading test scores. The point estimates of air pollution are quite similar in models that control for temperature bins and those that control for temperature extremes. In models with controlling for temperature bins (Columns 1 and 2), we find that a 1 μg/m^3 increase in the monthly concentration of PM2.5 in the month preceding exams (equivalent to 3.9 % of the country's 2019 average) leads to a decrease of 0.015 and 0.010 standard deviations in math and reading scores, respectively. Our results are consistent with recent studies such as those by Amanzadeh et al. (2020), Balakrishnan and Tsaneva (2021), and Carneiro et al. (2021), which show that air pollution negatively impacts the cognitive performance of students.[8]

For comparison, we present the OLS regressions of test scores on air pollution and temperature extremes in Table A.6 in the Appendix. It shows a negative and statistically significant correlation between air pollution and the standardized math scores (Columns 1 and 3). The correlation between air pollution and the standardized reading scores is small and not statistically significant. This indicates that our 2SLS estimates are larger than the OLS estimates, suggesting a downward bias in the OLS estimates. While there can be various omitted variables that we do not fully control for in the regressions, children's health may be one possible channel leading to this bias. This assumes that children's health is positively correlated with their test scores, and air pollution has negative effects on children's health.[9] We return to more discussion in Section 4.4.

In regard to the effects of temperature, we do not observe significant impacts of high temperatures on test scores. However, we find positive effects of low temperatures on test scores. Compared with the 21–24 °C reference bin, an additional day with a temperature below 15 °C is associated with a 0.011 increase in the standard deviation of math scores and a 0.009 increase in the standard deviation of reading scores (as reported in Columns 1 and 2 of Table 3). Estimates from the analysis of temperature extremes also yield consistent findings. An increase of one day with temperatures below the 5th percentile in the temperature distribution results in an increase of 0.017 and 0.010 standard deviations in math and reading scores, respectively. We further interact air pollution and temperature extremes, but the estimates on the interaction terms are not statistically significant (not shown).

While our findings on the positive effects of cold weather on education appear to contradict earlier findings in some studies including Johnston et al. (2021) and Alberto et al. (2021), a possible explanation for the positive effects of cold weather on test scores in our study is that cold temperatures in Vietnam are much milder and are not as extreme as in countries like Australia and the U.S.[10] In our data sample, cold weather is defined as degrees below 15 °C. However, only five districts (over three years) have an average monthly temperature between 7 °C and 10 °C. Among districts experiencing cold weather, almost all had an average temperature between 10 °C and 15 °C, and half had an average monthly temperature around 14 °C-15 °C. Indoor temperatures were likely higher, and as a result, this relatively mild (outdoor) cold weather might help improve students' educational performance, possibly through more beneficial impacts on health outcomes compared to hotter weather (Ballester et al., 2023; Ebi et al., 2021).

Regarding high temperatures, one possible reason we do not find a significant short-term effect is that in our sample approximately 90 % of students took the tests during November and December, with the remainder taking them between January and May. November and December have lower temperatures than the other months. Moreover,

[7] We use the Stata user-written command "ivreg2" to obtain these statistics (Baum et al., 2002).

[8] Amanzadeh, Vesal, and Ardestani (2020) find that a 1 standard deviation increase in PM2.5 reduces the test scores of students in Iran by 0.029 standard deviations. Carneiro, Cole, and Strobl (2021) show that a 10 μg/m^3 increase in PM_{10} on the examination day decreases entrance university scores in Brazil by 6.1 points (8% SD). Balakrishnan and Tsaneva (2021) find that a 1 μg/m3 increase in $PM_{2.5}$ reduces the math and reading outcomes of Indian students (aged 5–16) by 0.53–1.90 percentage points and 1.11–2.39 percentage points, respectively.

[9] Recent studies suggest that air pollution is harmful to brain development and could affect cognitive abilities (Suglia et al. 2008; Wang et al. 2009; Livingston et al. 2017; Marcotte 2017; Chandra et al. 2022). A lower cognitive ability can subsequently lead to reduced test scores among students.

[10] Johnston et al. (2021) find that cold days negatively affect test scores in Australia, while Alberto et al. (2021) report that cold days reduce class and self-study time for students in the U.S.

Table 3
2SLS regressions of students' test scores.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0146***	−0.0100**	−0.0152***	−0.0115**
	(0.0048)	(0.0048)	(0.0046)	(0.0046)
Number of days 0–15 °C	0.0112***	0.0085**		
	(0.0039)	(0.0039)		
Number of days 15–18 °C	0.0002	0.0059**		
	(0.0026)	(0.0024)		
Number of days 18–21 °C	0.0001	0.0042		
	(0.0028)	(0.0027)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0035	−0.0006		
	(0.0024)	(0.0022)		
Number of days 27–30 °C	−0.0010	0.0004		
	(0.0031)	(0.0031)		
Number of days 30 °C +	−0.0049	−0.0058		
	(0.0064)	(0.0067)		
Number of days below the 5th percentile of daily temperature			0.0171***	0.0102***
			(0.0037)	(0.0039)
Number of days above the 95th percentile of daily temperature			0.0021	0.0040
			(0.0041)	(0.0044)
Gender (boy = 1, girl = 0)	−0.0790***	−0.2926***	−0.0788***	−0.2928***
	(0.0117)	(0.0108)	(0.0118)	(0.0108)
Age	1.1499***	2.6234***	1.1529***	2.6234***
	(0.0993)	(0.2032)	(0.0999)	(0.2035)
Age squared	−0.0535***	−0.1275***	−0.0536***	−0.1276***
	(0.0052)	(0.0107)	(0.0052)	(0.0107)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4676***	0.4654***	0.4643***	0.4657***
	(0.0368)	(0.0389)	(0.0367)	(0.0389)
Urban areas (Urban = 1, rural = 0)	0.2795***	0.2123***	0.2805***	0.2142***
	(0.0484)	(0.0369)	(0.0483)	(0.0368)
Monthly precipitation (mm)	0.0241**	0.0232**	0.0227**	0.0212**
	(0.0102)	(0.0093)	(0.0099)	(0.0091)
Annual average temperature (°C)	−0.0377	0.0257	−0.1471***	−0.0407
	(0.0502)	(0.0496)	(0.0541)	(0.0554)
Monthly wind speed	0.0164	0.0200	0.0027	0.0119
	(0.0147)	(0.0161)	(0.0156)	(0.0171)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−4.4828***	−12.7417***	−1.6863	−10.8577***
	(1.3977)	(1.6435)	(1.5684)	(1.8250)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

our analysis uses district fixed-effect regressions. The reliance of these regressions on fewer within-district variations in temperatures during the test months may also help explain the lack of significant short-term effects.[11]

Table 3 also reveals several interesting findings regarding the relationship between test scores and the explanatory variables. Older children tend to achieve higher test scores than younger ones, while girls generally outperform boys. Notably, the gender gap in reading scores is more significant than in math. Boys score 0.079 standard deviations lower in math and 0.293 standard deviations lower in reading than girls (Columns 1 and 2).[12] As expected, Kinh and urban students have significantly higher scores than ethnic minority and rural students. Furthermore, students in districts with higher monthly precipitation achieve higher test scores than those in districts with lower monthly precipitation.

In Table 4, we examine the medium-term effects of air pollution by estimating the PM2.5 concentration over the past three months and the past 12 months on the test scores in the current month. Both regression models (using temperature bins and temperature extremes) reveal negative effects of the air pollution concentration during the past three months. Specifically, Columns 1 and 2 indicate that a 1 μg/m^3 increase in the concentration of PM2.5 in the three months preceding exams results in a decrease of 0.014 and 0.022 standard deviations in math and

[11] Appendix Figure A.2 presents the average daily temperature for districts included in the VNEN and RISE surveys during the years when students took the exams. The vertical axis shows the average daily temperature during the test months (January to May, and November to December), while the horizontal axis shows the average across all 12 months (Panel A). This figure indicates that temperatures during the test months are consistently lower than the annual average. Panel B shows that the within-district standard deviation of daily temperatures during the test months is also lower than that of the full year.

[12] This "reverse gender gap" is consistent with findings in earlier studies. For example, Dang and Glewwe (2018) observe that boys had better performance than girls in the 1990s and early 2000s. But girls started outperforming boys from around 2006 in both school enrolment and test scores.

Table 4
2SLS regressions of students' test scores: Medium-term effects.

Explanatory variables	Panel A. Effects of intensity of air pollution and temperature during the past 3 months				Panel B. Effects of intensity of air pollution and temperature during the past 12 months			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0135*	−0.0217***	−0.0140**	−0.0187***	0.0120	0.0164	0.0153	0.0115
	(0.0072)	(0.0080)	(0.0062)	(0.0069)	(0.0197)	(0.0202)	(0.0168)	(0.0173)
Number of days 0–15 °C	0.0017	−0.0009			0.0011	−0.0036		
	(0.0029)	(0.0032)			(0.0047)	(0.0047)		
Number of days 15–18 °C	0.0018	0.0041			−0.0007	−0.0032		
	(0.0030)	(0.0033)			(0.0029)	(0.0028)		
Number of days 18–21 °C	−0.0012	−0.0041*			0.0019	−0.0010		
	(0.0023)	(0.0024)			(0.0017)	(0.0016)		
Number of days 21–24 °C	0	0			0	0		
Number of days 24–27 °C	−0.0025	−0.0055**			0.0019	−0.0006		
	(0.0019)	(0.0023)			(0.0023)	(0.0022)		
Number of days 27–30 °C	−0.0002	−0.0042			0.0041	0.0021		
	(0.0025)	(0.0029)			(0.0029)	(0.0029)		
Number of days 30 °C +	0.0003	−0.0108*			0.0045	0.0001		
	(0.0053)	(0.0059)			(0.0036)	(0.0037)		
Number of days below the 5th percentile of daily temperature			0.0131***	0.0066*			0.0015	−0.0005
			(0.0035)	(0.0039)			(0.0014)	(0.0015)
Number of days above the 95th percentile of daily temperature			0.0047	0.0054			−0.0013	0.0005
			(0.0032)	(0.0035)			(0.0014)	(0.0013)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−2.8767*	−9.6929***	−1.8081	−9.0272***	−4.8937**	−13.6756***	−7.5083***	−13.9410***
	(1.7439)	(2.0243)	(2.0098)	(2.3924)	(2.3492)	(2.4333)	(2.3997)	(2.5714)
Observations	39,033	39,033	39,033	39,033	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
The control variables are the same as those in Table 3.
Source: Estimation using data from the VNEN and RISE projects.

reading scores, respectively. However, air pollution concentration during the past 12 months does not have significant impacts on the test scores. This finding suggests a shorter-term rather than a longer-term effect of air pollution on students' test scores. A possible reason is that since air pollution is highly seasonal in Viet Nam (Hien et al., 2011; Phung et al., 2016; Khuc et al., 2022; World Bank, 2022), air pollution concentration may be better measured in a shorter time window of the past three months rather than during the past 12 months.[13] But clearly more research and more data on longer exposure periods are needed to provide further insights on these results.

We also find some negative effects of hotter temperature but only for reading scores (Column 2). We return to more discussion with robustness checks when we change the reference temperature bin later (Section 4.3).

Table 5 reports 2SLS estimates of the impacts of temperature extremes and air pollution on school enrollment and the number of completed grades of children aged 6–17 using VHLSS data. (We report the OLS regressions in Table A.7 in the Appendix). We measure temperature and air pollution over the past 12 months, as opposed to the previous month, as in Table 3. We do not find any significant effects of temperature or air pollution on these variables. This finding appears to contrast those in recent studies for various countries including China, South Korea and the U.S., which find negative impacts of air pollution on school attendance likely through reduced student health (Park et al., 2002; Currie et al., 2009; Chen et al., 2018; Aziz & Elbakidze, 2025).

However, we hypothesize that since Viet Nam is a country with very high school enrollment rates, temperature and air pollution shocks might only affect students' cognitive performance in the short term but not their school enrollment.[14] This is consistent with the finding that there are no significant effects of air pollution intensity during the past

[13] Reviewing several publications on lung function growth in Austrian schoolchildren, Gotschi et al. (2008) observe that negative effects of O3 and, to a lesser degree, of PM10 on lung function growth during summer were compensated for during the winter seasons.

[14] Dang and Glewwe (2018) find that primary school enrolment and lower secondary school enrolment (for Vietnamese children in a similar age range as we study in this paper) hovers around 98% and 95% respectively. These numbers are consistent with the figures shown in Table 2.

Table 5
2SLS regressions of school enrollment and completed grades.

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0)	Number of completed grades	School enrollment (yes = 1, no = 0)	Number of completed grades
	(1)	(2)	(3)	(4)
PM2.5 (μg/m3)	0.0009	0.0230	0.0013	0.0206
	(0.0044)	(0.0148)	(0.0038)	(0.0125)
Number of days 0–15 °C	−0.0013*	−0.0015		
	(0.0007)	(0.0026)		
Number of days 15–18 °C	−0.0012**	−0.0021		
	(0.0005)	(0.0018)		
Number of days 18–21 °C	−0.0010***	−0.0011		
	(0.0003)	(0.0011)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	0.0001	−0.0001		
	(0.0002)	(0.0008)		
Number of days 27–30 °C	0.0004	−0.0010		
	(0.0003)	(0.0010)		
Number of days 30 °C +	0.0009**	0.0007		
	(0.0005)	(0.0017)		
Number of days below the 5th percentile of daily temperature			0.0001	−0.0004
			(0.0003)	(0.0011)
Number of days above the 95th percentile of daily temperature			0.0001	−0.0007
			(0.0002)	(0.0009)
Gender (boy = 1, girl = 0)	−0.0149***	−0.0633***	−0.0149***	−0.0632***
	(0.0033)	(0.0127)	(0.0033)	(0.0127)
Age	0.1029***	0.9971***	0.1029***	0.9964***
	(0.0050)	(0.0147)	(0.0050)	(0.0147)
Age squared	−0.0056***	−0.0030***	−0.0056***	−0.0030***
	(0.0002)	(0.0007)	(0.0002)	(0.0007)
Kinh (Kinh = 1, ethnic minorities = 0)	0.0722***	0.3518***	0.0721***	0.3506***
	(0.0087)	(0.0396)	(0.0087)	(0.0396)
Urban areas (Urban = 1, rural = 0)	0.0166***	0.0512**	0.0164***	0.0504**
	(0.0051)	(0.0215)	(0.0051)	(0.0216)
Annual precipitation (mm)	−0.0000	0.0050	−0.0003	0.0037
	(0.0018)	(0.0068)	(0.0018)	(0.0066)
Annual average temperature (°C)	−0.0465**	−0.0322	−0.0039	−0.0153
	(0.0207)	(0.0735)	(0.0115)	(0.0421)
Annual wind speed	0.0084	0.0226	0.0087	0.0210
	(0.0061)	(0.0245)	(0.0061)	(0.0247)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	1.6320***	−5.8436***	0.5524	−6.3402***
	(0.5492)	(1.9036)	(0.4016)	(1.3995)
Observations	26,558	26,558	26,558	26,558

Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

12 months on student test scores. Children living in districts with lower temperatures have a lower probability of school enrollment. However, the effects of temperature extremes on both school enrollment and school grades are not statistically significant (Column 3 and 4 in Table 5).

