Temperature and Learning in West and Central Africa

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Abstract

In this paper, we combine georeferenced temperature data with newly released learning data from 8 West and Central African (WCA) countries in the Programme on the Analysis of Education Systems (PASEC). In the first part of the paper, we provide benchmark estimates of the effect of high temperatures on learning outcomes in WCA, thus providing an important comparison point with other parts of the world. We find preliminary evidence of a temperature-learning gradient with higher temperatures associated with worse math and reading scores for students in our sample. In future analyses, we plan to explore heterogeneity in the association between heat and learning outcomes based on country, age, socioeconomic background, gender, and school quality. We also plan to explore the mechanisms linking temperature to learning by looking at child labor and hunger outcomes, and exploring whether results change if we restrict to temperatures during school vs. non school days (i.e weekends and vacations) or growing season vs. non growing season.

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1 Introduction

In the last three decades, the educational landscape in Sub-Saharan Africa (SSA) has been characterized by major policy changes—most notably removal of primary-school fees. Initiated by country-governments with support and funding of international efforts such as the UN's Education for All Initiative (1990), Millennium Development Goals (2000-2015), Global Education First Initiative (2012), and Sustainable Development Goals (2015-present), these policy changes led to dramatic expansion and equalization of primary-school access among diverse strata of society and significantly reduced gender, wealth, and rural-urban gaps in primary-school attendance (Lewin and Sabates 2011). However, the expansion in access to primary schooling corresponded with a crisis in learning. There are an estimated 52 million children in primary school in Sub-Saharan Africa who lack basic skills (UNESCO 2014) and there are vast socioeconomic inequalities in learning outcomes (Gruijters and Behrman 2020).

Changes in the educational landscape of SSA have occurred in the context of increasing severity and frequency of extreme weather events (Collier, Conway, and Venables 2008). Notably, there has been an increase in extreme heat events. For example, between late March and early April of 2024 the Sahel region of West Africa experienced a record breaking five-day heat wave characterized by temperatures reaching 45 degrees Celsius (119 degrees Fahrenheit) (Barnes et al. 2024). Today it is expected that events of this severity would occur about once every 200 years, and under future warming scenarios it could become a once in 20-year event (ibid). Given that high temperatures have been shown to negatively impact learning in other parts of the world (Park et al. 2020; Park 2022; Park, Behrer, and Goodman 2021; Prentice et al. 2024), there is reason to think temperature extremes might have important implications for Sub-Saharan learning outcomes, as suggested in a recent study on Ethiopia (Srivastava, Hirfrfot, and Behrer 2024). If anything, the high levels of reliance on agriculture for basic livelihoods, the weaker educational infrastructure, and the low levels of climate adaptation preparedness mean that many Sub-Saharan countries will be particularly vulnerable to climate shocks (Emediegwu, Wossink, and Hall 2022).

So far, it has been challenging to empirically explore the effects of temperature on learning in SSA due to a lack of high-quality learning data. In this paper, we combine georeferenced temperature data with standardized student learning data from the Programme on the Analysis of Education Systems (PASEC) in 8 West and Central African countries. The first aim of the paper is to explore whether high temperatures are associated with learning outcomes in West and Central Africa. In doing so, we not only provide an important comparison to other parts of the world where there has been a documented link between heat and learning (Park, Behrer, and Goodman 2021), but also, and most importantly, we focus our analysis on countries that have experienced both an increase in the severity and frequency of extreme heat (Barnes et al. 2024; WB 2018) and a learning crisis. In future analyses, we plan to advance beyond previous research by systematically exploring heterogeneities in the association between heat and learning outcomes across country, age, socioeconomic background, gender and school quality. We also plan to explore the mechanisms linking temperature to learning by looking at child labor and hunger outcomes, and exploring whether results change if we restrict to temperatures during school vs. non school days (i.e weekends and vacations) or growing season vs. non growing season.

