Research Proposal - 14.475

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1 Motivation

Climate change and the subsequent increase in temperatures can have a lot of impact on humans and other species in the planet. Heat waves can cause deaths, and humans might have different behavioral responses to adapt to heat depending on their socioeconomic background (Burgess et al. 2017). Another area of interest corresponds to the effects of high air temperature on educational outcomes and cognition.

There are some studies in the biology and health literature that analyze the short-term impacts of heat on cognition in laboratory settings (Mackworth 1946; Seppänen, Fisk, and Lei 2006). These papers conclude that indoor's temperature affects several human responses, including thermal comfort, perceived air quality, and performance at work. Other papers in biology have studied the effects of heat on animal cognition (Danner et al., 2021). This former paper is one of the first studies that provides experimental evidence that high air temperatures cause cognitive and motor performance decline in animals, in particular for birds.

Previous attempts in the economic literature have studied the effects of heat on learning using SAT scores (Park et al. 2020). In this paper, the authors study the effects of long term exposure to heat on learning capabilities of students. They demonstrate that heat inhibits learning and that school air conditioning may mitigate this effect in the context of the United States. Other works have shown that long term exposure to high temperatures reduce math and reading test scores among school-age children in India (Garg et al. 2020). The authors explain that agricultural income is one mechanism driving this relationship: hot days during the growing season reduce agricultural yields and test scores.

This research proposal would contribute to the previously mentioned literature by analyzing the effects of short term heat exposure on test scores and trying to disentangle effects of the long vs. short run exposure to temperature on educational outcomes in the context of a developing country.

2 Chilean Context

Chile is one of the richest countries in Latin America. For example, in year 2020, its GDP per capita in USD corresponded to 13,231 (World Bank, 2020). However, it suffers from high income inequality. For example, Chile is in 3rd place among OECD countries in terms of income inequality, only surpassed by Costa Rica and South Africa (OECD, 2022). Moreover, educational inequality is also high. Chile has one of the lowest performances in education from OECD countries. In 2013, 30% of students did not meet basic reading/science requirements, and 50% did not meet them in math (OECD, 2013). It is therefore an important context in which to study educational outcomes, especially since it is a developing country where education does not have high quality, and where not many economic studies are done.

Chile conducts standardized tests every year. On the one hand, SIMCE (*Sistema de Medición de la Calidad de la Educación*), is a test for elementary, middle and high school. The Ministry of Education has been conducting this test every year since 1992, with the objective of evaluating both the education quality and relative performance of each school. SIMCE is taken at the national level by students in 2nd, 4th, 6th, 8th and 10th grade. It evaluates concepts on math, reading and writing (in Spanish), and science. SIMCE is conducted in November (spring season) on the same day for every school in Chile and it is applied physically in each students' school.

On the other hand, PSU (*Prueba de Selección Universitaria*), is a test for 12th graders that was applied in Chile between the years 2003 and 2020.[1] This test is used for college admissions, which depend only on PSU scores and high school grades. PSU evaluates concepts on math, reading and writing (in Spanish), and science or history (students choose one of these two depending on their careers of interest). This test is conducted during the first week of December (summer season) and at the same day and time for every test taker all over Chile. The Spanish and math tests are conducted during the morning (usually from 9am to 12pm) in different but consecutive days. Likewise, history and science tests are conducted in the afternoons (usually from 2pm to 5pm) during the same days as the tests mentioned above.[2]

3 Data

For the climate data, I will use the Copernicus Climate Data which corresponds to ERA5 Hourly Data (on temperature and precipitations) from 1979 to present. This data comes in $0.25° \times 0.25°$ grid cells at the hour-day-month-year-grid level. Given the shape of Chile, I end up assigning each county in Chile to the closest grid cell of temperature. This could be perfected in the future: I could maybe use more than one neighbor, or construct a weighted average of the temperature depending on which cells cover each county. As a first step, I assigned each county to the closest grid cell to its centroid and I constructed the average temperature during each test's hours. Note that I could also obtain the maximum temperature for that the same time, or construct a new variable that represents how unusual the temperature levels during test hours are (e.g., deviations from average December temperature, deviations from the days prior to the test day, or consider night temperatures instead of test temperatures).

Even though the rest of the proposal is focused on PSU scores exclusively[3], I will describe both datasets. I was able to acquire datasets containing individual-level test results for both PSU and SIMCE. Each test score is linked to the corresponding student through a unique identifier that remains consistent over time. Even though this identifier is not the official ID number from Chile (for privacy reasons), it is possible to connect both SIMCE and PSU datasets through it. The data I have for PSU corresponds to the tests taken between 2003 and 2019, whereas the SIMCE results data are from 1999 to 2019. I acquired both datasets from the Ministry of Education. Additionally, both PSU and SIMCE tests conduct surveys both to test takers and their families, in which there are questions about individual characteristics (e.g., age, gender, residence, eligibility for government aids), household characteristics (e.g., income, parent's education, employment) and school characteristics (e.g., public or private status, location). Luckily, I also have information about those surveys' responses. Finally, for PSU test takers I also have information on their college application process, including the university/career combinations the student applied to and where he/she ended up being accepted.