4.2. Heterogeneous effects

In this section, we examine the heterogeneous effects of air pollution by running regressions of math and reading test scores on air pollution concentration, using the model specification in Eq. (1) for different student subgroups (Columns 1 and 2 in Table 3). Fig. 4 graphs the estimates and the 95 % confidence interval of the air pollution variable in these regressions (the full regression results are reported in Tables A.8, A.9, A.10, A.11, A.12, A.13, A.14, A.15 in the Appendix). The heterogeneous effects on the math scores (Panel A of Fig. 4) are quite similar to those on the reading scores (Panel B of Fig. 4). For interpretation purposes, we use the results for the math scores.

Air pollution has similar (negative) effects on both boys and girls. We also examine whether the effects differ between children under 10 years old and those age 10 and above. In our sample, children under 10 attend grades 2 to 4, while children age 10 and above attend grades 5 and 7. The results show that air pollution appears to adversely affect younger children (age 10 and below) more than older children (age above 10). The effects on students above 10 years old are small in magnitude and not statistically significant. This finding also suggests that the negative impacts of air pollution on test scores are primarily driven by its effects on younger children.

In terms of area, the impacts of air pollution tend to be higher in urban than in rural areas. The point estimates of air pollution on the test scores of Kinh and ethnic minority students are quite similar and both negative. However, the estimated impacts on ethnic minority students are statistically significant, while those on Kinh students are not.

We also estimate the effects of air pollution on test scores based on the months when students took the tests. The effects do not vary significantly here. Next, we divide the student sample based on the average temperature of their districts, using the median monthly temperature as a threshold. We find that the impacts of air pollution tend to be greater in warmer districts, though the differences are not statistically significant.[15] Generally, districts with high temperatures tend to be located in the Southeast and Mekong River Delta regions. This aligns with the heterogeneous analysis by regions, in which we find higher effects of air pollution on student test scores in the Mekong River Delta and smaller effects on the northern mountain region (a low-temperature region).

4.3. Robustness checks

We conduct a number of robustness checks to examine the sensitivity of the estimation results. First, we assess whether the estimates are sensitive to different control variables. In Tables A.17 and A.18 in the Appendix, we employ a model without controlling for explanatory

[15] We further examine the joint effect of temperature and air pollution by running 2SLS regressions on test scores for two subsamples: districts with PM2.5 levels below 27 μg/m³ (the median monthly PM2.5 in our dataset) and districts with PM2.5 levels at or above 27 μg/m³. The results, presented in Appendix Table A.16, indicate no negative effects of air pollution when PM2.5 levels are below 27 μg/m³. There are negative effects of PM2.5 when PM2.5 levels are at or above this threshold. We do not observe negative effects of high temperatures in areas with high PM2.5 levels.

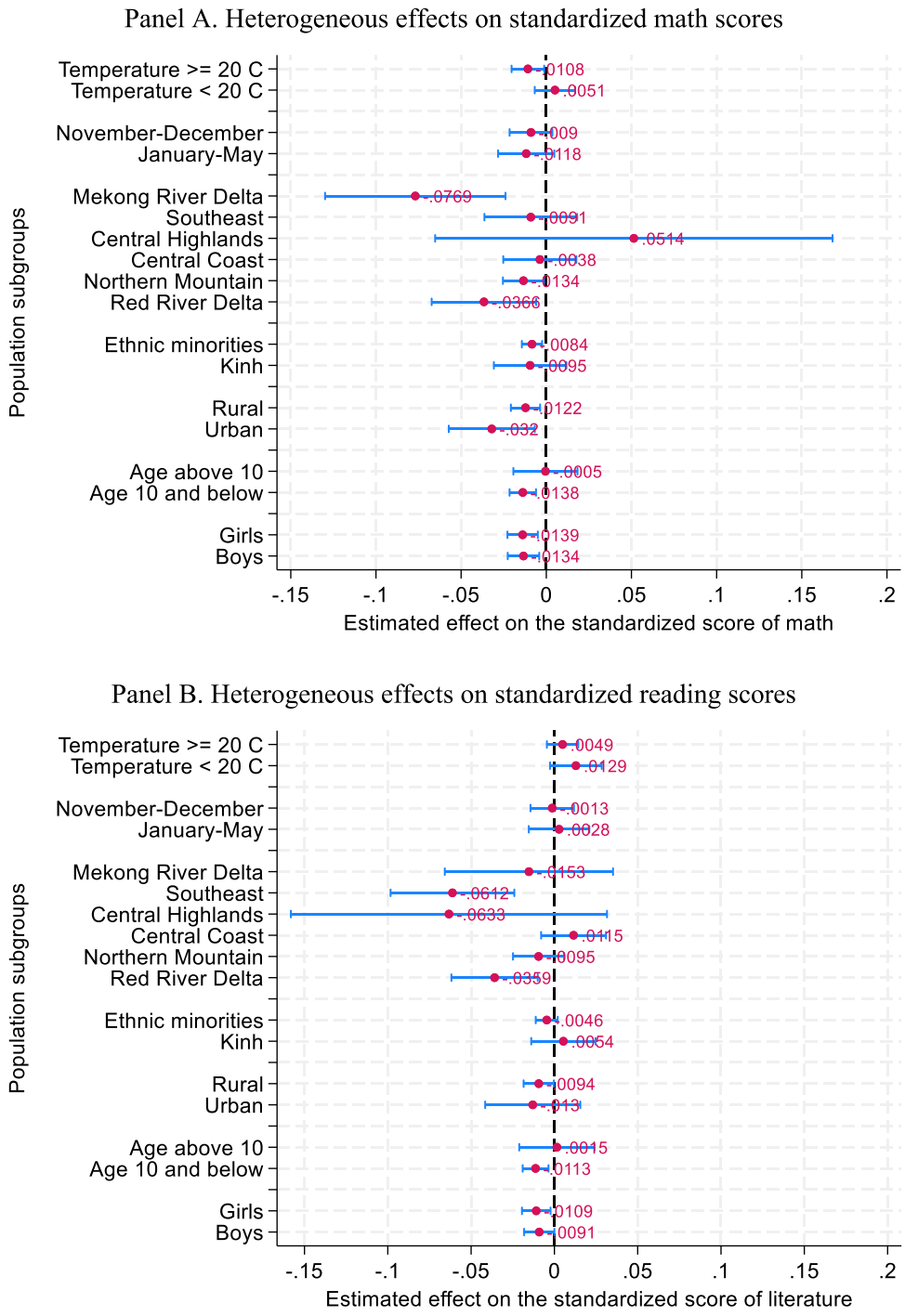

Fig. 4. Heterogeneous effects of air pollution on test scores.
Note: This figure graphs the estimates and their 90 % confidence intervals of air pollution (PM2.5 (μg/m3)) in regressions of the standardized scores of students in different population subgroups of students. The model specification is the same as in Table 3.

variables (demographic characteristics of students and meteorological variables). The estimated effects of air pollution are very similar to those in the previous tables.

Second, we include district-month fixed effects, which allow for controlling for district-specific seasonality. The results, reported in Appendix Table A.19, show that the effect estimates (the sign and magnitude) are very similar to those in Table 3. However, controlling for district-month fixed effects reduces the degrees of freedom, which in turn lowers the statistical significance of the air pollution estimates. Therefore, we do not use these results for interpretation.

Table 6
2SLS regressions of healthcare utilization of children.

Explanatory variables	Dependent variables			
	Number of healthcare contacts (1)	Log of healthcare expenditure (2)	Number of healthcare contacts (3)	Log of healthcare expenditure (4)
PM2.5 (μg/m3)	0.0240	−0.0644	0.0195	−0.0662
	(0.0392)	(0.0482)	(0.0332)	(0.0405)
Number of days 0–15 °C	0.0008	0.0008		
	(0.0065)	(0.0085)		
Number of days 15–18 °C	−0.0021	−0.0067		
	(0.0042)	(0.0057)		
Number of days 18–21 °C	0.0000	−0.0017		
	(0.0024)	(0.0034)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0009	−0.0021		
	(0.0016)	(0.0023)		
Number of days 27–30 °C	−0.0026	−0.0008		
	(0.0026)	(0.0033)		
Number of days 30 °C +	0.0005	0.0000		
	(0.0040)	(0.0056)		
Number of days below the 5th percentile of daily temperature			0.0025	0.0007
			(0.0026)	(0.0035)
Number of days above the 95th percentile of daily temperature			0.0018	0.0008
			(0.0019)	(0.0024)
Gender (boy = 1, girl = 0)	0.0463*	0.0812**	0.0454*	0.0810**
	(0.0237)	(0.0325)	(0.0236)	(0.0324)
Age	−0.1617***	−0.1684***	−0.1627***	−0.1688***
	(0.0328)	(0.0491)	(0.0329)	(0.0491)
Age squared	0.0045***	0.0042*	0.0045***	0.0042*
	(0.0015)	(0.0023)	(0.0015)	(0.0023)
Kinh (Kinh = 1, ethnic minorities = 0)	0.0459	0.1868***	0.0438	0.1858***
	(0.0495)	(0.0680)	(0.0495)	(0.0681)
Urban areas (Urban = 1, rural = 0)	−0.0147	0.0436	−0.0142	0.0412
	(0.0387)	(0.0529)	(0.0386)	(0.0529)
Annual precipitation (mm)	0.0130	0.0187	0.0114	0.0175
	(0.0150)	(0.0204)	(0.0144)	(0.0200)
Annual average temperature (°C)	−0.0794	−0.0901	−0.1289	−0.0524
	(0.1728)	(0.2220)	(0.0889)	(0.1198)
Annual average wind speed	0.0346	0.0127	0.0441	0.0111
	(0.0534)	(0.0704)	(0.0531)	(0.0700)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	5.0499	11.9348**	5.9791*	10.5296**
	(4.7348)	(5.8221)	(3.2122)	(4.3073)
Observations	26,558	26,558	26,558	26,558

Note: The sample includes children aged 6–15. For healthcare expenditure, we use the log(y + 1) transformation, since there are children with zero healthcare expenditure in the sample.
Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Third, we attempt to control for province-specific time trends, allowing for different growth rates in outcome variables across provinces. Table A.20 in the Appendix demonstrates that controlling for province-specific time trends yields similar estimates of air pollution impacts to those in Table 3 (without province-specific time trends). However, we do not rely on the results from Table A.20 for our preferred analysis, as controlling for province-specific time trends may obscure the effects of the key variables in this study —PM2.5 and temperature.[16]

Fourth, we examine whether the estimation results of air pollution are sensitive to the classification of wind direction bins. For the main analysis, we construct binary variables indicating eight wind direction bins. As a robustness check, we create four binary variables for wind directions: [0, 90) degrees for the east; [90, 180) degrees for the south; [180, 270) degrees for the west; and [270, 360) degrees for the north. The 2SLS regressions using these wind direction bins are reported in Table A.21 in the Appendix, showing similar estimates to those in Table 3.

Fifth, we examine different methods for clustering standard errors, and the results consistently show strong levels of statistical significance. For the main interpretation, we cluster the standard errors at the primary sampling unit level (Abadie et al., 2023). We also examine traditional heteroscedasticity-robust standard errors (Appendix Table A.22) and cluster the standard errors at the district level (Appendix Table A.23). The results also show negative and significant effects of air pollution and positive and significant effects of low temperatures on the test scores of students.

Sixth, we examine whether the effect of temperature bins is sensitive to different definitions of the bins. In Table 3, we use 21–24 °C as the reference temperature bin. To test the sensitivity of our estimates to this choice, we also use 15–18 °C and 18–21 °C as reference bins. The results, presented in Appendix Table A.24, show that low temperatures continue

[16] Previous studies suggest that if the effect of interest is more complex than an intercept shift, the trend terms may partially absorb this estimated effect and bias it downward (Wolfers 2006; Baum-Snow and Lutz 2011).

Table 7
2SLS regressions of per capita income and consumption expenditure.

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
PM2.5 (μg/m3)	−0.0006	0.0084	0.0047	−0.0043	0.0080	0.0039
	(0.0084)	(0.0069)	(0.0382)	(0.0071)	(0.0058)	(0.0324)
Number of days 0–15 °C	−0.0012	−0.0012	−0.0033			
	(0.0016)	(0.0013)	(0.0074)			
Number of days 15–18 °C	−0.0009	−0.0005	0.0028			
	(0.0010)	(0.0009)	(0.0048)			
Number of days 18–21 °C	−0.0002	−0.0002	−0.0004			
	(0.0005)	(0.0004)	(0.0023)			
Number of days 21–24 °C	0	0	0			
Number of days 24–27 °C	0.0002	−0.0004	0.0008			
	(0.0006)	(0.0005)	(0.0028)			
Number of days 27–30 °C	0.0003	−0.0001	0.0029			
	(0.0007)	(0.0006)	(0.0036)			
Number of days 30 °C +	0.0008	0.0014	0.0022			
	(0.0011)	(0.0009)	(0.0053)			
Number of days below the 5th percentile of daily temperature				−0.0005	0.0004	0.0013
				(0.0007)	(0.0005)	(0.0031)
Number of days above the 95th percentile of daily temperature				0.0006	0.0012***	0.0003
				(0.0005)	(0.0004)	(0.0024)
Gender of household head (male = 1, female = 0)	0.0414***	−0.0043	0.4012***	0.0414***	−0.0044	0.4009***
	(0.0098)	(0.0082)	(0.0511)	(0.0098)	(0.0082)	(0.0511)
Age of household head	0.0352***	0.0295***	−0.0130	0.0353***	0.0295***	−0.0131
	(0.0018)	(0.0014)	(0.0100)	(0.0018)	(0.0014)	(0.0100)
Age of household head squared	−0.0003***	−0.0003***	−0.0007***	−0.0003***	−0.0003***	−0.0007***
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4636***	0.4837***	0.8575***	0.4636***	0.4841***	0.8592***
	(0.0213)	(0.0201)	(0.0767)	(0.0213)	(0.0201)	(0.0767)
Urban areas (Urban = 1, rural = 0)	0.2951***	0.1967***	0.5323***	0.2951***	0.1965***	0.5317***
	(0.0160)	(0.0141)	(0.0577)	(0.0160)	(0.0141)	(0.0577)
Annual precipitation (mm)	0.0030	0.0023	−0.0029	0.0019	0.0024	−0.0004
	(0.0042)	(0.0035)	(0.0198)	(0.0041)	(0.0035)	(0.0193)
Annual average temperature (°C)	−0.0451	−0.0351	0.0666	−0.0333	−0.0126	0.1911
	(0.0419)	(0.0364)	(0.1970)	(0.0265)	(0.0221)	(0.1248)
Annual average wind speed	0.0008	−0.0032	−0.1110*	0.0012	0.0025	−0.1040
	(0.0144)	(0.0117)	(0.0669)	(0.0146)	(0.0118)	(0.0677)
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	10.4990***	10.2599***	5.8137	10.3894***	9.6240***	3.2233
	(0.9661)	(0.8390)	(4.5316)	(0.8401)	(0.7046)	(3.9259)
Observations	41,743	41,743	41,743	41,743	41,743	41,743

Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

to have a positive effect compared to the reference bin. For high temperatures (30 °C and above), the coefficient remains negative but is not statistically significant when 18–21 °C is used as the reference bin. However, when 15–18 °C is used as the reference bin, the coefficient for the number of days above 30 °C is negative and statistically significant at the 10 % level in the regression of reading scores.

