The Heat is On: Temperature and Test Scores in India

Sujaya Sircar

Indian Statistical Institute, Delhi

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Climate and economic outcomes

- Rising temperature across the globe is an old but an extremely important concern since climate change is known to cause adverse effects on ecosystems and life.
- Recent literature focuses on impact of climate on human cognition and physiology:
  - Deschenes and Greenstone (2011), Burgess et al.(2017), Adhvaryu et al. (2018), Somananthan et al. (2021): heat impact on mortality and labour productivity.
  - Cho (2017), Garg et al. (2020), Graff Zivin et al. (2020), Park (2022): heat impact on cognitive ability and human capital formation.

The Question

- What is the effect of temperature on test scores?
  - Heat can adversely affect student performance during an exam which in turn will lead to relatively lower scores.
  - This study analyzes the impact of temperature on human capital formation.
- We study the impact of temperature on test scores during secondary exams in India for the period 2012-2015.
- Data on exam scores are from CBSE, which is the single largest board of education with an all-India presence.
- Secondary exams serve as the first stepping stone for Indian students in career choice.

Preview of Results

- We find a negative impact of temperature on exam scores: a one degree Celsius rise in temperature leads to a fall in exam score by 0.004 standard deviations.
- Non-linear impact of temperature: test performance increasingly deteriorates as temperature increase away from optimal temperatures.
- Physiological mechanism:
  - Physical channel: differential results between male and female students.
  - Cognitive channel: differential results between quantitative and subjective tests.
- Additional results: suggestive evidence for vulnerable groups and heat adaptation.

Data

- European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5, 2012-2015: temperature data during exam time available at 0.25 degree latitude x 0.25 degree longitude global grid.
- Central Board of Secondary Examination (CBSE) administrative data, 2012-2015: board-based secondary exam scores of 1,719,366 students in 7,842 schools across 594 districts in India.
  - The unit of analysis is at the level of student-subject observations: each student takes more than one subject exam. Our data consists of 8,594,268 student-subject observations.

Temperature Variation

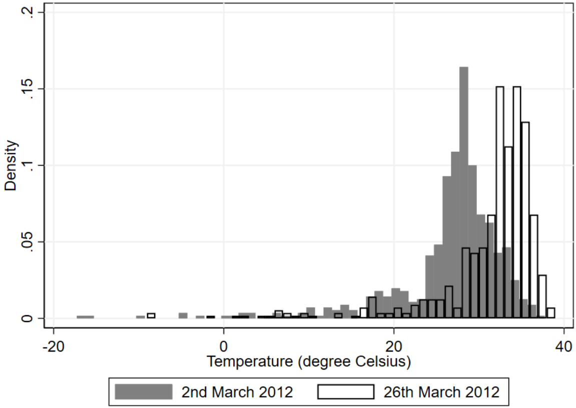

Figure 1: Temperature distribution across two test days in March

Empirical Strategy

- We exploit the variation in temperature across subject test days for a student.

$$S_{ispdy} = \gamma_i + \eta_y + \delta_s + X_{pdy} + \beta_1 temperature_{pdy} + \epsilon_{ispdy}$$

  - S_{ispdy} = standardized test scores of student i, subject s, Pincode p, date d, year y
  - γ_i = student fixed effects
  - η_y = year fixed effects
  - δ_s = subject fixed effects
  - X_{pdy} = weather controls of precipitation and humidity
  - $temperature_{pdy}$ = test-time temperature for Pincode p, date d, year y

- Identification: $temperature_{pdy}$ is exogenous to test scores.
- Standard errors clustered at the Pincode level.

Alternate Non-linear Specification

- Regress on $2^{\circ}C$ temperature bin dummies:

$$\begin{aligned} S_{ispdy} =& \gamma_i + \eta_y + \delta_s + X_{pdy} + \beta_1 temp(22^{\circ}C - 24^{\circ}C)_{pdy} + \\ & \beta_2 temp(24^{\circ}C - 26^{\circ}C)_{pdy} + \beta_3 temp(26^{\circ}C - 28^{\circ}C)_{pdy} + \\ & \beta_4 temp(28^{\circ}C - 30^{\circ}C)_{pdy} + \beta_5 temp(> 30^{\circ}C) + \epsilon_{ispdy} \end{aligned}$$

  - S_{ispdy} = standardized test scores for of student i, subject s, Pincode p, date d, year y
  - γ_i = student fixed effects
  - η_y = year fixed effects
  - δ_s = subject fixed effects
  - X_{pdy} = weather controls of precipitation and humidity
  - $temperature_{pdy}$ = test-time temperature for Pincode p, date d, year y