2 Temperature and Learning: Existing Evidence

To date, the most globally comprehensive study on heat and learning uses standardized learning data from 58 countries throughout Asia, Europe, the Americas, the Middle East and Australia who participated in the Programme for International Student Assessment (PISA) between 2000 and 2015 (Park, Behrer, and Goodman 2021). Park and colleagues show that the negative effects of heat on learning are significantly larger in low-income countries compared to high income countries, presumably due to differences in heat preparedness such as air conditioning. A number of other studies focused on high- and middle-income countries in Asia, Europe, and the Americas also document negative effects of heat on learning (Cho 2017; Garg, Jagnani, and Taraz 2020; Graff Zivin, Hsiang, and Neidell 2018; Park et al. 2020; Prentice et al. 2024; Graff Zivin et al. 2020; Porras-Salazar et al. 2018; Roach and Whitney 2022; Wang et al. 2018; Wargocki, Porras-Salazar, and Contreras-Espinoza 2019). One exception that does not find heat negatively affects learning is a study on Brazil, which finds that temperature has negligible impacts on college entrance exams (Li and Patel 2021).

Taken together, the aforementioned studies establish a robust evidence base on temperature and learning; nonetheless, to the best of our knowledge there is only one study focused on Sub-Saharan Africa, and more precisely on Ethiopia (Srivastava, Hirfrfot, and Behrer 2024). In this study, the authors observe that exposure to hot days corresponds with a decrease in performance on university entrance exams in Ethiopia. These negative effects are largest in cooler parts of the country, likely due to the lower adaptation to heat in these areas. By focusing on a university population, this study examines a selected group of individuals who have already overcome significant educational barriers and therefore overlooks the experiences of younger children, who are more susceptible to environmental stressors and are at a critical stage of cognitive and educational development.

The limited exploration of the effects of temperature on learning in Africa has been in part due to a lack of learning measures collected in commonly used data. Many major sources of data in SSA—such as the Demographic and Health Surveys (DHS)—collect information about children's school attendance, but not their learning. As a result other existing studies on temperature and schooling in SSA focus on school attendance outcomes (Pule et al. 2021; Randell and Gray 2019, 2016). The literature on temperature and school attendance in SSA generally finds heterogeneous effects. For example, there is no significant association between higher than average temperatures in early childhood and predicted years of schooling in pooled data from West and Central Africa (Randell and Gray 2019), but mild temperatures are associated with increased educational completion in Ethiopia (Randell and Gray 2016). A related literature documents the negative effects of other types of climatic shocks—such as rainfall shocks or drought— on various measures of learning in South and Southeastern Africa (Björkman-Nyqvist 2013; Nordstrom and Cotton 2020; Nubler et al. 2021), albeit with heterogeneity by gender (Björkman-Nyqvist 2013) and the age at which the shock was experienced (Nubler et al. 2021).

Considerable literature suggests that the effects of temperature shocks on schooling are heterogeneous depending on socioeconomic background. For example, Park and colleagues show that the negative effects of heat on learning observed in 58 OECD countries are significantly larger for lower income populations (Park, Behrer, and Goodman 2021). Yet, scholarship on West and Central Africa suggests children from higher-SES households face greater educational penalties in response to higher than average temperatures in early childhood (Randell and Gray 2019), raising important questions about how pathways of impact may operate differentially by SES across diverse contexts.

In addition to SES, other variables—such as age or gender—may also have heterogenous impacts. Several studies suggest that climatic shocks experienced at earlier ages have particularly deleterious impacts on eventual learning (Nubler et al. 2021; Park, Behrer, and Goodman 2021). Likewise, related scholarship suggests that rainfall shocks disproportionately decrease girls' (relative to boys) schooling outcomes in Kenya and Uganda (Björkman-Nyqvist 2013; Nubler et al. 2021), indicating that climatic shocks may exacerbate pre-existing gender-based inequalities. On the other hand, the negative impact of heat on university entrance exam performance was larger for boys compared to girls in Ethiopia, which could be due to lower rates of absenteeism and more efforts to cope with heat among girls (Srivastava, Hirfrfot, and Behrer 2024).