Finally, in addition to seven bins, we divide the temperature into five bins (0–15 °C; 15–20 °C; 20–25 °C; 25–30 °C; 30 °C +) and three bins (0–15 °C; 15–30 °C; 30 °C +). Table A.25 in the Appendix presents regressions of the test scores on these temperature bins. The table also shows positive and significant effects of low temperatures on the test scores of students.

We conduct similar robustness analyses for the effects of air pollution and temperature extremes on the school enrollment and grades of children in the VHLSSs. The results, reported in Tables A.26, A.27, A.28, A.29, A.30 in the Appendix, consistently show no statistically significant impacts of air pollution and temperature extremes on educational attainment.

4.4. Mechanism

Temperature extremes and air pollution can influence test scores through economic and health channels. In particular, elevated temperatures result in increased discomfort and fatigue, leading to a decline in labor productivity and income (e.g., Deryugina & Hsiang, 2017; Somanathan et al., 2021). Climate change could cause damages to agricultural production and lower economic growth (Dell et al., 2012; Miller et al., 2021; Somanathan et al., 2021; Otrachshenko & Popova, 2022). Air pollution has been found to decrease labor productivity at both the individual level and broader macro levels, even "when air quality is generally low" (Neidell, 2023).

Although health data are not available in our dataset, there is some limited information on healthcare utilization by children in VHLSSs. In Table 6, we estimate the effects of air pollution and temperature extremes on the number of healthcare contacts and the logarithm of

healthcare out-of-pocket expenditures for children aged 6–15.[17] We do not find statistically significant effects of air pollution and temperature extremes on the healthcare utilization and expenditure of children. But we acknowledge that due to limitations on health data, we cannot fully explore the effects of air pollution and temperature extremes on children's health indicators.

There is information on per capita income, per capita consumption expenditure, and per capita expenditure on education from VHLSS families. In Table 7, we estimate 2SLS regression of these outcome variables on air pollution and temperatures.[18] Overall, we do not find significant effects of air pollution and temperatures on household income and consumption. The only positive effects observed are of high temperature extremes on per capita expenditure (Column 5 of Table 7). This suggests that the negative effects of air pollution and the positive effects of low temperatures on students' test scores are unlikely to occur through economic channels.

5. Conclusions

We offer the first study to compare the impacts of temperature change (including weather extremes) and air pollution on children's education in Viet Nam, a developing country. Our findings suggest that air pollution has negative impacts on student cognitive skills, as measured by standardized test scores. While our results are consistent with the findings of recent studies for other countries, we do not find any significant impacts of air pollution on other educational outcomes, including school enrollment and the number of completed grades. One possible reason is that the school enrollment rates may already be high in Viet Nam. We also find that extreme temperatures could significantly affect test scores, with some limited negative effects of hotter temperatures on reading scores. But we do not find any significant effects of temperature extremes and air pollution over the past 12 months on students' test scores.

Our findings have significant policy implications for Viet Nam and highlight the importance of the country's continued initiatives to combat air pollution and address climate change. While temperature extremes have mixed effects on education, it is evident that air pollution negatively affects cognitive performance. Enhancing measures to control air quality can contribute to long-term improvements in students' cognitive performance and overall education achievement. While the Government of Viet Nam has made efforts to reduce air pollution (Nguyen, 2025; Quynh & Hui, 2025; Vietnamplus, 2025), our results provide supportive evidence for health experts' recent call for the country to adopt stronger actions to fight air pollution, especially because children are most vulnerable to poor air quality (Tran, 2023; Pratt et al., 2024).

Our study has some limitations, which we leave for future research. We analyze PM2.5 because this air pollutant is considered to pose the greatest risks to human health in Viet Nam (WHO, 2018a). But we acknowledge that there are other pollutants that might affect education outcomes. We are also unable to investigate children' health outcomes due to data constraints in the VHLSSs. Future research can also collect and analyze better longitudinal data, especially at the student level, to provide more rigorous modelling and richer insights into the effects of climate change and air quality.

Appendix A. Additional Figures and Tables

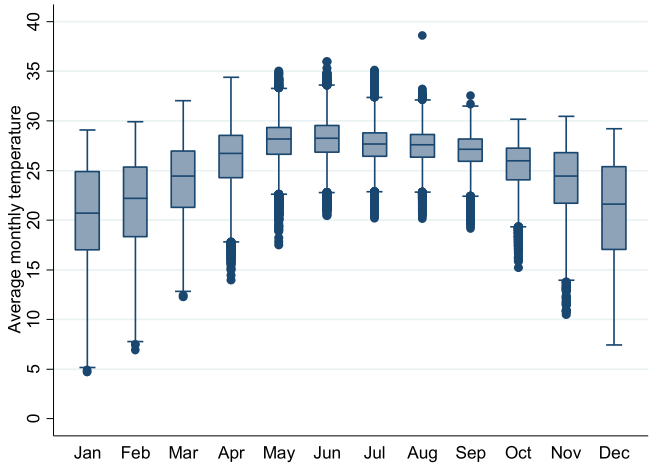

Fig. A.1. Daily temperature by months.
Note: This figure presents a box plot of the median and variation (upper quartile, lower quartile, and adjacent values) of daily temperature over time from 2010 to 2019.

[17] Since there are children with zero healthcare expenditure in the sample, we use the log(y + 1) transformation for healthcare expenditure.
[18] Further robustness checks on these regressions are reported in Tables A.31, A.32, A.33, A.34, A.35 in the Appendix, using similar robustness procedures to the previous section.

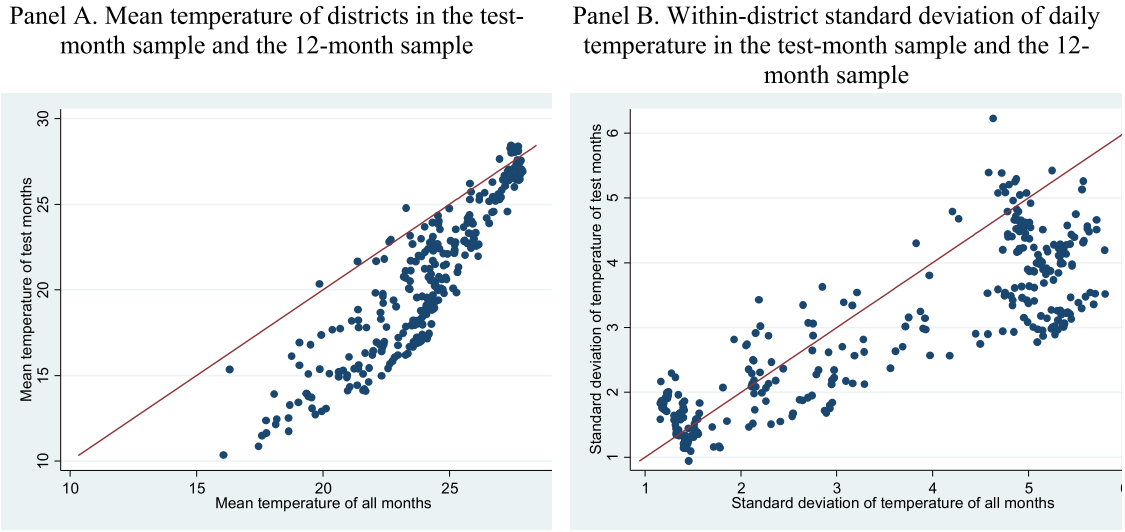

Fig. A.2. Mean and within-district standard deviation of daily temperature.
Note: Panel A shows the average daily temperatures of districts included in the VNEN and RISE surveys during the years when students took exams. Each dot represents a district in the sample. The vertical axis shows the average daily temperature during the test months (January, February, March, April, May, November, and December), while the horizontal axis shows the average daily temperature across all 12 months. Panel B displays the within-district standard deviation of daily temperatures over time. The vertical axis shows the standard deviation for the test months, and the horizontal axis shows the standard deviation for all 12 months.

Table A.1
The number of students by years and grades.

Survey years	Grades					
	2	3	4	5	7	Total
2013	0	5973	0	5727	0	11,700
2014	0	0	9130	0	0	9130
2015	0	0	0	8729	0	8729
2017	4018	0	0	0	2802	6820
2018	1321	0	0	0	0	1321
2019	1333	0	0	0	0	1333
Total	6672	5973	9130	14,456	2802	39,033

Source: Estimation using data from the VNEN and RISE projects.

Table A.2
Characteristics of students by years.

Survey years	Percentage of male students	Age	Percentage of Kinh students	Percentage of urban students
2013	50.2	9.1	61.9	17.4
	(0.4)	(0.0)	(0.4)	(0.3)
2014	50.6	9.1	63.0	17.7
	(0.5)	(0.0)	(0.5)	(0.4)
2015	50.3	10.1	62.9	17.6
	(0.5)	(0.0)	(0.5)	(0.4)
2017	51.7	9.0	0.0	0.0
	(0.6)	(0.0)	(0.0)	(0.0)
2018	52.6	10.2	32.2	20.9
	(1.0)	(0.0)	(0.9)	(0.8)
2019	50.2	8.1	0.0	20.4
	(1.3)	(0.0)	(0.0)	(1.1)
Total	50.7	9.3	47.9	14.8
	(0.2)	(0.0)	(0.2)	(0.2)

Note: Standard errors of means in parentheses.
Source: Estimation using data from the VNEN and RISE projects.

Table A.3
First-stage regressions of air pollution in estimating the effect on test scores.

Explanatory variables	The dependent variable is PM2.5	
	Model 1 (1)	Model 2 (2)
Wind direct degree [0, 45)	0.9139	1.7965***
	(0.6626)	(0.6898)
Wind direct degree [45, 90)	4.1227***	5.5699***
	(1.1845)	(1.0991)
Wind direct degree [90, 135)	−0.5726	0.1110
	(1.1452)	(1.1638)
Wind direct degree [180, 225)	5.4825*	1.1318
	(3.1116)	(2.8824)
Wind direct degree [225, 270)	11.6279***	7.4844**
	(3.0731)	(2.9802)
Wind direct degree [270, 315)	−1.9780	−3.5261**
	(1.8420)	(1.6918)
Number of days 0–15 °C	0.3862***	
	(0.0666)	
Number of days 15–18 °C	−0.0286	
	(0.0504)	
Number of days 18–21 °C	−0.0835	
	(0.0517)	
Number of days 21–24 °C	0	
Number of days 24–27 °C	−0.1540***	
	(0.0481)	
Number of days 27–30 °C	−0.0961	
	(0.0674)	
Number of days 30 °C +	−0.6848***	
	(0.2259)	
Number of days below the 5th percentile of daily temperature		0.0935
		(0.0644)
Number of days above the 95th percentile of daily temperature		−0.1511
		(0.1135)
Control variables	Yes	Yes
Year-by-month fixed effects	Yes	Yes
District fixed effects	Yes	Yes
Constant	125.6043***	232.1745***
	(23.2142)	(23.1796)
Observations	39,033	39,033
R-squared	0.918	0.923
Weak identification test (Cragg-Donald Wald F statistic)	492.9	188.93
Effective F statistic	310.3	49.2

Control variables include individual-level variables (age, gender, Kinh, urban dummy of students) and district-level variables (monthly precipitation, annual average temperature, and monthly wind speed).
Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.4
First-stage regressions of air pollution in estimating the effect on children's educational attainment.

Explanatory variables	The dependent variable is PM2.5	
	Model 1 (1)	Model 2 (2)
Wind direct degree [0, 45)	−0.0129	−0.0194
	(0.0307)	(0.0312)
Wind direct degree [45, 90)	0.1050***	0.1019***
	(0.0360)	(0.0371)
Wind direct degree [90, 135)	0.2185***	0.2337***
	(0.0578)	(0.0579)
Wind direct degree [135, 180)	−0.0022	−0.1901**
	(0.0756)	(0.0742)
Wind direct degree [180, 225)	−0.6533***	−0.8607***
	(0.0519)	(0.0505)
Wind direct degree [225, 270)	−0.6478***	−0.7638***
	(0.0504)	(0.0516)
Wind direct degree [270, 315)	−0.2483***	−0.2768***
	(0.0382)	(0.0396)
Number of days 0–15 °C	0.0785***	
	(0.0084)	

(*continued on next page*)

Table A.4 (*continued*)

Explanatory variables	The dependent variable is PM2.5	
	Model 1 (1)	Model 2 (2)
Number of days 15–18 °C	0.0434***	
	(0.0058)	
Number of days 18–21 °C	−0.0028	
	(0.0041)	
Number of days 21–24 °C	0	
Number of days 24–27 °C	−0.0166***	
	(0.0024)	
Number of days 27–30 °C	−0.0026	
	(0.0032)	
Number of days 30 °*C* +	−0.0411***	
	(0.0053)	
Number of days below the 5th percentile of daily temperature		−0.0016
		(0.0039)
Number of days above the 95th percentile of daily temperature		−0.0046*
		(0.0027)
Control variables	Yes	Yes
Year-by-month fixed effects	Yes	Yes
District fixed effects	Yes	Yes
Constant	38.5617***	68.6983***
	(6.0067)	(4.0001)
Observations	26,558	26,558
R-squared	0.969	0.968
Weak identification test (Cragg-Donald Wald *F* statistic)	156.7	211.0
Effective *F* statistic	45.6	60.9

Control variables include individual-level variables (age, gender, Kinh, urban dummy of students) and district-level variables (monthly precipitation, annual average temperature, and monthly wind speed).
Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.5
First-stage regressions of air pollution in estimating the effect on household-level outcomes.