Descriptive Statistics

Summary statistics

Subject	Percent
Science	20.01
Social Science	20.01
Mathematics	20.01
English Comm.	16.70
Hindi Course A	9.31
Hindi Course B	5.12
English Lng & Lit.	3.30
Foundation of IT	2.84
Comm. Sanskrit	2.71
Total	100.00

Variable	Mean
Temperature ($^\circ$C)	27.65
	(3.91)
Exam scores	69.88
	(16.19)
Female fraction	0.39
	(0.49)
Rural fraction	0.41
	(0.49)
SC,ST,OBC fraction	0.34
	(0.47)
Controls:	
Precipitation (mm)	0.07
	(0.24)
Humidity ($^\circ$C)	13.05
	(5.44)
Observations	8594268

Results: Temperature and Exam Scores

	(1)	(2)
Dependent variable: Score		
Temperature	-0.004***	-0.004***
	(0.001)	(0.001)
Observations	8593610	8593610
R^2	0.882	0.882
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	No	Yes
Controls	Yes	Yes

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Results: Temperature and Exam Scores (contd.)

- A fall of 0.016 standard deviations in performance results from one standard deviation rise in temperature (0.003×5.36).
- Compared to the 10^{th} percentile, a student exposed to the 75^{th} percentile temperature will score 0.029 standard deviations lower in an exam (0.004×7.35).
- One standard deviation increase in temperature leads to a decline in 0.092 years of schooling (0.016×5.75) (Evans and Yuan (2019)).

Results: Non-linear Specification

	(1)	(2)
Dependent variable: Score		
Temperature bin (°C):		
22-24	-0.009*	-0.009*
	(0.005)	(0.005)
24-26	-0.010*	-0.010*
	(0.006)	(0.006)
26-28	-0.018***	-0.018***
	(0.006)	(0.006)
28-30	-0.046***	-0.046***
	(0.007)	(0.007)
>30	-0.044***	-0.044***
	(0.007)	(0.007)
Observations	8593610	8593610
R^2	0.882	0.882
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	No	Yes
Controls	Yes	Yes

▸ Alternate Non-linear Specification ▸ Alternate Reference Temperature

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Results: Non-linear Specification (contd.)

- The magnitude of coefficients increases progressively for each succeeding temperature bin.
- Impact is largest for temperatures above 28°C: 0.046 for temperatures between 28°C and 30°C, and 0.044 above 30°C.

Heterogeneity: Rural and Urban

Dependent variable: Score	(1) Urban	(2) Rural
Temperature	-0.004***	-0.003***
	(0.001)	(0.001)
Observations	5074154	3519456
R^2	0.881	0.885
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

Non-linear Specification

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Heterogeneity: Caste

Dependent variable: Score	(1) General	(2) SC-ST-OBC
Temperature	-0.004***	-0.003***
	(0.001)	(0.001)
Observations	5646868	2946742
R^2	0.880	0.885
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

Non-linear Specification

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Heterogeneity: Heat Adaptation

- Students who cannot afford cooling mechanisms at home are more adapted to warmer temperatures.
- Economically disadvantaged students (rural, backward castes) may be more relatively more adapted to living and studying in uncomfortable temperatures.
- If urban, general caste students on average adopt more cooling mechanisms at home and area adapted to living in comfortable temperatures, this may be one reason for relatively poorer scores.
- Suggestive evidence that marginal or vulnerable groups are performing relatively better in this context.

Heterogeneity: Very Hot Districts

	(1)	(2)	(3)
Dependent variable: Score	Past March	Test time (90^{th} percentile)	Region
Temperature	-0.004***	-0.005***	0.006***
	(0.001)	(0.001)	(0.001)
Temperature×HotDistrict	0.004***		
	(0.001)		
Temperature×90^{th}perc		0.001***	
		(0.000)	
Temperature×North			-0.013***
			(0.001)
Temperature×East			-0.007***
			(0.002)
Temperature×West			-0.009***
			(0.001)
Observations	8593610	8593610	8593610
R^2	0.882	0.882	0.882
Student FE	Yes	Yes	Yes
Subject FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Heterogeneity: Heat Adaptation (contd.)

- Students in very hot districts may be physiologically adapted to high temperatures.
- In line with literature (Cho (2017), Alberto et al. (2021)).

Mechanism

- Two possible mechanisms: Agriculture and Physiology:
- Agriculture: students may perform relatively poorly on their tests through an agriculture income channel.
- Physiology: temperature negatively affects physical and cognitive ability of students affecting their test performance.

Agriculture Mechanism

- Agriculture: we are studying test-time temperatures, therefore a long-term agricultural channel may not be at work in this case.
- The tests take place during March which is not part of the major growing season in India.
- However, we still check for an agriculture mechanism explicitly:
  - We interact the temperature variable with a dummy that takes value 1 if the growing season temperature for a district in the previous year is above the median, and 0 otherwise.

Agriculture Mechanism (contd.)