3 Why Might Temperature Impact Learning?

Generally, there are two sets of explanations for why high temperatures might affect learning. The first explanation focuses on how heat directly impacts children's learning. For example, extreme heat might negatively affect students' physical abilities to concentrate, retain information, and perform academic assessments. In support of this perspective, Park and colleagues show that high temperatures experienced during school days, but not vacation days, have a negative effect on student learning in 58 OECD countries (Park, Behrer, and Goodman 2021). These findings suggest that negative effects of temperature on learning are driven by school-based experiences, and not broader changes in environment that might have occurred during non-school days. Likewise, an experiment in Costa Rica that randomly varied classroom temperature over a two week period showed that neutral (compared to warm) classroom temperatures led to improved student performance on language and logical thinking tasks (Porras-Salazar et al. 2018). These findings build on other studies suggesting that heat has a negative effect on short-run cognition (Graff Zivin, Hsiang, and Neidell 2018; Park et al. 2020).

The second explanation focuses on the ways in which heat might indirectly impact learning. Notably, heat might lead to increased student absenteeism, which in turn is detrimental for learning (Cattan et al. 2023). For example, heat shocks that affect agricultural livelihoods might lead families to diversify livelihoods by reducing school attendance and increasing child labor (Björkman-Nyqvist 2013; Garg, Jagnani, and Taraz 2020). Students may also avoid schools during critically hot days if they have long commutes. While commuting data is hard to come by for the countries in our study, available evidence from Ghana in West Africa shows that 90 percent of primary school children commute on foot with average commutes of about 20 minutes daily (Afoakwah and Koomson 2021). Lack of adequate climate controls in schools might also contribute to student absenteeism during hot weather. About half the population of West and Central Africa does not have access to electricity (Bank 2024) and many school facilities lack basic climate controls that require electricity. Temperature shocks that lead to crop failure and corresponding hunger and lack of dietary diversity might render students physically incapable of attending school or learning much while in school (Taras 2005). Additionally, teachers could also avoid work during particularly hot days with consequences for student learning (Léonard 2019).

4 Data and Sample

We combine data from two sources: (1) gridded publicly available temperature and precipitation data from the ERA5 archive; and (2) micro-data on schooling and learning from PASEC. In what follows we describe each of these data sources in more detail.

First, ERA5 gridded temperature and precipitation data are retrieved from the European Centre for Medium-Term Weather Forecasting. These data contain high-resolution temperature and precipitation data for the whole globe on a grid of parallels and meridians at a 0.25×0.25-degree resolution. We extract data on temperature and precipitation for every hour for the period between 2014 and 2019 and for every strata (the smallest geographic unit in the PASEC) in our sample. We compute a daily average temperature and precipitation for each strata by averaging across all hours in a day in a given strata.

The micro-data on schooling and learning, PASEC, are standardized learning assessments collected by the Conference of Ministers of Education of Francophone Countries (CONFEM) that are nationally representative of children in primary schools. We focus on 8 West and Central African countries that participated in both rounds of PASEC data collection in 2014 and 2019 and have available information on temperature (Benin, Burkina Faso, Burundi, Congo, Niger, Senegal, Tchad, and Togo). In each country that participates in PASEC, approximately 150-250 schools are randomly chosen from an official database of all registered public, private, and community schools. Within each selected school, students are randomly chosen from one second grade class and one sixth grade class to participate. Participating respondents complete a standardized reading and math assessment and provide basic information about themselves and their families; the test occurs in April at the end of the academic year. Schools participating in the PASEC assessments also provide basic information about school characteristics (i.e. student to teacher ratio etc.). Our final sample includes 81,663 students (Table 1).

To create our final dataset, we match each PASEC respondent in our dataset with temperature and precipitation data for the preceding academic year based on their strata of residence. We define the academic year as starting on September 1st of 2013 or 2018 (depending on the survey wave) and ending on March 31st of 2014 or 2019 (depending on the survey wave) because the PASEC exam is administered in April.

5 Measures

Learning: PASEC collects reading and math tests scores across countries (similar to the PISA). These test scores, which are standardized to have a mean of 500 and a standard deviation of 100 across all pupils, are our main measure of learning. We look at math and reading scores separately because other scholarship has found temperature has larger impacts on math compared to reading (Park et al. 2020). Table 2 shows country level variations in these scores ranging from a low of 467 in Togo to a high of 604 in Burundi.

Temperature: We construct a measure of the average strata temperature in the preceding academic year (in Celsius) counting the number of days in six temperature ranges to account for non-linearities. More precisely, we count the number of days average temperature in the categories: less than 21, 21-24, 24-27, 27-30, 30-33, greater than 33. We use 21-24 degrees as the reference category.