Explanatory variables	The dependent variable is PM2.5	
	Model 1 (1)	Model 2 (2)
Wind direct degree [0, 45)	0.1068***	0.1108***
	(0.0250)	(0.0261)
Wind direct degree [45, 90)	−0.0256	0.0207
	(0.0287)	(0.0294)
Wind direct degree [90, 135)	0.0580	0.1469***
	(0.0472)	(0.0467)
Wind direct degree [135, 180)	−0.2599***	−0.4232***
	(0.0607)	(0.0607)
Wind direct degree [180, 225)	−0.8248***	−1.0504***
	(0.0411)	(0.0404)
Wind direct degree [225, 270)	−0.8816***	−0.9784***
	(0.0401)	(0.0399)
Wind direct degree [270, 315)	−0.4066***	−0.4247***
	(0.0314)	(0.0317)
Number of days 0–15 °C	0.1221***	
	(0.0060)	
Number of days 15–18 °C	0.0659***	
	(0.0047)	
Number of days 18–21 °C	0.0025	
	(0.0022)	
Number of days 21–24 °C	0	
Number of days 24–27 °C	−0.0157***	
	(0.0025)	
Number of days 27–30 °C	−0.0067**	
	(0.0031)	
Number of days 30 °*C* +	−0.0499***	
	(0.0043)	
Number of days below the 5th percentile of daily temperature		−0.0074**
		(0.0030)
Number of days above the 95th percentile of daily temperature		−0.0019
		(0.0021)
Control variables	Yes	Yes

(*continued on next page*)

Table A.5 (*continued*)

Explanatory variables	The dependent variable is PM2.5	
	Model 1 (1)	Model 2 (2)
Year-by-month fixed effects	Yes	Yes
District fixed effects	Yes	Yes
Constant	13.5524***	71.9539***
	(4.6118)	(3.1357)
Observations	41,743	41,743
R-squared	0.973	0.970
Weak identification test (Cragg-Donald Wald *F* statistic)	368.7	469.1
Effective *F* statistic	98.2	136.7

Control variables include household-level variables (age, gender, Kinh, urban dummy of household heads) and district-level variables (monthly precipitation, annual average temperature, and monthly wind speed).
Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$.
** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.6
OLS regressions of students' test scores.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0032**	0.0001	−0.0026**	−0.0002
	(0.0014)	(0.0015)	(0.0013)	(0.0014)
Number of days 0–15 °C	0.0063**	0.0041		
	(0.0032)	(0.0033)		
Number of days 15–18 °C	0.0002	0.0059**		
	(0.0025)	(0.0024)		
Number of days 18–21 °C	0.0012	0.0051*		
	(0.0027)	(0.0027)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0023	0.0004		
	(0.0023)	(0.0022)		
Number of days 27–30 °C	0.0003	0.0016		
	(0.0030)	(0.0030)		
Number of days 30 °*C* +	0.0021	0.0004		
	(0.0059)	(0.0062)		
Number of days below the 5th percentile of daily temperature			0.0154***	0.0087**
			(0.0035)	(0.0039)
Number of days above the 95th percentile of daily temperature			0.0032	0.0051
			(0.0038)	(0.0040)
Gender (boy = 1, girl = 0)	−0.0781***	−0.2919***	−0.0778***	−0.2920***
	(0.0118)	(0.0109)	(0.0118)	(0.0109)
Age	1.1539***	2.6269***	1.1558***	2.6261***
	(0.0991)	(0.2029)	(0.0996)	(0.2032)
Age squared	−0.0535***	−0.1276***	−0.0535***	−0.1275***
	(0.0052)	(0.0107)	(0.0052)	(0.0107)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4656***	0.4636***	0.4656***	0.4669***
	(0.0369)	(0.0390)	(0.0368)	(0.0389)
Urban areas (Urban = 1, rural = 0)	0.2787***	0.2116***	0.2788***	0.2126***
	(0.0484)	(0.0370)	(0.0484)	(0.0369)
Monthly precipitation (mm)	0.0324***	0.0306***	0.0324***	0.0299***
	(0.0091)	(0.0087)	(0.0090)	(0.0086)
Annual average temperature (°C)	−0.0069	0.0531	−0.0557	0.0416
	(0.0494)	(0.0488)	(0.0479)	(0.0463)
Monthly wind speed	0.0219	0.0249	0.0146	0.0226
	(0.0142)	(0.0156)	(0.0144)	(0.0162)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−6.1697***	−14.8499***	−5.0690***	−14.5131***
	(1.3006)	(1.5366)	(1.2758)	(1.4939)
Observations	39,031	39,031	39,031	39,031
R-squared	0.282	0.374	0.282	0.373

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.7
OLS regressions of school enrollment and completed grades.

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)	School enrollment (yes = 1, no = 0) (3)	Number of completed grades (4)
PM2.5 (μg/m3)	0.0026***	0.0151***	0.0025***	0.0133***
	(0.0009)	(0.0034)	(0.0009)	(0.0032)
Number of days 0–15 °C	−0.0015**	−0.0008		
	(0.0007)	(0.0025)		
Number of days 15–18 °C	−0.0013***	−0.0016		
	(0.0005)	(0.0017)		
Number of days 18–21 °C	−0.0009***	−0.0006		
	(0.0003)	(0.0011)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	0.0002	−0.0001		
	(0.0002)	(0.0008)		
Number of days 27–30 °C	0.0005	−0.0008		
	(0.0003)	(0.0011)		
Number of days 30 °C +	0.0010**	0.0008		
	(0.0005)	(0.0016)		
Number of days below the 5th percentile of daily temperature			0.0001	−0.0006
			(0.0003)	(0.0011)
Number of days above the 95th percentile of daily temperature			0.0002	−0.0004
			(0.0002)	(0.0009)
Gender (boy = 1, girl = 0)	−0.0150***	−0.0640***	−0.0151***	−0.0641***
	(0.0033)	(0.0128)	(0.0033)	(0.0128)
Age	0.1028***	0.9976***	0.1027***	0.9970***
	(0.0050)	(0.0149)	(0.0050)	(0.0149)
Age squared	−0.0056***	−0.0031***	−0.0056***	−0.0030***
	(0.0002)	(0.0008)	(0.0003)	(0.0008)
Kinh (Kinh = 1, ethnic minorities = 0)	0.0726***	0.3528***	0.0725***	0.3517***
	(0.0088)	(0.0402)	(0.0088)	(0.0402)
Urban areas (Urban = 1, rural = 0)	0.0166***	0.0501**	0.0165***	0.0494**
	(0.0052)	(0.0220)	(0.0052)	(0.0220)
Monthly precipitation (mm)	0.0007	0.0068	0.0005	0.0052
	(0.0017)	(0.0064)	(0.0017)	(0.0064)
Annual average temperature (°C)	−0.0513**	−0.0485	−0.0062	−0.0396
	(0.0221)	(0.0777)	(0.0117)	(0.0433)
Monthly wind speed	0.0088	0.0215	0.0097	0.0194
	(0.0061)	(0.0245)	(0.0061)	(0.0243)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	1.6277***	−5.3374***	0.5139*	−5.6197***
	(0.5302)	(1.8564)	(0.2983)	(1.1036)
Observations	26,556	26,556	26,556	26,556
R-squared	0.141	0.916	0.141	0.916

Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VHLSS data.

Table A.8
Heterogeneous effects on standardized math score by gender and age.

Explanatory variables	Groups of students			
	Boys (1)	Girls (2)	Age ≤ 10 (3)	Age > 10 (4)
PM2.5 (μg/m3)	−0.0134**	−0.0139***	−0.0138***	−0.0005
	(0.0056)	(0.0054)	(0.0047)	(0.0114)
Number of days 0–15 °C	0.0093**	0.0120***	0.0137***	−0.0477***
	(0.0045)	(0.0045)	(0.0040)	(0.0131)
Number of days 15–18 °C	0.0008	−0.0005	0.0018	−0.0054
	(0.0029)	(0.0029)	(0.0025)	(0.0112)
Number of days 18–21 °C	0.0007	−0.0004	0.0009	−0.0290**
	(0.0032)	(0.0032)	(0.0028)	(0.0122)
Number of days 21–24 °C	0	0	0	0
Number of days 24–27 °C	−0.0040	−0.0026	−0.0025	0.0032
	(0.0028)	(0.0027)	(0.0024)	(0.0090)
Number of days 27–30 °C	−0.0004	−0.0009	−0.0011	0.0308***
	(0.0036)	(0.0036)	(0.0031)	(0.0117)
Number of days 30 °C +	−0.0026	−0.0037	−0.0065	0.0718

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Table A.8 (*continued*)

Explanatory variables	Groups of students			
	Boys (1)	Girls (2)	Age ≤ 10 (3)	Age > 10 (4)
	(0.0080)	(0.0082)	(0.0064)	(0.0451)
Gender (boy = 1, girl = 0)			−0.0731***	−0.0565**
			(0.0125)	(0.0261)
Age	1.1618***	1.1219***	−0.7410***	0.0874
	(0.1311)	(0.1225)	(0.2570)	(0.3318)
Age squared	−0.0544***	−0.0516***	0.0503***	−0.0075
	(0.0068)	(0.0064)	(0.0144)	(0.0128)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4528***	0.4875***	0.4807***	0.2679***
	(0.0465)	(0.0395)	(0.0384)	(0.0823)
Urban areas (Urban = 1, rural = 0)	0.2682***	0.2915***	0.2921***	0.0896
	(0.0538)	(0.0520)	(0.0497)	(0.1203)
Monthly precipitation (mm)	0.0184	0.0307***	0.0174*	0.0294
	(0.0122)	(0.0109)	(0.0095)	(0.0364)
Annual average temperature (°C)	−0.0512	−0.0263	0.0200	−0.3330
	(0.0586)	(0.0582)	(0.0494)	(0.2196)
Monthly wind speed	0.0213	0.0154	0.0192	−0.0399
	(0.0174)	(0.0173)	(0.0143)	(0.0542)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−4.4546***	−4.6475***	2.6517	7.2166
	(1.6431)	(1.6303)	(1.8380)	(5.7092)
Observations	19,483	19,550	35,251	3782

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.9
Heterogeneous effects on standardized math score by urban/rural and ethnic groups.

Explanatory variables	Groups of students			
	Urban areas (1)	Rural areas (2)	Kinh (3)	Ethnic minorities (4)
PM2.5 (μg/m3)	−0.0320**	−0.0122**	−0.0095	−0.0084**
	(0.0153)	(0.0052)	(0.0129)	(0.0036)
Number of days 0–15 °C	0.0231*	0.0104**	0.0128	−0.0015
	(0.0119)	(0.0041)	(0.0127)	(0.0042)
Number of days 15–18 °C	−0.0027	0.0011	0.0013	−0.0015
	(0.0062)	(0.0028)	(0.0035)	(0.0033)
Number of days 18–21 °C	0.0042	−0.0003	0.0018	−0.0058
	(0.0070)	(0.0028)	(0.0035)	(0.0037)
Number of days 21–24 °C	0	0	0	0
Number of days 24–27 °C	−0.0032	−0.0021	0.0014	−0.0034
	(0.0077)	(0.0025)	(0.0034)	(0.0033)
Number of days 27–30 °C	0.0021	−0.0006	0.0063	0.0028
	(0.0093)	(0.0033)	(0.0046)	(0.0041)
Number of days 30 °C +	−0.0253	0.0017	−0.2356	0.0035
	(0.0255)	(0.0063)	(0.1472)	(0.0066)
Gender (boy = 1, girl = 0)	−0.0626*	−0.0794***	−0.0868***	−0.0643***
	(0.0350)	(0.0123)	(0.0201)	(0.0125)
Age	1.7155***	1.0766***	2.2649***	0.8773***
	(0.6055)	(0.0884)	(0.4537)	(0.0810)
Age squared	−0.0842***	−0.0497***	−0.1152***	−0.0388***
	(0.0327)	(0.0046)	(0.0247)	(0.0041)
Kinh (Kinh = 1, ethnic minorities = 0)	0.5915***	0.4470***		
	(0.0953)	(0.0396)		
Urban areas (Urban = 1, rural = 0)			0.3544***	0.2084***
			(0.0697)	(0.0648)
Monthly precipitation (mm)	0.0130	0.0273**	0.0137	0.0142
	(0.0220)	(0.0113)	(0.0144)	(0.0125)
Annual average temperature (°C)	0.0722	−0.0366	0.0375	−0.1019*
	(0.1076)	(0.0558)	(0.0885)	(0.0590)
Monthly wind speed	−0.0819**	0.0261	−0.0070	0.0146
	(0.0389)	(0.0159)	(0.0260)	(0.0174)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−9.7054***	−4.3553***	−11.0160***	−1.4233
	(3.7130)	(1.5281)	(2.9437)	(1.5103)
Observations	5796	33,237	18,807	20,226

Robust standard errors in parentheses. Standard errors are clustered at the school level.

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.10
Heterogeneous effects on standardized math score by regions.

Explanatory variables	Regions					
	Red River Delta (1)	Northern Mountain (2)	Central Coast (3)	Highland (4)	Southeast (5)	Mekong River Delta (6)
PM2.5 (μg/m3)	−0.0366**	−0.0134*	−0.0038	0.0514	−0.0091	−0.0769**
	(0.0186)	(0.0073)	(0.0130)	(0.0707)	(0.0165)	(0.0321)
Number of days 0–15 °C	−0.0431	0.0081	0.0114	−0.1267		−0.5320***
	(0.0827)	(0.0104)	(0.0104)	(0.0778)		(0.1601)
Number of days 15–18 °C	−0.0898	0.0037	0.0022	−0.0226*		
	(0.0641)	(0.0081)	(0.0041)	(0.0136)		
Number of days 18–21 °C	−0.0411	0.0055	0.0046	−0.0212***		
	(0.0417)	(0.0084)	(0.0044)	(0.0075)		
Number of days 21–24 °C	0	0	0	0	0	0
Number of days 24–27 °C	−0.0576	−0.0008	−0.0026	−0.0040	−0.0274	−0.0311**
	(0.0429)	(0.0115)	(0.0035)	(0.0075)	(0.0239)	(0.0156)
Number of days 27–30 °C	−0.0603	0.0065	−0.0008	0.0069	−0.0759*	−0.0402**
	(0.0663)	(0.0241)	(0.0054)	(0.0354)	(0.0426)	(0.0172)
Number of days 30 °C +	0.0277	−0.0744	−0.0141		−0.0926*	−0.0201
	(0.0667)	(0.0697)	(0.0177)		(0.0528)	(0.0169)
Gender (boy = 1, girl = 0)	−0.0771	−0.0975***	−0.0639***	−0.0369	−0.0830	−0.1111***
	(0.0480)	(0.0225)	(0.0191)	(0.0303)	(0.0596)	(0.0322)
Age	2.9420**	1.3889***	1.4722***	1.1298***	2.0849***	0.4200***
	(1.3856)	(0.1902)	(0.1802)	(0.2104)	(0.5610)	(0.1365)
Age squared	−0.1454**	−0.0686***	−0.0684***	−0.0531***	−0.1043***	−0.0178**
	(0.0728)	(0.0101)	(0.0094)	(0.0111)	(0.0294)	(0.0069)
Kinh (Kinh = 1, ethnic minorities = 0)	0.5521**	0.4470***	0.4677***	0.7543***	0.5449***	0.3264***
	(0.2694)	(0.0678)	(0.0772)	(0.0890)	(0.1277)	(0.0623)
Urban areas (Urban = 1, rural = 0)	0.0497	0.3773***	0.2706***	0.3811***	0.1095***	0.0585
	(0.1326)	(0.1007)	(0.0703)	(0.0902)	(0.0168)	(0.1293)
Monthly precipitation (mm)	0.0900	0.0257	0.0198	−0.0415	0.0091	0.0202
	(0.0759)	(0.0219)	(0.0163)	(0.0255)	(0.0389)	(0.0410)
Annual average temperature (°C)	0.2501	0.0175	−0.0240	−1.1343**	0.2352	0.2363
	(0.9664)	(0.1679)	(0.0814)	(0.5437)	(0.7678)	(0.3415)
Monthly wind speed	−0.0674	−0.0125	0.0380	−0.0009	0.1267	−0.0284
	(0.1681)	(0.0351)	(0.0341)	(0.0831)	(0.1452)	(0.0393)
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−15.9415	−7.9399**	−6.6785***	19.2979*	−15.6604	−5.9307
	(25.4592)	(3.9457)	(2.3331)	(11.1108)	(22.1284)	(9.4095)
Observations	1712	11,562	15,627	4173	1048	4911

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.11
Heterogeneous effects on standardized math score by season and temperature.