Dependent variable: Score	(1) Growing season	(2) Non-growing season
Temperature	-0.004***	-0.004***
	(0.001)	(0.001)
Temperature×GrowingTemp	0.001	
	(0.001)	
Temperature×NongrowingTemp		-0.006
		(0.008)
Observations	8593610	8593610
R^2	0.882	0.882
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Physiological Mechanism

- Physiological differences such as lower muscle mass, lower metabolic rates, greater surface to volume ratio may work in favour of female students for heat dissipation during high temperatures (Deschenes and Greenstone (2011), Mishra and Ramgopal (2013), Schweiker et al. (2018)).
- Male students may feel relatively more discomfort from heat than female students during the tests.

Physiological Mechanism (contd.)

	(1)	(2)
Dependent variable: Score	Male	Female
Temperature	-0.005***	-0.002***
	(0.001)	(0.001)
Observations	5239218	3354392
R^2	0.882	0.884
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Physiological Mechanism (contd.)

- Specific areas of the brain are sensitive to high temperatures (Hocking et al. (2001), Hancock and Vasmatzidis (2003)).
- Quantitative test scores are relatively more affected due to heat than subjective test scores (Graff Zivin et al. (2018)).

Physiological Mechanism (contd.)

	(1) Overall	(2) Female	(3) Male
Temperature	-0.002**	-0.000	-0.004***
	(0.001)	(0.001)	(0.001)
Temperature×Quant	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)
Observations	6630486	2589598	4040888
R^2	0.889	0.889	0.890
Student FE	Yes	Yes	Yes
Subject FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Robustness Checks

Dependent variable: Score	(1) Exclude controls	(2) Exclude outliers	(3) SE clustered at school level	(4) Date-year FE
Temperature	-0.003***	-0.004***	-0.004***	-0.006***
	(0.001)	(0.001)	(0.000)	(0.001)
Observations	8593610	8414684	8594268	8593610
R^2	0.882	0.882	0.882	0.883
Student FE	Yes	Yes	Yes	Yes
Subject FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	No
Date $\times$ Year FE	No	No	No	Yes
Controls	No	Yes	Yes	Yes

Notes: *p$<$0.10, **p$<$0.05, ***p$<$0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Conclusion

- We analyze how high temperatures can affect secondary exam scores (CBSE) in India.
- We find that temperature negatively affects exam scores: one standard deviation increase in temperature leads to a fall in 0.016 standard deviations in score: one standard deviation increase in temperature leads to a decline in 0.092 years of schooling (Evans and Yuan (2019)).
- We find evidence of temperature affecting scores through physiological impact of heat on students.

Alternate Non-linear Specification

	(1)
Dependent variable: Score	
Temperature bin (°C):	
22-24	-0.009*
	(0.005)
24-26	-0.010*
	(0.006)
26-28	-0.018***
	(0.006)
28-30	-0.046***
	(0.007)
30-32	-0.044***
	(0.007)
>32	-0.043***
	(0.007)
Observations	8593610
R^2	0.882
Student FE	Yes
Subject FE	Yes
Year FE	Yes
Controls	Yes

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Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Alternate Reference Temperature

	(1)
Dependent variable: Score	
Temperature bin (°C):	
<22	0.018***
	(0.006)
22-24	0.011**
	(0.004)
24-26	0.012***
	(0.004)
28-30	-0.019***
	(0.003)
>30	-0.012***
	(0.003)
Observations	8594268
R^2	0.882
Controls	Yes
Student FE	Yes
Subject FE	Yes
Year FE	Yes

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Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Rural and Urban Non-linear Specification

	(1) Urban	(2) Rural
Temperature bin (°C):		
22-24	-0.017***	0.003
	(0.006)	(0.006)
24-26	-0.020***	0.006
	(0.008)	(0.007)
26-28	-0.031***	0.001
	(0.008)	(0.007)
28-30	-0.055***	-0.032***
	(0.008)	(0.009)
>30	-0.055***	-0.025***
	(0.009)	(0.009)
Observations	5074154	3519456
R^2	0.881	0.885
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

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Notes: *p<0.10, **p<0.05, ***p<0.01. Standard errors reported in parentheses. Standard errors clustered at the Pincode level.

Caste Non-linear Specification

	(1) General	(2) SC-ST-OBC
Temperature bin (°C):		
22-24	-0.016***	0.005
	(0.005)	(0.007)
24-26	-0.019***	0.009
	(0.006)	(0.007)
26-28	-0.029***	0.002
	(0.006)	(0.008)
28-30	-0.055***	-0.031***
	(0.006)	(0.009)
>30	-0.054***	-0.023**
	(0.007)	(0.010)
Observations	5646868	2946742
R^2	0.880	0.885
Student FE	Yes	Yes
Subject FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes

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