Precipitation and humidity: To account for other climatic conditions, we control for continuous measures of the average precipitation and humidity in strata in the preceding academic year.

Child demographic characteristics: We control for a binary measure of child gender and a continuous measure of child age.

Child socioeconomic status: For students in grade six we construct a composite measure of household wealth using principal component analysis on household assets reported by the students (i.e. fridge, television etc.). We also include binary measures of whether the respondent reports that their mother and father can read (the only available measure of parents' education). Assets and parental literacy are only collected for students in grade six. Thus, for students in grade two, we create a measure of whether the respondent always speaks French at home, which likely proxies for socioeconomic background.

All models and summary statistics also include year and strata fixed effects. We use country weights that take into account the number of students in each country in a given year and grade and the number of students in our sample in a given year and grade to ensure that our results are representative of the individuals living in the eight countries (**dhs˙demographic˙2012**).

6 Methods

We estimate the effect of temperature on learning by assessing how variations in temperature at the strata level (e.g. our "treatment") affect children's primary-school learning using data from PASEC. Our identification strategy exploits the randomness of weather events in the local community in a given year. To explore whether the effect temperature on learning is moderated by key axes of stratification, we will interact our treatment measure of temperature with the variables for socioeconomic status (as proxied by assets, parental literacy, and home language), gender, and country. This analysis will allow us to (i) investigate the unequal distribution of the impacts of heat shocks and (ii) identify the role of SES, gender, and country in moderating children's vulnerability to climatic shocks.

7 Preliminary Results

Figure 1 shows the average strata temperature for the 8 West and Central African countries during the time-frame of our study (between 2014 and 2019). As Figure 1 shows, most of the strata in our dataset have high average temperatures ranging between 25 and 28 degrees Celsius. There is, nonetheless, important variation. For example, Burkina Faso, Niger, and Tchad all have an average of 3-5 days in the academic year above 33 degrees Celsius (Table 2), whereas Burundi and Congo have no days in this range. Burundi has the mildest overall climate (Figure 1), with an average of 86 days during the school year below 21 degrees Celsius, 53 days between 21 and 24 degrees Celsius and no days above 27 degrees Celsius (Table 2). There is also considerable country level variation in relative humidity and precipitation: Burundi, Congo and Benin have particularly high humidity, whereas Burkina Faso, Tchad, Senegal, and Niger have particularly low precipitation.

In our main analyses we explore whether temperature experienced during the academic year is associated with the test scores of children in grades 2 and 6 in the West and Central African countries in our study. Table 3 shows regression coefficients and Figure 2 visualizes the coefficients. Figure 2 shows a general pattern whereby lower temperatures are associated with higher reading and math scores and higher temperatures are associated with lower test scores. More specifically, each additional day during the academic year below 21 degrees

Celsius (compared to 21-24 degrees Celsius, the reference category) is associated with almost a one-point higher mean math and reading score in the pooled sample (Table 3). Likewise, each additional day during the academic year between 24 and 27 degrees Celsius (compared to 21-24 degrees Celsius) is associated with almost three-point lower mean math and reading scores in the pooled sample (the same is true for the higher temperature categories) (Table 3). These are fairly sizable coefficients if we take into account the variations in temperature throughout the academic year experienced by students in our sample 1).

As a next step, we run analyses separately for students in Grade 2 (Table 4) and Grade 6 (Table 5). These disaggregated results reveal several findings of note. First, there is again a clear temperature gradient with higher temperatures associated with worse math scores for both students in grades 2 and 6. The negative relationship between higher temperature and reading scores is much more consistent and robust among students in Grade 2 compared to Grade 6. This could be because climatic shocks experienced at earlier ages have particularly deleterious impacts on learning (Nubler et al. 2021; Park et al. 2020). Among students in Grade 2 and Grade 6 relative humidity is negatively correlated with math and reading scores (with fairly sizeable coefficients), but there is no significant association between rain and test scores. In Grade 6, females are negatively associated with both math and reading scores, but in Grade 2 they are negatively associated with math scores only. Interestingly, age is negatively associated with age and math and reading scores in Grade 6, but is positively correlated with math scores in Grade 2. We suspect these differences in the effects of age have to do with the differences in the compositions of students in Grades 2 versus 6. While students in Grade 2 may be more likely to be on track for their age since they are still at the start of primary school, those in Grade 6 include both students who are on track for their age and those who have dropped out and returned to school (a common experience in many parts of West and Central Africa). In this case, being older may actually be a disadvantage for those in Grade 6 as it corresponds with schooling interruptions. We plan to explore these interesting age effects in more detail in future analyses.