Explanatory variables	Groups of students			
	Surveyed in January–May (1)	Surveyed in November–December (2)	Living in districts with temperature below 20 degrees Celsius (3)	Living in districts with temperature 20 and above degrees Celsius (4)
PM2.5 (μg/m3)	−0.0118	−0.0090	0.0051	−0.0108*
	(0.0100)	(0.0076)	(0.0072)	(0.0058)
Number of days 0–15 °C	0.0298	0.0069	0.0133	0.0526
	(0.0312)	(0.0053)	(0.0112)	(0.0604)
Number of days 15–18 °C	0.0403***	−0.0016	0.0102	0.0169
	(0.0135)	(0.0029)	(0.0122)	(0.0176)
Number of days 18–21 °C	0.0200	−0.0011	0.0116	0.0011
	(0.0134)	(0.0033)	(0.0134)	(0.0051)
Number of days 21–24 °C	0	0	0	0
Number of days 24–27 °C	0.0027	−0.0030	0.0283	0.0003
	(0.0065)	(0.0033)	(0.0293)	(0.0028)
Number of days 27–30 °C	0.0040	−0.0004		0.0040
	(0.0086)	(0.0040)		(0.0045)

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Table A.11 (*continued*)

Explanatory variables	Groups of students			
	Surveyed in January–May (1)	Surveyed in November–December (2)	Living in districts with temperature below 20 degrees Celsius (3)	Living in districts with temperature 20 and above degrees Celsius (4)
Number of days 30 °C +	−0.0021			0.0065
	(0.0140)			(0.0086)
Gender (boy = 1, girl = 0)	−0.0637***	−0.0782***	−0.0851***	−0.0702***
	(0.0230)	(0.0124)	(0.0155)	(0.0162)
Age	−0.7974*	1.1872***	1.3352***	0.9916***
	(0.4590)	(0.1003)	(0.1525)	(0.1267)
Age squared	0.0344	−0.0552***	−0.0628***	−0.0453***
	(0.0248)	(0.0052)	(0.0081)	(0.0065)
Kinh (Kinh = 1, ethnic minorities = 0)	0.5361**	0.4677***	0.4321***	0.5606***
	(0.2198)	(0.0375)	(0.0475)	(0.0545)
Urban areas (Urban = 1, rural = 0)	0.1303	0.2980***	0.3717***	0.2098***
	(0.1380)	(0.0531)	(0.0718)	(0.0580)
Monthly precipitation (mm)	0.0050	0.0307***	0.0458***	0.0143
	(0.0192)	(0.0110)	(0.0144)	(0.0127)
Annual average temperature (°C)	0.0229	−0.0382	−0.2327*	0.0312
	(0.1136)	(0.0651)	(0.1191)	(0.0710)
Monthly wind speed	−0.0109	0.0155	−0.0110	0.0024
	(0.0403)	(0.0197)	(0.0294)	(0.0192)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	3.8772	−4.4292**	−1.6968	−5.7840***
	(3.4873)	(1.8033)	(2.8372)	(1.9470)
Observations	3091	35,942	20,408	18,625

Robust standard errors in parentheses. Standard errors are clustered at the school level.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Source: Estimation using data from the VNEN and RISE projects.

Table A.12

Heterogeneous effects on standardized reading score by gender and age.

Explanatory variables	Groups of students			
	Boys (1)	Girls (2)	Age ≤ 10 (3)	Age > 10 (4)
PM2.5 (μg/m3)	−0.0091*	−0.0109**	−0.0113**	0.0015
	(0.0055)	(0.0052)	(0.0047)	(0.0137)
Number of days 0–15 °C	0.0045	0.0122***	0.0116***	−0.0280**
	(0.0042)	(0.0045)	(0.0039)	(0.0121)
Number of days 15–18 °C	0.0045*	0.0068**	0.0073***	0.0144
	(0.0026)	(0.0029)	(0.0024)	(0.0108)
Number of days 18–21 °C	0.0010	0.0067**	0.0052*	−0.0131
	(0.0030)	(0.0032)	(0.0027)	(0.0106)
Number of days 21–24 °C	0	0	0	0
Number of days 24–27 °C	−0.0013	−0.0001	−0.0008	0.0089
	(0.0026)	(0.0026)	(0.0022)	(0.0093)
Number of days 27–30 °C	0.0024	−0.0017	−0.0018	0.0359***
	(0.0033)	(0.0037)	(0.0030)	(0.0130)
Number of days 30 °C +	0.0011	−0.0103	−0.0065	0.0453
	(0.0087)	(0.0083)	(0.0065)	(0.0456)
Gender (boy = 1, girl = 0)			−0.3017***	−0.1830***
			(0.0113)	(0.0197)
Age	2.3731***	2.8826***	−2.1944***	−0.1871
	(0.1932)	(0.3741)	(0.3518)	(0.4177)
Age squared	−0.1152***	−0.1403***	0.1515***	0.0043
	(0.0101)	(0.0198)	(0.0196)	(0.0163)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4486***	0.4874***	0.4759***	0.5720***
	(0.0471)	(0.0411)	(0.0408)	(0.0865)
Urban areas (Urban = 1, rural = 0)	0.1764***	0.2481***	0.2196***	−0.0344
	(0.0425)	(0.0395)	(0.0387)	(0.0986)
Monthly precipitation (mm)	0.0310***	0.0173*	0.0286***	0.0822**
	(0.0109)	(0.0102)	(0.0097)	(0.0393)
Annual average temperature (°C)	0.0670	−0.0106	0.0480	0.0013
	(0.0573)	(0.0575)	(0.0484)	(0.2033)
Monthly wind speed	0.0094	0.0327*	0.0210	−0.0074
	(0.0182)	(0.0182)	(0.0157)	(0.0671)

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Table A.12 (*continued*)

Explanatory variables	Groups of students			
	Boys (1)	Girls (2)	Age ≤ 10 (3)	Age > 10 (4)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−12.8881***	−13.0582***	7.1646***	0.1657
	(1.8105)	(2.2591)	(2.1191)	(5.9980)
Observations	19,483	19,550	35,251	3782

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.13
Heterogeneous effects on standardized reading score by urban/rural and ethnic groups.

Explanatory variables	Groups of students			
	Urban areas (1)	Rural areas (2)	Kinh (3)	Ethnic minorities (4)
PM2.5 (μg/m3)	−0.0130	−0.0094*	0.0054	−0.0046
	(0.0173)	(0.0055)	(0.0117)	(0.0040)
Number of days 0–15 °C	0.0247**	0.0071	0.0069	0.0057
	(0.0121)	(0.0043)	(0.0109)	(0.0043)
Number of days 15–18 °C	0.0137**	0.0051*	0.0108***	0.0067*
	(0.0066)	(0.0026)	(0.0032)	(0.0034)
Number of days 18–21 °C	0.0090	0.0036	0.0022	0.0026
	(0.0069)	(0.0029)	(0.0037)	(0.0038)
Number of days 21–24 °C	0	0	0	0
Number of days 24–27 °C	0.0030	−0.0015	0.0014	0.0032
	(0.0060)	(0.0024)	(0.0030)	(0.0031)
Number of days 27–30 °C	−0.0013	0.0004	0.0064	0.0037
	(0.0075)	(0.0033)	(0.0044)	(0.0039)
Number of days 30 °C +	−0.0012	−0.0023	0.0561	0.0054
	(0.0283)	(0.0069)	(0.1059)	(0.0068)
Gender (boy = 1, girl = 0)	−0.3614***	−0.2801***	−0.3412***	−0.2458***
	(0.0279)	(0.0117)	(0.0156)	(0.0137)
Age	3.4955***	2.4622***	4.2046***	1.6083***
	(0.6070)	(0.2036)	(0.4321)	(0.1589)
Age squared	−0.1644***	−0.1196***	−0.2015***	−0.0767***
	(0.0327)	(0.0107)	(0.0235)	(0.0083)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4469***	0.4682***		
	(0.0933)	(0.0419)		
Urban areas (Urban = 1, rural = 0)			0.2299***	0.2510***
			(0.0417)	(0.0622)
Monthly precipitation (mm)	0.0218	0.0262***	0.0521***	0.0164
	(0.0254)	(0.0100)	(0.0144)	(0.0136)
Annual average temperature (°C)	0.0539	0.0410	0.1764**	−0.0698
	(0.1317)	(0.0548)	(0.0793)	(0.0650)
Monthly wind speed	0.0295	0.0156	0.0470*	0.0282
	(0.0440)	(0.0177)	(0.0261)	(0.0186)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−19.3106***	−12.4632***	−25.0200***	−6.1398***
	(4.5015)	(1.7527)	(2.8240)	(1.6834)
Observations	5796	33,237	18,807	20,226

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.14
Heterogeneous effects on standardized reading score by regions.

Explanatory variables	Regions					
	Red River Delta (1)	Northern Mountain (2)	Central Coast (3)	Highland (4)	Southeast (5)	Mekong River Delta (6)
PM2.5 (μg/m3)	−0.0359**	−0.0095	0.0115	−0.0633	−0.0612***	−0.0153
	(0.0157)	(0.0093)	(0.0118)	(0.0575)	(0.0225)	(0.0306)

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Table A.14 (*continued*)

Explanatory variables	Regions					
	Red River Delta (1)	Northern Mountain (2)	Central Coast (3)	Highland (4)	Southeast (5)	Mekong River Delta (6)
Number of days 0–15 °C	−0.0981	0.0076	−0.0053	−0.0797		−0.0794
	(0.0696)	(0.0144)	(0.0098)	(0.0640)		(0.1841)
Number of days 15–18 °C	−0.1118*	0.0003	0.0021	0.0231**		
	(0.0578)	(0.0105)	(0.0035)	(0.0110)		
Number of days 18–21 °C	−0.0648*	0.0081	0.0022	−0.0022		
	(0.0345)	(0.0101)	(0.0041)	(0.0075)		
Number of days 21–24 °C	0	0	0	0	0	0
Number of days 24–27 °C	−0.0858**	−0.0055	0.0019	−0.0076	−0.1368***	−0.0003
	(0.0334)	(0.0141)	(0.0033)	(0.0057)	(0.0418)	(0.0180)
Number of days 27–30 °C	−0.0875	0.0022	0.0000	0.0314	−0.1560***	−0.0028
	(0.0595)	(0.0251)	(0.0055)	(0.0243)	(0.0576)	(0.0198)
Number of days 30 °C +	0.0235	−0.1319*	−0.0247		−0.1911**	0.0136
	(0.0594)	(0.0777)	(0.0165)		(0.0847)	(0.0234)
Gender (boy = 1, girl = 0)	−0.2472***	−0.3266***	−0.2551***	−0.2891***	−0.4400***	−0.3195***
	(0.0343)	(0.0215)	(0.0156)	(0.0289)	(0.0662)	(0.0350)
Age	3.6053***	3.8136***	3.0931***	2.2228***	3.7919***	1.4109***
	(0.9547)	(0.3566)	(0.3756)	(0.3980)	(0.6070)	(0.2359)
Age squared	−0.1759***	−0.1875***	−0.1528***	−0.1072***	−0.1798***	−0.0650***
	(0.0502)	(0.0190)	(0.0197)	(0.0206)	(0.0298)	(0.0119)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4525	0.4209***	0.4373***	0.8533***	0.6507***	0.4114***
	(0.4306)	(0.0640)	(0.0854)	(0.0917)	(0.1403)	(0.0699)
Urban areas (Urban = 1, rural = 0)	−0.0458	0.2602***	0.2528***	0.1990**	0.1472***	0.1109
	(0.0980)	(0.0797)	(0.0502)	(0.0830)	(0.0246)	(0.0885)
Monthly precipitation (mm)	−0.0314	0.0180	0.0231	0.0713***	−0.0029	−0.0016
	(0.0621)	(0.0260)	(0.0147)	(0.0237)	(0.0323)	(0.0403)
Annual average temperature (°C)	1.4051*	−0.2697	0.0352	0.3194	−0.3663	−0.0142
	(0.8461)	(0.2007)	(0.0706)	(0.4216)	(1.4595)	(0.3490)
Monthly wind speed	−0.0225	0.0199	0.0341	−0.1066	−0.1016	0.0695*
	(0.1131)	(0.0398)	(0.0305)	(0.0670)	(0.1258)	(0.0358)
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−44.5788**	−13.6348***	−16.4608***	−17.4192*	−3.1451	−6.2561
	(20.6312)	(4.9747)	(2.6195)	(8.9851)	(40.0768)	(10.3614)
Observations	1712	11,562	15,627	4173	1048	4911

Robust standard errors in parentheses. Standard errors are clustered at the school level.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Source: Estimation using data from the VNEN and RISE projects.

Table A.15

Heterogeneous effects on standardized reading score by season and temperature.

Explanatory variables	Groups of students			
	Surveyed in January–May (1)	Surveyed in November–December (2)	Living in districts with temperature below 20 degrees Celsius (3)	Living in districts with temperature 20 and above degrees Celsius (4)
PM2.5 (μg/m3)	0.0028	−0.0013	0.0129	0.0049
	(0.0110)	(0.0079)	(0.0094)	(0.0057)
Number of days 0–15 °C	−0.0682**	0.0051	0.0291**	−0.0127
	(0.0345)	(0.0053)	(0.0114)	(0.0524)
Number of days 15–18 °C	0.0102	0.0062**	0.0315***	0.0331**
	(0.0157)	(0.0028)	(0.0102)	(0.0136)
Number of days 18–21 °C	−0.0197	0.0065*	0.0299***	0.0054
	(0.0169)	(0.0035)	(0.0107)	(0.0046)
Number of days 21–24 °C	0	0	0	0
Number of days 24–27 °C	0.0009	−0.0015	−0.0156	0.0018
	(0.0068)	(0.0030)	(0.0287)	(0.0024)
Number of days 27–30 °C	0.0085	−0.0004		0.0013
	(0.0095)	(0.0040)		(0.0040)
Number of days 30 °C +	0.0170			0.0019
	(0.0168)			(0.0084)
Gender (boy = 1, girl = 0)	−0.2674***	−0.2926***	−0.2983***	−0.2838***
	(0.0232)	(0.0114)	(0.0146)	(0.0147)
Age	−0.1572	2.6815***	3.6710***	1.8049***
	(0.6757)	(0.2050)	(0.3147)	(0.2057)
Age squared	−0.0025	−0.1300***	−0.1807***	−0.0861***
	(0.0356)	(0.0108)	(0.0167)	(0.0106)
Kinh (Kinh = 1, ethnic minorities = 0)	0.6486***	0.4745***	0.4249***	0.5928***

(*continued on next page*)

Table A.15 (*continued*)

Explanatory variables	Groups of students			
	Surveyed in January–May (1)	Surveyed in November–December (2)	Living in districts with temperature below 20 degrees Celsius (3)	Living in districts with temperature 20 and above degrees Celsius (4)
	(0.1812)	(0.0394)	(0.0491)	(0.0577)
Urban areas (Urban = 1, rural = 0)	0.1239	0.2126***	0.3205***	0.1443***
	(0.1575)	(0.0406)	(0.0585)	(0.0406)
Monthly precipitation (mm)	−0.0189	0.0341***	0.0481***	0.0217
	(0.0202)	(0.0105)	(0.0153)	(0.0136)
Annual average temperature (°C)	−0.1843	0.0667	−0.0066	0.0676
	(0.1213)	(0.0642)	(0.1274)	(0.0679)
Monthly wind speed	−0.0441	0.0342	0.0325	0.0200
	(0.0431)	(0.0216)	(0.0345)	(0.0189)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	7.2046*	−14.0241***	−19.3459***	−10.5801***
	(4.0739)	(1.9956)	(3.3329)	(1.9951)
Observations	3091	35,942	20,408	18,625

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.16
Heterogeneous effects on standardized math and reading scores by the level of PM2.5.