4 Empirical Strategy

The main specification of this work is:

$$Score_{iscrt} = \beta\, Temp_{scrt} + \gamma\, Female_i + \delta\, GPA_{it} + \zeta X'_{it} + \eta_{rt} + \lambda_{st} + \varepsilon_{iscrt},$$

where $Score_{isrct}$ is the result obtained by student i in the test of subject s of the PSU taken in county c of region r at the end of year t. $Temp_{srct}$ is the average temperature registered during the test. $Female_i$ is a dummy that takes a value of 1 if the student is female. GPA_{it} is the average high school grade obtained by the student, expressed in a normalized score according to a transformation defined by DEMRE for year

[1] Starting year 2021 the PSU test went through several modifications: the test changed its name and the way it evaluated concepts, so I will leave that new version of the test out of this proposal.

[2] For example, the PSU conducted in 2006 took place during the 18th and 19th of December 2006. Spanish and science during Monday the 18th, and math and history during Tuesday the 19th.

[3] Mainly due to time restrictions I was only able to process the PSU and climate data, leaving SIMCE data for future progress of this work.

t. Finally, η_{rt} and λ_{st} are region × year and test subject × year fixed effects, respectively. ε_{iscrt} represents the standard errors that I cluster at the county level.

I write down X_{it} in the main regression for future progress of this project to represent a vector of controls for each student i during year t. X could include the student's household income, student's age and/or the educational level of the student's parents.

The parameter of interest is β, that captures the causal effect of a temperature increase on test scores under the identifying assumption that there is no sorting nor self selection of students into areas with particular temperature shocks depending on their potential scores. In other words, the temperature shocks experienced during the taking of the PSU are as good as random.

5 Preliminary Results

Table 1: Main Results

Variables	(1) PSU Score	(2) Afternoon Test	(3) Morning Test	(4) Below 10°C	(5) Above 25°C
Temperature	-2.244***	-2.243***	-2.716**	4.742*	-3.359**
	(0.837)	(0.751)	(1.134)	(2.577)	(1.492)
GPA Score	0.505***	0.477***	0.522***	0.554***	0.443***
	(0.0147)	(0.0130)	(0.0158)	(0.0339)	(0.0109)
Female	-29.66***	-34.13***	-26.74***	-24.64***	-35.36***
	(1.464)	(1.431)	(1.502)	(2.215)	(3.394)
Constant	268.6***	292.6***	261.0***	165.9***	352.6***
	(12.60)	(13.89)	(15.92)	(23.91)	(39.54)
Observations	6,884,542	2,720,501	4,164,041	330,399	779,696
R-squared	0.280	0.268	0.290	0.382	0.232

Clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 1 presents the effect of temperature: for all test scores in Column (1), for afternoon tests (i.e., History and Science) in Column (2), for morning tests (i.e., Spanish and Math) in Column (3), for tests done at cold temperatures in Column (4), and for tests done at hot temperatures in Column (5). Table 2 presents the effect of temperature by test subject. Finally, Table 3 presents the effect of temperature by geographic area in Chile. Note that I display Chile's capital in a separate column from the rest (even though Santiago belongs to the central regions) since it has most of Chile's inhabitants.

Table 2: Results by Test Subject

Variables	(1) Math	(2) Spanish	(3) History	(4) Science
Temperature	-3.239**	-2.561**	-2.628***	-2.063***
	(1.344)	(1.120)	(0.842)	(0.756)
GPA Score	0.527***	0.516***	0.432***	0.530***
	(0.0173)	(0.0143)	(0.0143)	(0.0120)
Female	-39.03***	-14.50***	-31.53***	-36.65***
	(1.548)	(1.472)	(1.337)	(1.586)
Constant	275.4***	252.6***	329.5***	254.2***
	(19.57)	(15.56)	(15.61)	(14.63)
Observations	2,076,809	2,087,232	1,501,975	1,218,526
R-squared	0.307	0.279	0.220	0.333

Clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Results by Geographic Area

Variables	(1) Big North	(2) Small North	(3) Central Regions	(4) Capital	(5) South Regions	(6) Austral Regions
Temperature	-2.481*	0.357	-1.173*	-5.452***	4.530***	0.478
	(1.450)	(0.602)	(0.683)	(1.679)	(0.928)	(2.373)
GPA Score	0.454***	0.482***	0.506***	0.514***	0.502***	0.489***
	(0.0168)	(0.0260)	(0.0124)	(0.0274)	(0.0165)	(0.0168)
Female	-24.64***	-27.26***	-31.21***	-32.95***	-26.01***	-24.38***
	(1.068)	(1.839)	(1.570)	(3.063)	(1.740)	(3.005)
Constant	285.1***	223.0***	233.6***	346.1***	142.9***	225.7***
	(31.50)	(13.42)	(11.27)	(28.89)	(14.38)	(27.42)
Observations	546,955	1,100,814	904,967	2,800,463	1,147,602	383,741
R-squared	0.236	0.255	0.269	0.315	0.261	0.245

Clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6 Conclusions and Next Steps

So far the results look promising. There seems to be a negative effect of temperature on test scores, at least for high temperatures (above 25° C). Interestingly, and given that Chile is a long country, for counties that experience low temperatures (below 10° C) an increase in temperature seems to be a good thing for scores. Preliminary results are also different in magnitude depending on the subject of the test in question (i.e., whether the test was on Math, Spanish, History or Science).

Some next steps to consider:

- Repeat the regression run in the tables above but for different definitions for the variable $Temp$ as discussed in the data section.

- Process the SIMCE data and merge it to the PSU scores.
- Process the remaining PSU data to obtain information on student's household income, parents education, etc.
- Improve assignment of temperature to each county based on grid cells' information.
- Try to replicate Park et al. (2020) paper to try to separate the long term vs short term effects of temperature on standardized test scores.

7 References

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