8 Limitations

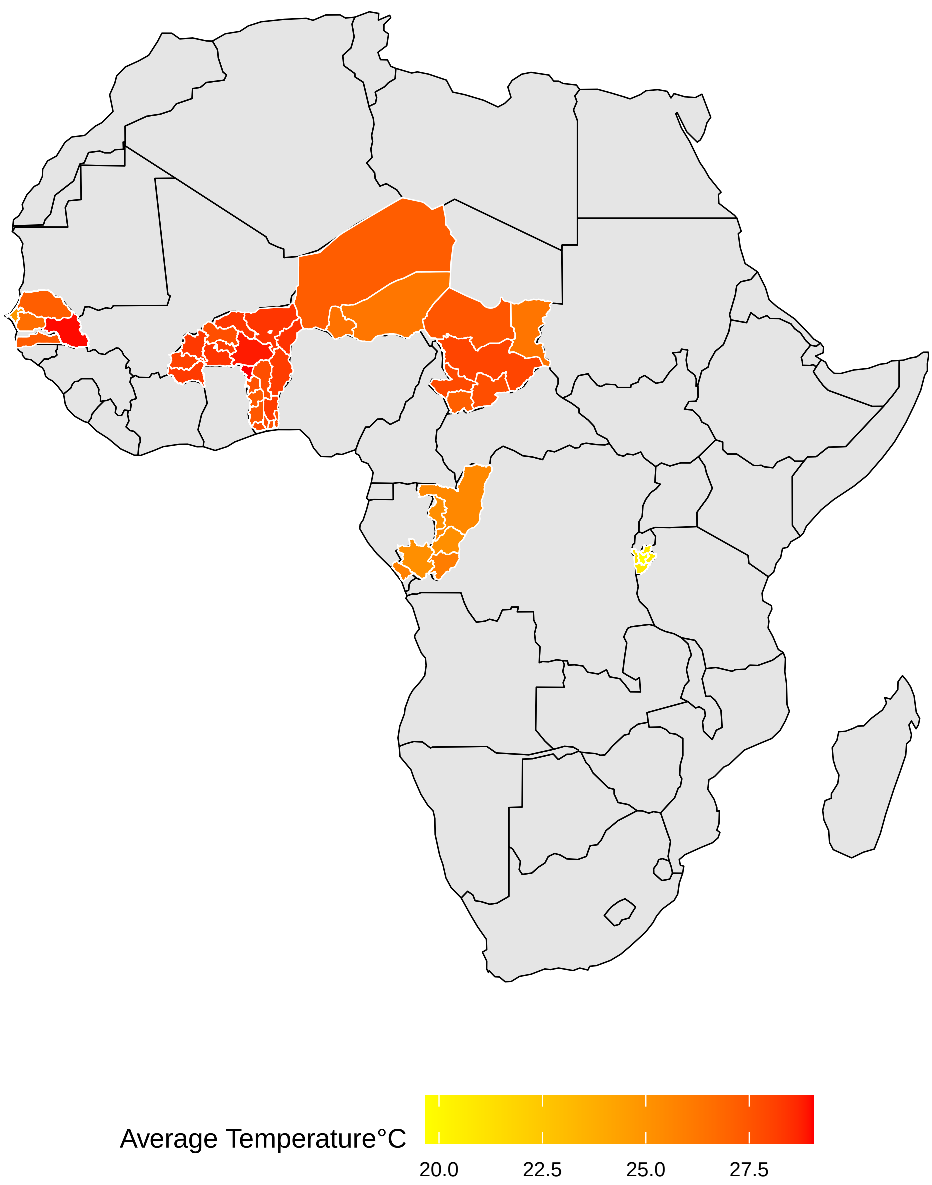
PASEC provides nationally representative learning assessments among primary-school children but does not capture students not in school. It is plausible that extreme heat leads students to drop out of school or migrate to other regions of the country, and these students would not be captured in our data. If anything, this limitation means that our estimates of the effects of heat on learning may be conservative since we would expect the most vulnerable populations to be at the highest risk of drop out.