Explanatory variables	Monthly PM2.5 level below 27 μg/m3 (median)				Monthly PM2.5 level equal or above 27 μg/m3 (median)			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)	Standardized math score (5)	Standardized reading score (6)	Standardized math score (7)	Standardized reading score (8)
PM2.5 (μg/m3)	0.0091	0.0128	0.0121	0.0246	−0.0132***	−0.0044	−0.0178***	−0.0087
	(0.0257)	(0.0263)	(0.0292)	(0.0305)	(0.0049)	(0.0055)	(0.0063)	(0.0064)
Number of days 0–15 °C	0.0200	0.0214			0.0007	0.0225***		
	(0.0126)	(0.0133)			(0.0074)	(0.0085)		
Number of days 15–18 °C	0.0009	0.0105*			−0.0152**	0.0118*		
	(0.0047)	(0.0054)			(0.0063)	(0.0066)		
Number of days 18–21 °C	−0.0017	0.0087**			−0.0080	0.0097		
	(0.0037)	(0.0036)			(0.0067)	(0.0073)		
Number of days 21–24 °C	0	0			0	0		
Number of days 24–27 °C	−0.0028	−0.0001			−0.0265***	−0.0027		
	(0.0030)	(0.0024)			(0.0096)	(0.0109)		
Number of days 27–30 °C	0.0010	−0.0050			−0.0165	−0.0038		
	(0.0052)	(0.0048)			(0.0105)	(0.0120)		
Number of days 30 °C +	0.0066	−0.0039			−0.0275	0.0009		
	(0.0086)	(0.0097)			(0.0190)	(0.0174)		
Number of days below the 5th percentile of daily temperature			0.0031	0.0161**			0.0336***	0.0046
			(0.0063)	(0.0072)			(0.0069)	(0.0072)
Number of days above the 95th percentile of daily temperature			−0.0055	0.0031			0.0316	0.0360*
			(0.0068)	(0.0077)			(0.0220)	(0.0189)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−3.6298	−9.3599***	−3.2238	−8.8776***	−3.9066	−18.2663***	−4.5734*	−16.0549***
	(2.9103)	(2.6901)	(3.0650)	(2.8885)	(2.9332)	(3.3997)	(2.7500)	(3.2377)
Observations	14,049	14,049	14,049	14,049	24,984	24,984	24,984	24,984

Control variables are the same as in Table 3. Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.

* $p < 0.1$.

Source: Estimation using data from the VNEN and RISE projects.

Table A.17
2SLS regressions of students' test scores without controlling for explanatory variables.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0135***	−0.0097**	−0.0145***	−0.0123***
	(0.0051)	(0.0048)	(0.0046)	(0.0044)
Number of days 0–15 °C	0.0126***	0.0095**		
	(0.0042)	(0.0040)		
Number of days 15–18 °C	0.0008	0.0060**		
	(0.0027)	(0.0024)		
Number of days 18–21 °C	0.0037	0.0083***		
	(0.0032)	(0.0030)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0039	−0.0010		
	(0.0028)	(0.0024)		
Number of days 27–30 °C	−0.0026	−0.0016		
	(0.0034)	(0.0032)		
Number of days 30 °C +	−0.0011	−0.0001		
	(0.0074)	(0.0071)		
Number of days below the 5th percentile of daily temperature			0.0175***	0.0104**
			(0.0044)	(0.0044)
Number of days above the 95th percentile of daily temperature			0.0061	0.0064*
			(0.0040)	(0.0038)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	0.5938*	0.9490***	0.7436**	1.2713***
	(0.3190)	(0.3206)	(0.2936)	(0.3033)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Source: Estimation using data from the VNEN and RISE projects.

Table A.18
2SLS regressions of students' test scores without controlling for explanatory variables and temperature.

Explanatory variables	Dependent variables	
	Standardized math score (1)	Standardized reading score (2)
PM2.5 (μg/m3)	−0.0134***	−0.0114***
	(0.0045)	(0.0044)
Year-by-month fixed effects	Yes	Yes
District fixed effects	Yes	Yes
Constant	0.6825**	1.2149***
	(0.2905)	(0.3019)
Observations	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.

*** $p < 0.01$.

** $p < 0.05$

* $p < 0.1$.

Source: Estimation using data from the VNEN and RISE projects.

Table A.19
2SLS Regressions of students' test scores with controlling for district-month fixed effect.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0180*	−0.0108*	−0.0177***	−0.0198***
	(0.0100)	(0.0063)	(0.0064)	(0.0068)
Number of days 0–15 °C	0.0127**	0.0033		
	(0.0064)	(0.0040)		
Number of days 15–18 °C	−0.0014	0.0017		
	(0.0026)	(0.0015)		
Number of days 18–21 °C	−0.0014	0.0028		
	(0.0032)	(0.0020)		

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Table A.19 (*continued*)

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0040	−0.0011		
	(0.0036)	(0.0021)		
Number of days 27–30 °C	−0.0022	0.0020		
	(0.0034)	(0.0021)		
Number of days 30 °C +	−0.0027	0.0003		
	(0.0071)	(0.0066)		
Number of days below the 5th percentile of daily temperature			0.0203***	0.0123**
			(0.0048)	(0.0052)
Number of days above the 95th percentile of daily temperature			−0.0083*	0.0015
			(0.0045)	(0.0053)
Gender (boy = 1, girl = 0)	−0.0793***	−0.2938***	−0.0793***	−0.2943***
	(0.0088)	(0.0081)	(0.0088)	(0.0090)
Age	1.1546***	2.6311***	1.1564***	2.6302***
	(0.0951)	(0.1643)	(0.0957)	(0.2032)
Age squared	−0.0536***	−0.1276***	−0.0538***	−0.1277***
	(0.0049)	(0.0087)	(0.0050)	(0.0106)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4623***	0.4701***	0.4642***	0.4678***
	(0.0334)	(0.0169)	(0.0328)	(0.0347)
Urban areas (Urban = 1, rural = 0)	0.2988***	0.2171***	0.2984***	0.2195***
	(0.0432)	(0.0181)	(0.0430)	(0.0340)
Monthly precipitation (mm)	0.0233**	0.0271***	0.0236***	0.0220**
	(0.0099)	(0.0062)	(0.0090)	(0.0104)
Annual average temperature (°C)	−0.0745	−0.0252	−0.1871***	−0.1059
	(0.0478)	(0.0287)	(0.0584)	(0.0650)
Monthly wind speed	0.0044	0.0170	−0.0048	0.0087
	(0.0178)	(0.0123)	(0.0176)	(0.0217)
District-by-month fixed effects	Yes	Yes	Yes	Yes
Year-by-month fixed effects	Yes	Yes	Yes	Yes
Constant	−2.8955**	−11.8505***	−0.1504	−9.4109***
	(1.3415)	(1.1285)	(1.6809)	(2.0562)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.20
2SLS regressions of students' test scores with controlling for province-specific time trend.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0118**	−0.0110**	−0.0150***	−0.0112**
	(0.0048)	(0.0047)	(0.0053)	(0.0051)
Number of days 0–15 °C	0.0044*	0.0034		
	(0.0025)	(0.0023)		
Number of days 15–18 °C	−0.0026	0.0038**		
	(0.0019)	(0.0016)		
Number of days 18–21 °C	−0.0006	0.0004		
	(0.0021)	(0.0019)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0034*	−0.0001		
	(0.0019)	(0.0017)		
Number of days 27–30 °C	−0.0001	−0.0010		
	(0.0024)	(0.0021)		
Number of days 30 °C +	−0.0121**	−0.0141**		
	(0.0059)	(0.0061)		
Number of days below the 5th percentile of daily temperature			0.0107***	0.0039
			(0.0030)	(0.0027)
Number of days above the 95th percentile of daily temperature			−0.0045	−0.0029
			(0.0036)	(0.0036)
Gender (boy = 1, girl = 0)	−0.0784***	−0.2923***	−0.0785***	−0.2924***
	(0.0087)	(0.0081)	(0.0087)	(0.0081)
Age	1.1582***	2.6347***	1.1595***	2.6360***
	(0.0778)	(0.1636)	(0.0784)	(0.1640)
Age squared	−0.0538***	−0.1278***	−0.0539***	−0.1279***
	(0.0041)	(0.0087)	(0.0041)	(0.0087)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4900***	0.4940***	0.4909***	0.4936***

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Table A.20 (*continued*)

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
	(0.0174)	(0.0169)	(0.0174)	(0.0169)
Urban areas (Urban = 1, rural = 0)	0.2795***	0.2059***	0.2804***	0.2085***
	(0.0192)	(0.0171)	(0.0191)	(0.0170)
Monthly precipitation (mm)	0.0250***	0.0204***	0.0235***	0.0186***
	(0.0071)	(0.0068)	(0.0072)	(0.0069)
Annual average temperature (°C)	−0.0710*	0.0202	−0.1086***	−0.0038
	(0.0367)	(0.0326)	(0.0377)	(0.0334)
Monthly wind speed	0.0208*	0.0142	0.0089	0.0058
	(0.0121)	(0.0112)	(0.0129)	(0.0119)
Province-specific time trend	Yes	Yes	Yes	Yes
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−3.2992***	−13.1769***	−2.3208**	−12.6826***
	(1.0484)	(1.1543)	(1.0968)	(1.1878)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.21
2SLS Regressions of students' test scores using three-bins wind direction as the instrumental variables for air pollution.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0143**	−0.0090	−0.0162***	−0.0123**
	(0.0056)	(0.0057)	(0.0059)	(0.0061)
Number of days 0–15 °C	0.0111***	0.0081**		
	(0.0041)	(0.0041)		
Number of days 15–18 °C	0.0002	0.0059**		
	(0.0025)	(0.0024)		
Number of days 18–21 °C	0.0001	0.0043		
	(0.0028)	(0.0027)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0035	−0.0005		
	(0.0024)	(0.0023)		
Number of days 27–30 °C	−0.0010	0.0005		
	(0.0031)	(0.0031)		
Number of days 30 °C +	−0.0047	−0.0052		
	(0.0067)	(0.0070)		
Number of days below the 5th percentile of daily temperature			0.0172***	0.0103***
			(0.0037)	(0.0040)
Number of days above the 95th percentile of daily temperature			0.0020	0.0039
			(0.0042)	(0.0044)
Gender (boy = 1, girl = 0)	−0.0789***	−0.2926***	−0.0789***	−0.2929***
	(0.0117)	(0.0108)	(0.0117)	(0.0108)
Age	1.1500***	2.6237***	1.1526***	2.6232***
	(0.0992)	(0.2030)	(0.1000)	(0.2036)
Age squared	−0.0535***	−0.1275***	−0.0536***	−0.1276***
	(0.0052)	(0.0107)	(0.0052)	(0.0107)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4676***	0.4653***	0.4642***	0.4656***
	(0.0368)	(0.0389)	(0.0367)	(0.0390)
Urban areas (Urban = 1, rural = 0)	0.2795***	0.2122***	0.2806***	0.2143***
	(0.0483)	(0.0369)	(0.0483)	(0.0368)
Monthly precipitation (mm)	0.0243**	0.0240**	0.0219**	0.0206**
	(0.0103)	(0.0097)	(0.0103)	(0.0096)
Annual average temperature (°C)	−0.0368	0.0285	−0.1547**	−0.0465
	(0.0517)	(0.0505)	(0.0630)	(0.0634)
Monthly wind speed	0.0165	0.0205	0.0017	0.0112
	(0.0148)	(0.0162)	(0.0163)	(0.0176)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−4.5232***	−12.8720***	−1.4346	−10.6648***
	(1.4833)	(1.6889)	(1.8780)	(2.0659)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.

** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.22
2SLS regressions of students' test scores with heteroscedasticity-consistent standard errors.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0146***	−0.0100***	−0.0152***	−0.0115***
	(0.0030)	(0.0028)	(0.0029)	(0.0027)
Number of days 0–15 °C	0.0112***	0.0085***		
	(0.0025)	(0.0023)		
Number of days 15–18 °C	0.0002	0.0059***		
	(0.0016)	(0.0014)		
Number of days 18–21 °C	0.0001	0.0042**		
	(0.0019)	(0.0017)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0035**	−0.0006		
	(0.0017)	(0.0015)		
Number of days 27–30 °C	−0.0010	0.0004		
	(0.0020)	(0.0019)		
Number of days 30 °C +	−0.0049	−0.0058		
	(0.0048)	(0.0050)		
Number of days below the 5th percentile of daily temperature			0.0171***	0.0102***
			(0.0026)	(0.0024)
Number of days above the 95th percentile of daily temperature			0.0021	0.0040
			(0.0024)	(0.0025)
Gender (boy = 1, girl = 0)	−0.0790***	−0.2926***	−0.0788***	−0.2928***
	(0.0087)	(0.0081)	(0.0087)	(0.0081)
Age	1.1499***	2.6234***	1.1529***	2.6234***
	(0.0775)	(0.1657)	(0.0781)	(0.1662)
Age squared	−0.0535***	−0.1275***	−0.0536***	−0.1276***
	(0.0041)	(0.0088)	(0.0041)	(0.0088)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4676***	0.4654***	0.4643***	0.4657***
	(0.0167)	(0.0162)	(0.0167)	(0.0162)
Urban areas (Urban = 1, rural = 0)	0.2795***	0.2123***	0.2805***	0.2142***
	(0.0191)	(0.0170)	(0.0190)	(0.0170)
Monthly precipitation (mm)	0.0241***	0.0232***	0.0227***	0.0212***
	(0.0059)	(0.0055)	(0.0059)	(0.0055)
Annual average temperature (°C)	−0.0377	0.0257	−0.1471***	−0.0407
	(0.0331)	(0.0299)	(0.0366)	(0.0326)
Monthly wind speed	0.0164	0.0200**	0.0027	0.0119
	(0.0106)	(0.0098)	(0.0110)	(0.0102)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−4.4828***	−12.7417***	−1.6863	−10.8577***
	(0.9644)	(1.1125)	(1.0890)	(1.1857)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.23
2SLS regressions of students' test scores with clustering standard errors at the district level.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0146***	−0.0100*	−0.0152***	−0.0115**
	(0.0053)	(0.0057)	(0.0052)	(0.0056)
Number of days 0–15 °C	0.0112**	0.0085*		
	(0.0045)	(0.0046)		
Number of days 15–18 °C	0.0002	0.0059*		
	(0.0028)	(0.0033)		
Number of days 18–21 °C	0.0001	0.0042		
	(0.0030)	(0.0032)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0035	−0.0006		
	(0.0026)	(0.0027)		

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Table A.23 (*continued*)