9 Discussion of Next Steps

Climate change poses a critical challenge to education, in SSA and the Global South more broadly. Yet, existing work on climatic shocks and schooling in Africa has been limited by the lack of nationally comparable and representative micro-data with information on school attendance and learning. Our study makes an important contribution by exploring how temperature affects learning outcomes in 8 West and Central African countries, where high temperatures are expected to increase in frequency and duration. We find preliminary evidence of a temperature-learning gradient with higher temperatures associated with worse math and reading scores for students in our sample. As a next step, we plan to explore whether our results are heterogeneous by key respondent characteristics including socioeconomic background, gender, and age. We also plan to explore the mechanisms through which temperature effects learning by looking at additional outcomes available in the PASEC data including hunger in school and child labor. Other scholars find heat experienced during school days—but not vacation days—affects learning (Park et al. 2021), which the authors interpret as evidence that the mechanism has to do with in-class experience of heat as opposed to broader disruption to the agrarian system. In preliminary analyses we find our results are robust to inclusion or exclusion of vacation days. In further analyses we plan to explore heterogeneity based on temperature during in vs. out of school time in more detail. A specific examination of the mechanisms by which heat impacts learning will help clarify whether the observed effects are primarily driven by in-class conditions or disruption to the agrarian system. Finally, we also plan to make use of the PASEC measures on school quality (i.e. student to teach ratio, school resources etc.) to explore whether there is variation in the effect of heat on learning depending on school quality. Given that students of different socioeconomic backgrounds attend schools of different quality (Gruijters and Behrman 2020), we anticipate this may be important for our understanding of mechanisms and socioeconomic stratification in learning.

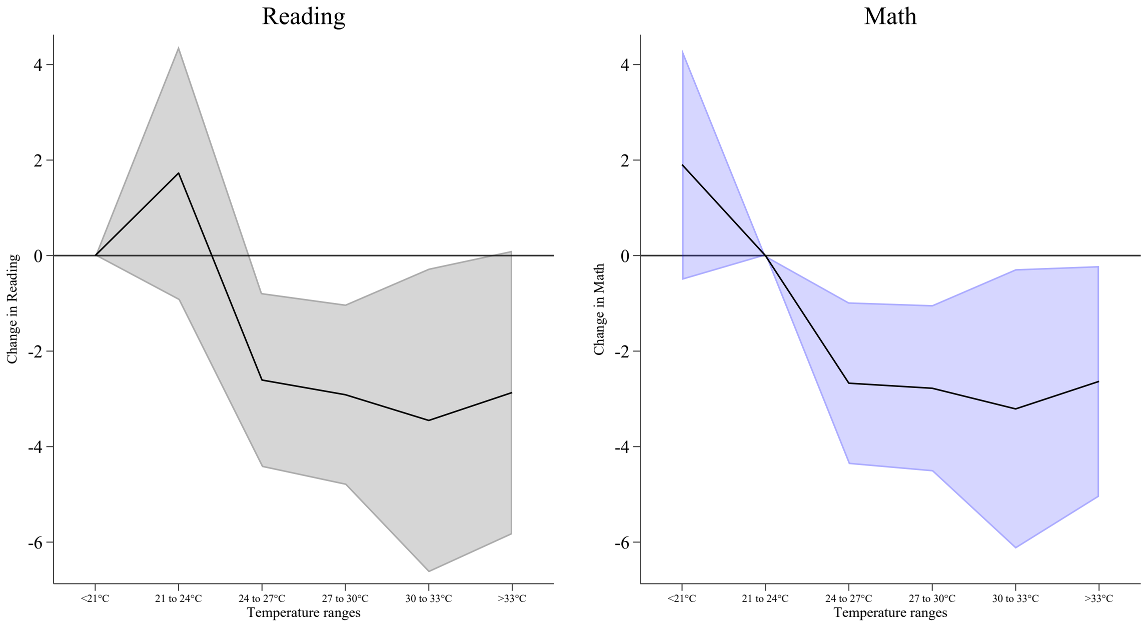
Tables and Figures

Fig. 1. Average temperature for the countries in our study



Note: Average temperature over the study time frame (2014-2019) in Benin, Burkina Faso, Burundi, Congo, Niger, Senegal, Tchad and Togo.