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
Number of days 27–30 °C	−0.0010	0.0004		
	(0.0036)	(0.0037)		
Number of days 30 °C +	−0.0049	−0.0058		
	(0.0069)	(0.0079)		
Number of days below the 5th percentile of daily temperature			0.0171***	0.0102**
			(0.0041)	(0.0047)
Number of days above the 95th percentile of daily temperature			0.0021	0.0040
			(0.0038)	(0.0045)
Gender (boy = 1, girl = 0)	−0.0790***	−0.2926***	−0.0788***	−0.2928***
	(0.0118)	(0.0111)	(0.0118)	(0.0111)
Age	1.1499***	2.6234***	1.1529***	2.6234***
	(0.1084)	(0.2259)	(0.1090)	(0.2258)
Age squared	−0.0535***	−0.1275***	−0.0536***	−0.1276***
	(0.0056)	(0.0119)	(0.0057)	(0.0119)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4676***	0.4654***	0.4643***	0.4657***
	(0.0487)	(0.0522)	(0.0485)	(0.0522)
Urban areas (Urban = 1, rural = 0)	0.2795***	0.2123***	0.2805***	0.2142***
	(0.0616)	(0.0462)	(0.0613)	(0.0456)
Monthly precipitation (mm)	0.0241**	0.0232**	0.0227**	0.0212*
	(0.0111)	(0.0118)	(0.0107)	(0.0113)
Annual average temperature (°C)	−0.0377	0.0257	−0.1471**	−0.0407
	(0.0538)	(0.0607)	(0.0590)	(0.0677)
Monthly wind speed	0.0164	0.0200	0.0027	0.0119
	(0.0154)	(0.0207)	(0.0167)	(0.0211)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−4.4828***	−12.7417***	−1.6863	−10.8577***
	(1.4663)	(1.9446)	(1.7061)	(2.1841)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the district level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.24
2SLS regressions of students' test scores using the different reference temperature bins.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0146***	−0.0100**	−0.0146***	−0.0101**
	(0.0048)	(0.0048)	(0.0048)	(0.0048)
Number of days 0–15 °C	0.0112***	0.0042	0.0111***	0.0026
	(0.0039)	(0.0037)	(0.0037)	(0.0035)
Number of days 15–18 °C	0.0003	0.0014	0	0
	(0.0030)	(0.0027)		
Number of days 18–21 °C	0	0	−0.0001	−0.0020
			(0.0030)	(0.0027)
Number of days 21–24 °C	0.0001	−0.0048*	−0.0000	−0.0063***
	(0.0027)	(0.0026)	(0.0026)	(0.0025)
Number of days 24–27 °C	−0.0035	−0.0051**	−0.0036	−0.0068**
	(0.0026)	(0.0025)	(0.0028)	(0.0027)
Number of days 27–30 °C	−0.0009	−0.0043	−0.0011	−0.0060
	(0.0039)	(0.0040)	(0.0041)	(0.0041)
Number of days 30 °C +	−0.0047	−0.0105	−0.0049	−0.0122*
	(0.0069)	(0.0072)	(0.0071)	(0.0074)
Gender (boy = 1, girl = 0)	−0.0790***	−0.2926***	−0.0790***	−0.2926***
	(0.0117)	(0.0108)	(0.0117)	(0.0108)
Age	1.1499***	2.6232***	1.1499***	2.6232***
	(0.0993)	(0.2031)	(0.0993)	(0.2032)
Age squared	−0.0535***	−0.1275***	−0.0535***	−0.1275***
	(0.0052)	(0.0107)	(0.0052)	(0.0107)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4677***	0.4652***	0.4676***	0.4654***
	(0.0368)	(0.0389)	(0.0368)	(0.0389)
Urban areas (Urban = 1, rural = 0)	0.2795***	0.2121***	0.2796***	0.2120***
	(0.0484)	(0.0370)	(0.0484)	(0.0370)
Monthly precipitation (mm)	0.0241**	0.0232**	0.0241**	0.0232**
	(0.0101)	(0.0093)	(0.0102)	(0.0093)
Annual average temperature (°C)	−0.0378	0.0255	−0.0383	0.0260

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Table A.24 (*continued*)

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
	(0.0502)	(0.0496)	(0.0502)	(0.0496)
Monthly wind speed	0.0163	0.0199	0.0162	0.0199
	(0.0146)	(0.0161)	(0.0146)	(0.0161)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−4.4815***	−12.5991***	−4.4620***	−12.5533***
	(1.3886)	(1.6333)	(1.3822)	(1.6240)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.25
2SLS regressions of students' test scores using different temperature bins.

Explanatory variables	Dependent variables			
	Standardized math score (1)	Standardized reading score (2)	Standardized math score (3)	Standardized reading score (4)
PM2.5 (μg/m3)	−0.0159***	−0.0106**	−0.0165***	−0.0120**
	(0.0050)	(0.0049)	(0.0050)	(0.0050)
Number of days 0–15 °C	0.0134***	0.0085**	0.0118***	0.0048
	(0.0036)	(0.0034)	(0.0034)	(0.0032)
Number of days 15–20 °C	0.0019	0.0060***		
	(0.0018)	(0.0017)		
Number of days 20–25 °C	0	0		
Number of days 25–30 °C	−0.0008	0.0008		
	(0.0022)	(0.0021)		
Number of days 30 °C +	−0.0031	−0.0040	−0.0004	−0.0013
	(0.0059)	(0.0061)	(0.0050)	(0.0049)
Gender (boy = 1, girl = 0)	−0.0790***	−0.2927***	−0.0791***	−0.2930***
	(0.0117)	(0.0108)	(0.0117)	(0.0108)
Age	1.1481***	2.6227***	1.1478***	2.6219***
	(0.0993)	(0.2031)	(0.0992)	(0.2030)
Age squared	−0.0534***	−0.1275***	−0.0534***	−0.1275***
	(0.0052)	(0.0107)	(0.0052)	(0.0107)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4681***	0.4655***	0.4684***	0.4666***
	(0.0368)	(0.0390)	(0.0368)	(0.0390)
Urban areas (Urban = 1, rural = 0)	0.2783***	0.2112***	0.2796***	0.2141***
	(0.0485)	(0.0369)	(0.0485)	(0.0369)
Monthly precipitation (mm)	0.0231**	0.0223**	0.0222**	0.0207**
	(0.0104)	(0.0095)	(0.0103)	(0.0095)
Annual average temperature (°C)	−0.0497	0.0218	−0.0656	−0.0183
	(0.0515)	(0.0509)	(0.0494)	(0.0489)
Monthly wind speed	0.0174	0.0205	0.0148	0.0155
	(0.0146)	(0.0160)	(0.0145)	(0.0162)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	−4.1305***	−12.5871***	−3.6685***	−11.4029***
	(1.4461)	(1.6795)	(1.3817)	(1.6171)
Observations	39,033	39,033	39,033	39,033

Robust standard errors in parentheses. Standard errors are clustered at the school level.
*** $p < 0.01$.
** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from the VNEN and RISE projects.

Table A.26
2SLS regressions of children's educational attainment without controlling for explanatory variables.

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)	School enrollment (yes = 1, no = 0) (3)	Number of completed grades (4)
PM2.5 (μg/m3)	0.0009	−0.0029	0.0004	0.0177
	(0.0045)	(0.0499)	(0.0035)	(0.0378)
Number of days 0–15 °C	−0.0001	0.0039		
	(0.0005)	(0.0055)		
Number of days 15–18 °C	−0.0004	0.0026		
	(0.0003)	(0.0039)		
Number of days 18–21 °C	−0.0005*	−0.0031		
	(0.0003)	(0.0029)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	−0.0002	−0.0006		
	(0.0002)	(0.0020)		
Number of days 27–30 °C	−0.0001	−0.0004		
	(0.0002)	(0.0020)		
Number of days 30 °C +	−0.0000	−0.0006		
	(0.0003)	(0.0037)		
Number of days below the 5th percentile of daily temperature			0.0000	0.0041
			(0.0003)	(0.0029)
Number of days above the 95th percentile of daily temperature			−0.0000	0.0008
			(0.0002)	(0.0023)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	1.1072***	1.0268	1.0698***	−0.1197
	(0.2254)	(2.4845)	(0.1769)	(1.9061)
Observations	26,558	26,558	26,558	26,558

Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.27
2SLS regressions of children's educational attainment without controlling for explanatory variables and temperature.

Explanatory variables	Dependent variables	
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)
PM2.5 (μg/m3)	0.0005	0.0196
	(0.0033)	(0.0362)
Year-by-month fixed effects	Yes	Yes
District fixed effects	Yes	Yes
Constant	1.0635***	−0.1429
	(0.1683)	(1.8211)
Observations	26,558	26,558

Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$
** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.28
2SLS regressions of children's educational attainment with controlling for province-specific time trend.

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)	School enrollment (yes = 1, no = 0) (3)	Number of completed grades (4)
PM2.5 (μg/m3)	−0.0059	−0.0403	−0.0051	−0.0200
	(0.0077)	(0.0264)	(0.0059)	(0.0197)
Number of days 0–15 °C	−0.0002	0.0072*		
	(0.0012)	(0.0042)		
Number of days 15–18 °C	−0.0006	0.0022		
	(0.0006)	(0.0020)		
Number of days 18–21 °C	−0.0007*	0.0011		
	(0.0004)	(0.0014)		

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Table A.28 (*continued*)

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)	School enrollment (yes = 1, no = 0) (3)	Number of completed grades (4)
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	0.0003	0.0001		
	(0.0002)	(0.0008)		
Number of days 27–30 °C	0.0004	−0.0012		
	(0.0003)	(0.0011)		
Number of days 30 °*C* +	0.0007	−0.0021		
	(0.0005)	(0.0017)		
Number of days below the 5th percentile of daily temperature			0.0000	−0.0010
			(0.0003)	(0.0013)
Number of days above the 95th percentile of daily temperature			0.0003	−0.0004
			(0.0003)	(0.0010)
Gender (boy = 1, girl = 0)	−0.0147***	−0.0628***	−0.0146***	−0.0626***
	(0.0033)	(0.0127)	(0.0033)	(0.0127)
Age	0.1034***	0.9993***	0.1033***	0.9984***
	(0.0050)	(0.0147)	(0.0050)	(0.0147)
Age squared	−0.0056***	−0.0032***	−0.0056***	−0.0031***
	(0.0002)	(0.0007)	(0.0002)	(0.0007)
Kinh (Kinh = 1, ethnic minorities = 0)	0.0734***	0.3537***	0.0733***	0.3531***
	(0.0087)	(0.0399)	(0.0087)	(0.0398)
Urban areas (Urban = 1, rural = 0)	0.0150***	0.0441**	0.0150***	0.0454**
	(0.0051)	(0.0217)	(0.0050)	(0.0216)
Annual precipitation (mm)	0.0002	0.0020	−0.0005	−0.0009
	(0.0017)	(0.0062)	(0.0017)	(0.0063)
Annual average temperature (°C)	−0.0340	0.0427	−0.0162	−0.0809
	(0.0212)	(0.0741)	(0.0180)	(0.0651)
Annual average wind speed	0.0131**	0.0278	0.0122*	0.0186
	(0.0064)	(0.0257)	(0.0068)	(0.0267)
Province-specific time trend	Yes	Yes	Yes	Yes
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	1.5436***	−5.2069***	1.1132*	−2.8026
	(0.5401)	(1.8762)	(0.6333)	(2.2084)
Observations	26,558	26,558	26,558	26,558

Robust standard errors in parentheses. Standard errors are clustered at the commune level.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

Source: Estimation using data from VHLSSs 2010–2018.

Table A.29

2SLS regressions of children's educational attainment with heteroscedasticity-consistent standard errors.

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)	School enrollment (yes = 1, no = 0) (3)	Number of completed grades (4)
PM2.5 (μg/m3)	0.0009	0.0230	0.0013	0.0206*
	(0.0039)	(0.0140)	(0.0033)	(0.0118)
Number of days 0–15 °C	−0.0013*	−0.0015		
	(0.0007)	(0.0025)		
Number of days 15–18 °C	−0.0012***	−0.0021		
	(0.0005)	(0.0016)		
Number of days 18–21 °C	−0.0010***	−0.0011		
	(0.0003)	(0.0010)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	0.0001	−0.0001		
	(0.0002)	(0.0007)		
Number of days 27–30 °C	0.0004	−0.0010		
	(0.0003)	(0.0009)		
Number of days 30 °*C* +	0.0009**	0.0007		
	(0.0005)	(0.0016)		
Number of days below the 5th percentile of daily temperature			0.0001	−0.0004
			(0.0003)	(0.0011)
Number of days above the 95th percentile of daily temperature			0.0001	−0.0007
			(0.0002)	(0.0008)
Gender (boy = 1, girl = 0)	−0.0149***	−0.0633***	−0.0149***	−0.0632***
	(0.0030)	(0.0107)	(0.0030)	(0.0107)
Age	0.1029***	0.9971***	0.1029***	0.9964***
	(0.0047)	(0.0147)	(0.0047)	(0.0147)

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Table A.29 (*continued*)

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)	School enrollment (yes = 1, no = 0) (3)	Number of completed grades (4)
Age squared	−0.0056***	−0.0030***	−0.0056***	−0.0030***
	(0.0002)	(0.0008)	(0.0002)	(0.0008)
Kinh (Kinh = 1, ethnic minorities = 0)	0.0722***	0.3518***	0.0721***	0.3506***
	(0.0070)	(0.0270)	(0.0070)	(0.0271)
Urban areas (Urban = 1, rural = 0)	0.0166***	0.0512***	0.0164***	0.0504***
	(0.0045)	(0.0164)	(0.0045)	(0.0164)
Annual precipitation (mm)	−0.0000	0.0050	−0.0003	0.0037
	(0.0016)	(0.0062)	(0.0016)	(0.0060)
Annual average temperature (°C)	−0.0465**	−0.0322	−0.0039	−0.0153
	(0.0189)	(0.0651)	(0.0107)	(0.0399)
Annual average wind speed	0.0084	0.0226	0.0087	0.0210
	(0.0059)	(0.0219)	(0.0059)	(0.0222)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	1.6320***	−5.8436***	0.5524	−6.3402***
	(0.4914)	(1.6966)	(0.3601)	(1.2997)
Observations	26,558	26,558	26,558	26,558

Robust standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.30
2SLS regressions of children's educational attainment with clustering standard errors at the district level.

Explanatory variables	Dependent variables			
	School enrollment (yes = 1, no = 0) (1)	Number of completed grades (2)	School enrollment (yes = 1, no = 0) (3)	Number of completed grades (4)
PM2.5 (μg/m3)	−0.0005	0.0175	0.0005	0.0176
	(0.0048)	(0.0180)	(0.0040)	(0.0151)
Number of days 0–15 °C	−0.0011	−0.0007		
	(0.0007)	(0.0027)		
Number of days 15–18 °C	−0.0011**	−0.0010		
	(0.0004)	(0.0018)		
Number of days 18–21 °C	−0.0010***	−0.0012		
	(0.0003)	(0.0012)		
Number of days 21–24 °C	0	0		
Number of days 24–27 °C	0.0000	−0.0002		
	(0.0002)	(0.0008)		
Number of days 27–30 °C	0.0003	−0.0014		
	(0.0003)	(0.0010)		
Number of days 30 °C +	0.0006	0.0002		
	(0.0004)	(0.0017)		
Number of days below the 5th percentile of daily temperature			0.0000	−0.0004
			(0.0003)	(0.0012)
Number of days above the 95th percentile of daily temperature			0.0001	−0.0009
			(0.0002)	(0.0011)
Gender (boy = 1, girl = 0)	−0.0145***	−0.0531***	−0.0145***	−0.0530***
	(0.0036)	(0.0145)	(0.0036)	(0.0145)
Age	0.1090***	1.0069***	0.1090***	1.0066***
	(0.0054)	(0.0151)	(0.0054)	(0.0151)
Age squared	−0.0059***	−0.0038***	−0.0059***	−0.0038***
	(0.0003)	(0.0008)	(0.0003)	(0.0008)
Kinh (Kinh = 1, ethnic minorities = 0)	0.0745***	0.3779***	0.0744***	0.3769***
	(0.0095)	(0.0462)	(0.0095)	(0.0463)
Urban areas (Urban = 1, rural = 0)	0.0167***	0.0589**	0.0165***	0.0584**
	(0.0058)	(0.0238)	(0.0058)	(0.0239)
Annual precipitation (mm)	−0.0002	0.0027	−0.0003	0.0016
	(0.0018)	(0.0072)	(0.0018)	(0.0071)
Annual average temperature (°C)	−0.0417**	−0.0234	−0.0085	−0.0279
	(0.0202)	(0.0812)	(0.0117)	(0.0467)
Annual average wind speed	0.0067	0.0187	0.0066	0.0186
	(0.0060)	(0.0270)	(0.0061)	(0.0275)
Year-by-month fixed effects	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes
Constant	1.5867***	−5.8383***	0.6819*	−5.9587***
	(0.5293)	(2.2224)	(0.3717)	(1.4786)
Observations	26,558	26,558	26,558	26,558

Robust standard errors in parentheses. Standard errors are clustered at the district level.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.31
2SLS regressions of household-level outcomes without controlling for explanatory variables.

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
PM2.5 (μg/m3)	−0.0057	0.0047	0.0059	−0.0086	0.0039	−0.0104
	(0.0082)	(0.0070)	(0.0406)	(0.0063)	(0.0053)	(0.0314)
Number of days 0–15 °C	0.0002	0.0001	−0.0074			
	(0.0011)	(0.0009)	(0.0055)			
Number of days 15–18 °C	0.0001	0.0005	−0.0007			
	(0.0009)	(0.0008)	(0.0046)			
Number of days 18–21 °C	−0.0002	−0.0001	−0.0010			
	(0.0005)	(0.0005)	(0.0025)			
Number of days 21–24 °C	0	0	0			
Number of days 24–27 °C	−0.0004	−0.0008*	−0.0000			
	(0.0005)	(0.0004)	(0.0024)			
Number of days 27–30 °C	−0.0004	−0.0006	0.0021			
	(0.0006)	(0.0005)	(0.0029)			
Number of days 30 $°C+$	−0.0006	−0.0000	0.0021			
	(0.0008)	(0.0007)	(0.0040)			
Number of days below the 5th percentile of daily temperature				0.0001	0.0007	−0.0019
				(0.0005)	(0.0005)	(0.0028)
Number of days above the 95th percentile of daily temperature				−0.0003	0.0005	0.0005
				(0.0005)	(0.0004)	(0.0025)
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	11.3768***	11.0779***	6.4565***	11.4286***	10.9882***	7.3111***
	(0.3720)	(0.3305)	(1.9264)	(0.3199)	(0.2801)	(1.6501)
Observations	41,743	41,743	41,743	41,743	41,743	41,743

Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.32
2SLS regressions of household-level outcomes without controlling for explanatory variables and temperature.

Explanatory variables	Dependent variables		
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)
PM2.5 (μg/m3)	−0.0079	0.0039	−0.0112
	(0.0061)	(0.0052)	(0.0304)
Year-by-month fixed effects	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes
Constant	11.3831***	11.0105***	7.3489***
	(0.3060)	(0.2691)	(1.5813)
Observations	41,743	41,743	41,743

Robust standard errors in parentheses. Standard errors are clustered at the commune level.
*** $p < 0.01$
** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.33
2SLS regressions of household-level outcomes with controlling for province-specific time trend.

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
PM2.5 (μg/m3)	−0.0180	−0.0014	−0.0530	−0.0190	−0.0022	−0.0587

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Table A.33 (*continued*)

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
	(0.0188)	(0.0151)	(0.0829)	(0.0127)	(0.0101)	(0.0560)
Number of days 0–15 °C	0.0010	−0.0001	0.0082			
	(0.0025)	(0.0020)	(0.0109)			
Number of days 15–18 °C	0.0004	0.0000	0.0067			
	(0.0010)	(0.0009)	(0.0047)			
Number of days 18–21 °C	−0.0002	−0.0002	−0.0032			
	(0.0006)	(0.0005)	(0.0028)			
Number of days 21–24 °C	0	0	0			
Number of days 24–27 °C	0.0001	−0.0002	−0.0021			
	(0.0006)	(0.0005)	(0.0027)			
Number of days 27–30 °C	0.0005	0.0001	−0.0015			
	(0.0007)	(0.0006)	(0.0036)			
Number of days 30 °*C* +	0.0003	0.0010	−0.0027			
	(0.0011)	(0.0010)	(0.0053)			
Number of days below the 5th percentile of daily temperature				−0.0007	0.0003	−0.0013
				(0.0008)	(0.0007)	(0.0039)
Number of days above the 95th percentile of daily temperature				0.0008	0.0009*	0.0033
				(0.0006)	(0.0005)	(0.0026)
Gender of household head (male = 1, female = 0)	0.0422***	−0.0038	0.4034***	0.0422***	−0.0039	0.4031***
	(0.0097)	(0.0082)	(0.0509)	(0.0097)	(0.0082)	(0.0509)
Age of household head	0.0357***	0.0298***	−0.0148	0.0357***	0.0298***	−0.0149
	(0.0018)	(0.0014)	(0.0100)	(0.0018)	(0.0014)	(0.0100)
Age of household head squared	−0.0004***	−0.0003***	−0.0006***	−0.0004***	−0.0003***	−0.0006***
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4588***	0.4809***	0.8668***	0.4591***	0.4813***	0.8684***
	(0.0212)	(0.0200)	(0.0770)	(0.0212)	(0.0200)	(0.0770)
Urban areas (Urban = 1, rural = 0)	0.2964***	0.1992***	0.5330***	0.2964***	0.1990***	0.5329***
	(0.0160)	(0.0141)	(0.0574)	(0.0160)	(0.0141)	(0.0574)
Annual precipitation (mm)	0.0010	0.0008	0.0017	0.0006	0.0009	−0.0004
	(0.0038)	(0.0033)	(0.0179)	(0.0038)	(0.0033)	(0.0181)
Annual average temperature (°C)	−0.0190	−0.0165	0.3315*	−0.0519	−0.0122	0.0492
	(0.0429)	(0.0368)	(0.1963)	(0.0408)	(0.0338)	(0.1899)
Annual average wind speed	0.0020	0.0091	−0.0041	−0.0023	0.0119	−0.0288
	(0.0153)	(0.0123)	(0.0706)	(0.0162)	(0.0132)	(0.0748)
Province-specific time trend	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	11.1857***	10.5016***	4.2334	12.1277***	10.4102***	11.1124*
	(1.0687)	(0.9008)	(4.9370)	(1.3893)	(1.1457)	(6.3596)
Observations	41,743	41,743	41,743	41,743	41,743	41,743

Robust standard errors in parentheses. Standard errors are clustered at the commune level.

*** $p < 0.01$

** $p < 0.05$.

* $p < 0.1$.

Source: Estimation using data from VHLSSs 2010–2018.

Table A.34

2SLS Regressions of household-level outcomes with heteroscedasticity-consistent standard errors.

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
PM2.5 (μg/m3)	−0.0006	0.0084	0.0047	−0.0043	0.0080	0.0039
	(0.0078)	(0.0063)	(0.0397)	(0.0065)	(0.0053)	(0.0337)
Number of days 0–15 °C	−0.0012	−0.0012	−0.0033			
	(0.0015)	(0.0012)	(0.0076)			
Number of days 15–18 °C	−0.0009	−0.0005	0.0028			
	(0.0010)	(0.0008)	(0.0049)			
Number of days 18–21 °C	−0.0002	−0.0002	−0.0004			
	(0.0004)	(0.0004)	(0.0024)			
Number of days 21–24 °C	0	0	0			
Number of days 24–27 °C	0.0002	−0.0004	0.0008			
	(0.0005)	(0.0005)	(0.0029)			
Number of days 27–30 °C	0.0003	−0.0001	0.0029			
	(0.0007)	(0.0006)	(0.0037)			
Number of days 30 °*C* +	0.0008	0.0014	0.0022			
	(0.0010)	(0.0009)	(0.0055)			

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Table A.34 (*continued*)

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
Number of days below the 5th percentile of daily temperature				−0.0005	0.0004	0.0013
				(0.0007)	(0.0005)	(0.0035)
Number of days above the 95th percentile of daily temperature				0.0006	0.0012***	0.0003
				(0.0005)	(0.0004)	(0.0025)
Gender of household head (male = 1, female = 0)	0.0414***	−0.0043	0.4012***	0.0414***	−0.0044	0.4009***
	(0.0083)	(0.0068)	(0.0421)	(0.0083)	(0.0068)	(0.0421)
Age of household head	0.0352***	0.0295***	−0.0130	0.0353***	0.0295***	−0.0131
	(0.0015)	(0.0012)	(0.0081)	(0.0015)	(0.0012)	(0.0081)
Age of household head squared	−0.0003***	−0.0003***	−0.0007***	−0.0003***	−0.0003***	−0.0007***
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4636***	0.4837***	0.8575***	0.4636***	0.4841***	0.8592***
	(0.0144)	(0.0121)	(0.0642)	(0.0144)	(0.0121)	(0.0642)
Urban areas (Urban = 1, rural = 0)	0.2951***	0.1967***	0.5323***	0.2951***	0.1965***	0.5317***
	(0.0105)	(0.0087)	(0.0517)	(0.0105)	(0.0087)	(0.0517)
Annual precipitation (mm)	0.0030	0.0023	−0.0029	0.0019	0.0024	−0.0004
	(0.0040)	(0.0032)	(0.0202)	(0.0039)	(0.0031)	(0.0196)
Annual average temperature (°C)	−0.0451	−0.0351	0.0666	−0.0333	−0.0126	0.1911
	(0.0392)	(0.0324)	(0.1991)	(0.0251)	(0.0203)	(0.1250)
Annual average wind speed	0.0008	−0.0032	−0.1110*	0.0012	0.0025	−0.1040
	(0.0133)	(0.0103)	(0.0657)	(0.0135)	(0.0104)	(0.0667)
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	10.4990***	10.2599***	5.8137	10.3894***	9.6240***	3.2233
	(0.9124)	(0.7569)	(4.6043)	(0.7952)	(0.6479)	(4.0003)
Observations	41,743	41,743	41,743	41,743	41,743	41,743

Robust standard errors in parentheses.
*** $p < 0.01$
** $p < 0.05$.
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Table A.35
2SLS regressions of household-level outcomes with clustering standard errors at the district level.

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
PM2.5 (μg/m3)	−0.0006	0.0084	0.0047	−0.0043	0.0080	0.0039
	(0.0096)	(0.0077)	(0.0394)	(0.0081)	(0.0066)	(0.0338)
Number of days 0–15 °C	−0.0012	−0.0012	−0.0033			
	(0.0018)	(0.0015)	(0.0078)			
Number of days 15–18 °C	−0.0009	−0.0005	0.0028			
	(0.0012)	(0.0009)	(0.0047)			
Number of days 18–21 °C	−0.0002	−0.0002	−0.0004			
	(0.0005)	(0.0005)	(0.0024)			
Number of days 21–24 °C	0	0	0			
Number of days 24–27 °C	0.0002	−0.0004	0.0008			
	(0.0006)	(0.0005)	(0.0030)			
Number of days 27–30 °C	0.0003	−0.0001	0.0029			
	(0.0008)	(0.0007)	(0.0038)			
Number of days 30 °C +	0.0008	0.0014	0.0022			
	(0.0012)	(0.0010)	(0.0055)			
Number of days below the 5th percentile of daily temperature				−0.0005	0.0004	0.0013
				(0.0007)	(0.0006)	(0.0032)
Number of days above the 95th percentile of daily temperature				0.0006	0.0012**	0.0003
				(0.0006)	(0.0005)	(0.0024)
Gender of household head (male = 1, female = 0)	0.0414***	−0.0043	0.4012***	0.0414***	−0.0044	0.4009***
	(0.0107)	(0.0082)	(0.0528)	(0.0107)	(0.0082)	(0.0528)
Age of household head	0.0352***	0.0295***	−0.0130	0.0353***	0.0295***	−0.0131
	(0.0020)	(0.0017)	(0.0130)	(0.0020)	(0.0017)	(0.0130)
Age of household head squared	−0.0003***	−0.0003***	−0.0007***	−0.0003***	−0.0003***	−0.0007***
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)
Kinh (Kinh = 1, ethnic minorities = 0)	0.4636***	0.4837***	0.8575***	0.4636***	0.4841***	0.8592***
	(0.0251)	(0.0254)	(0.0839)	(0.0252)	(0.0254)	(0.0839)
Urban areas (Urban = 1, rural = 0)	0.2951***	0.1967***	0.5323***	0.2951***	0.1965***	0.5317***
	(0.0189)	(0.0175)	(0.0664)	(0.0189)	(0.0174)	(0.0668)
Annual precipitation (mm)	0.0030	0.0023	−0.0029	0.0019	0.0024	−0.0004
	(0.0048)	(0.0041)	(0.0214)	(0.0047)	(0.0041)	(0.0207)

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Table A.35 (*continued*)

Explanatory variables	Dependent variables					
	Log of per capita income (1)	Log of per capita expenditure (2)	Log of educational expenditure (3)	Log of per capita income (4)	Log of per capita expenditure (5)	Log of educational expenditure (6)
Annual average temperature (°C)	−0.0451	−0.0351	0.0666	−0.0333	−0.0126	0.1911
	(0.0451)	(0.0414)	(0.2095)	(0.0292)	(0.0262)	(0.1323)
Annual average wind speed	0.0008	−0.0032	−0.1110	0.0012	0.0025	−0.1040
	(0.0163)	(0.0138)	(0.0763)	(0.0164)	(0.0138)	(0.0765)
Year-by-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	10.4990***	10.2599***	5.8137	10.3894***	9.6240***	3.2233
	(1.0157)	(0.9710)	(4.7462)	(0.9222)	(0.8221)	(4.1488)
Observations	41,743	41,743	41,743	41,743	41,743	41,743

Robust standard errors in parentheses. Standard errors are clustered at the district level.
*** $p < 0.01$.
** $p < 0.05$
* $p < 0.1$.
Source: Estimation using data from VHLSSs 2010–2018.

Data availability

The data that has been used is confidential.

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