Fig. 2. Visualization of change in reading and math score by temperature.



Note: This figure plots the effect of accumulated exposure over the previous academic year, including vacation days on student test score. Generated following multi-variable regression of the association between temperature and learning.

Table 1: Summary Statistics

	Mean	SD	N
Outcome Variables			
Mean Math Score	514	104	81663
Mean Reading Score	512	108	81663
Absolute Temperature			
# of Days Below 21° C	11	27	81663
# of Days Between 21 and 24° C	16	20	81663
# of Days Between 24 and 27° C	40.11	23.42	81663
# of Days Between 27 and 30° C	52.41	27.50	81663
# of Days Between 30 and 33° C	17.30	14.05	81663
# of Days Above 33° C	2.52	3.63	81663
Other Variables			
Proportion of Students in Grade 6	0.13	0.34	81663
Relative Humidity	46.47	18.75	81663
Precipitation	9.59	14.97	81663
Student's Age	8.99	2.15	81663
Female (=1 if student is female)	0.48	0.50	81663

Note: Student test scores are obtained by combining two cross sectional datasets collected in 2014 and 2019.

Table 2: Summary Statistics: By Country

	BENIN	BURKINA FASO	BURUNDI	CONGO	NIGER	SENEGAL	TCHAD	TOGO
Mean Math Score	490.84	505.12	603.97	560.52	495.68	538.91	495.45	467.43
	(97.58)	(97.91)	(56.75)	(93.67)	(118.62)	(98.25)	(89.90)	(88.78)
Mean Reading Score	498.53	506.21	608.38	553.62	492.17	526.72	488.93	457.95
	(93.10)	(106.50)	(93.68)	(101.11)	(111.87)	(114.49)	(80.89)	(92.30)
# of Days Below 21° C	0.00	0.00	86.48	0.00	9.05	2.11	1.55	0.00
	(0.00)	(0.00)	(31.50)	(0.00)	(10.19)	(4.38)	(2.68)	(0.00)
# of Days Between 21 and 24° C	0.36	7.02	53.17	12.73	20.62	23.78	11.64	0.58
	(1.06)	(6.51)	(31.12)	(5.96)	(9.44)	(19.13)	(10.06)	(0.78)
# of Days Between 24 and 27° C	37.35	39.70	0.90	119.54	32.65	47.85	44.55	44.67
	(9.99)	(6.30)	(1.05)	(6.74)	(8.68)	(11.76)	(8.84)	(15.00)
# of Days Between 27 and 30° C	87.50	69.41	0.00	14.19	44.88	41.48	62.15	77.15
	(14.86)	(11.74)	(0.00)	(9.96)	(13.22)	(15.65)	(9.59)	(16.05)
# of Days Between 30 and 33° C	9.33	23.09	0.00	0.00	33.74	8.20	20.08	12.33
	(10.59)	(7.44)	(0.00)	(0.00)	(9.56)	(10.03)	(7.32)	(10.51)
# of Days Above 33° C	0.47	4.24	0.00	0.00	3.62	0.19	5.03	2.27
	(1.61)	(3.33)	(0.00)	(0.00)	(3.52)	(0.55)	(4.06)	(5.27)
Proportion of Students in Grade 6	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.14
	(0.34)	(0.34)	(0.34)	(0.34)	(0.34)	(0.34)	(0.34)	(0.34)
Relative Humidity	67.99	37.62	73.49	81.73	28.06	43.80	36.18	59.57
	(15.38)	(4.28)	(3.42)	(2.70)	(2.75)	(9.33)	(7.18)	(12.32)
Precipitation	11.34	4.07	47.37	30.36	1.11	0.92	4.05	9.85
	(4.42)	(1.39)	(15.52)	(6.32)	(0.36)	(0.80)	(1.67)	(4.14)
Student's Age	7.89	9.40	10.02	8.45	8.78	8.84	9.48	8.29
	(2.18)	(2.25)	(2.26)	(1.96)	(1.74)	(1.79)	(2.27)	(2.08)
Female (=1 if student is female)	0.50	0.48	0.51	0.51	0.46	0.53	0.41	0.46
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.49)	(0.50)

Note: Same as Table 1.

Table 3: Multi-variable regression of the association between temperature and math and reading test scores for students in Grades 2 and 6.

	(1) Mean Math Score	(2) Mean Reading Score
# of Days Below 21° C	0.895*	0.965*
	(0.525)	(0.565)
# of Days Between 24 and 27° C	-2.768***	-2.665***
	(0.757)	(0.816)
# of Days Between 27 and 30° C	-2.619***	-2.765***
	(0.824)	(0.883)
# of Days Between 30 and 33° C	-3.080**	-3.321**
	(1.438)	(1.541)
# of Days Above 33° C	-2.464*	-2.690*
	(1.441)	(1.591)
Relative Humidity	-8.684**	-12.437***
	(3.774)	(4.225)
Rain	0.960	1.508
	(2.846)	(3.209)
Student's Age	-0.894	-2.304*
	(1.014)	(1.268)
Female (=1 if student is female)	-12.173***	-2.009
	(2.099)	(1.692)
Observations	81663	81663
Year FE	Yes	Yes
Strate FE	Yes	Yes

Notes: Robust standard errors clustered at strata level in parentheses. Reported estimates describe how learning in math and reading change for pupils in grade 2 and grade 6 when they are exposed to different temperature percentiles. Vacation days are included. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4: Multi-variable regression of the association between temperature and math and reading tests scores for students in Grade 2

	(1) Mean Math Score	(2) Mean Reading Score
# of Days Below 21° C	0.778	0.866
	(0.515)	(0.582)
# of Days Between 24 and 27° C	-3.084***	-2.969***
	(0.828)	(0.884)
# of Days Between 27 and 30° C	-2.890***	-3.094***
	(0.912)	(0.963)
# of Days Between 30 and 33° C	-3.455**	-3.730**
	(1.583)	(1.677)
# of Days Above 33° C	-2.850*	-3.113*
	(1.504)	(1.696)
Relative Humidity	-8.833**	-13.369***
	(3.854)	(4.418)
Rain	0.929	1.437
	(3.006)	(3.474)
Student's Age	6.200***	1.151
	(1.140)	(1.417)
Female (=1 if student is female)	-12.606***	-2.010
	(2.319)	(1.838)
Observations	19768	19768
Year FE	Yes	Yes
Strate FE	Yes	Yes

Notes: Robust standard errors clustered at strata level in parentheses. Reported estimates describe how learning in math and reading change for pupils in grade 2 when they are exposed to different temperature percentiles. Vacation days are included. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Multi-variable regression of the association between temperature and math and reading tests scores for students in Grade 6

	(1) Mean Math Score	(2) Mean Reading Score
# of Days Below 21° C	1.646***	1.677***
	(0.448)	(0.377)
# of Days Between 24 and 27° C	-0.953**	-0.837*
	(0.471)	(0.467)
# of Days Between 27 and 30° C	-1.354***	-0.945*
	(0.483)	(0.499)
# of Days Between 30 and 33° C	-1.634**	-1.224
	(0.777)	(0.829)
# of Days Above 33° C	-1.806**	-0.895
	(0.816)	(0.779)
Relative Humidity	-7.135**	-6.627**
	(3.484)	(3.255)
Rain	1.131	1.903
	(2.086)	(1.879)
Student's Age	-7.722***	-9.608***
	(1.040)	(1.157)
Female (=1 if student is female)	-7.763***	-3.452***
	(1.068)	(1.141)
Observations	61895	61895
Year FE	Yes	Yes
Strate FE	Yes	Yes

Notes: Robust standard errors clustered at strata level in parentheses. Reported estimates describe how learning in math and reading change for pupils in grade 6 when they are exposed to different temperature percentiles. Vacation days are included. *** p<0.01, ** p<0.05, * p<0.1.

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